中核能源科技有限公司
CHINERGY CO.,LTD.

Deputy Director of design management department

- Donghui Wang;
- Ph.D
- Senior Engineer
- specialized in Small Modular Reactor design(HTGR, ACP100).
- Email: dhwang@chinergy.com.cn

中核能源科技有限公司
CHINERGY CO.,LTD.

中核集团
CNNC

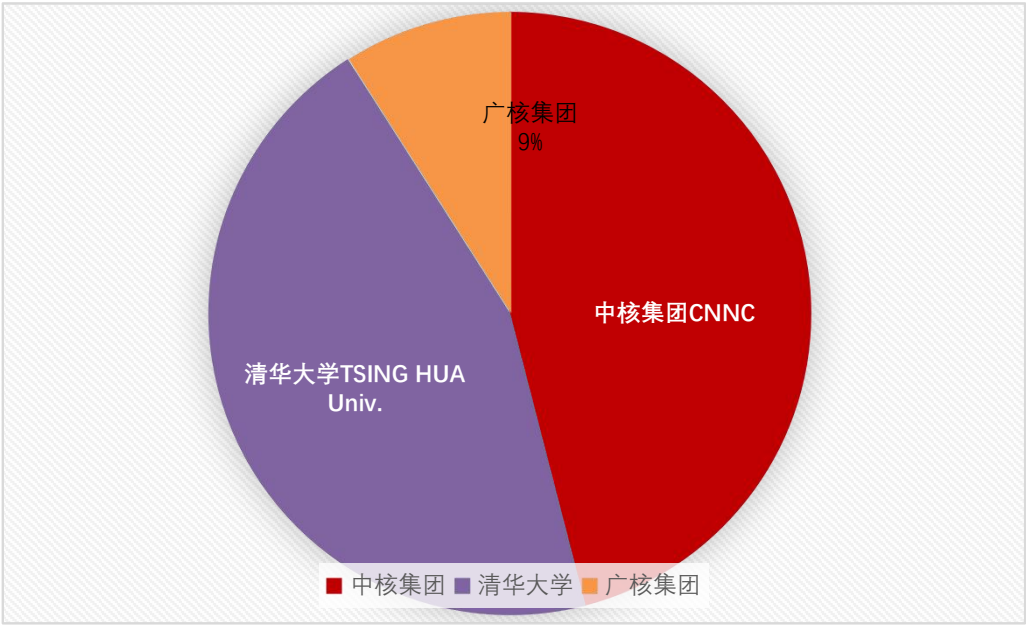
Technology and Application of High Temperature Gas-Cooled Reactor Pebble-bed Module (HTR-PM)

CHINERGY CO., LTD.

April 14, 2026

Company Introduction

- **Company name**: CHINERGY CO.,LTD.
- Registered date: 2003-08-26
- Shareholder
  - China National Nuclear Corporation
  - Tsinghua Holding Corporation
  - China General Nuclear Power Group

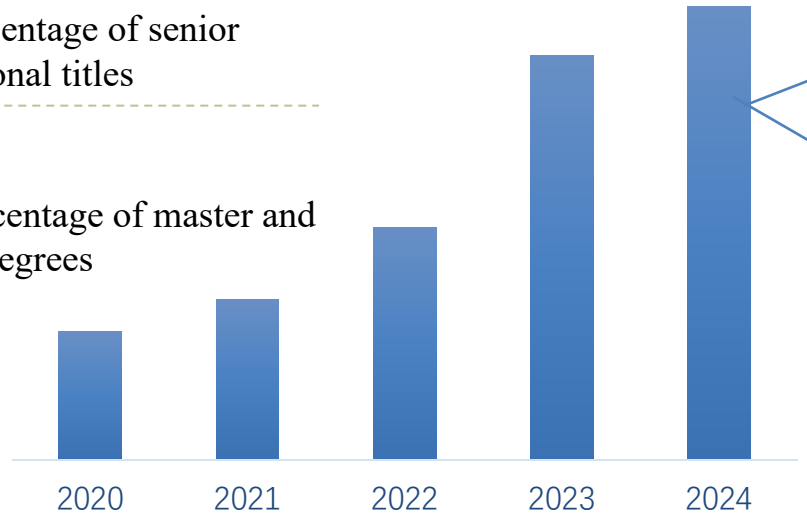


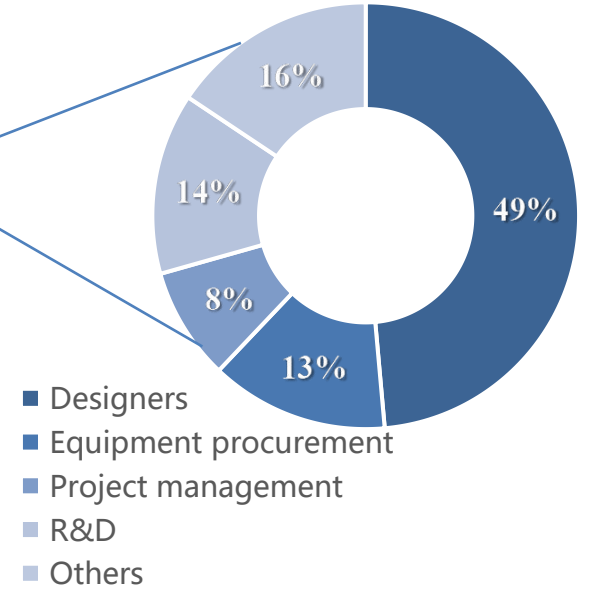
Company Introduction

- The total number of employees is nearly 1,000 at present
- The structure of the talent team constantly improved

33 %
The percentage of senior professional titles

54 %
The percentage of master and doctor degrees



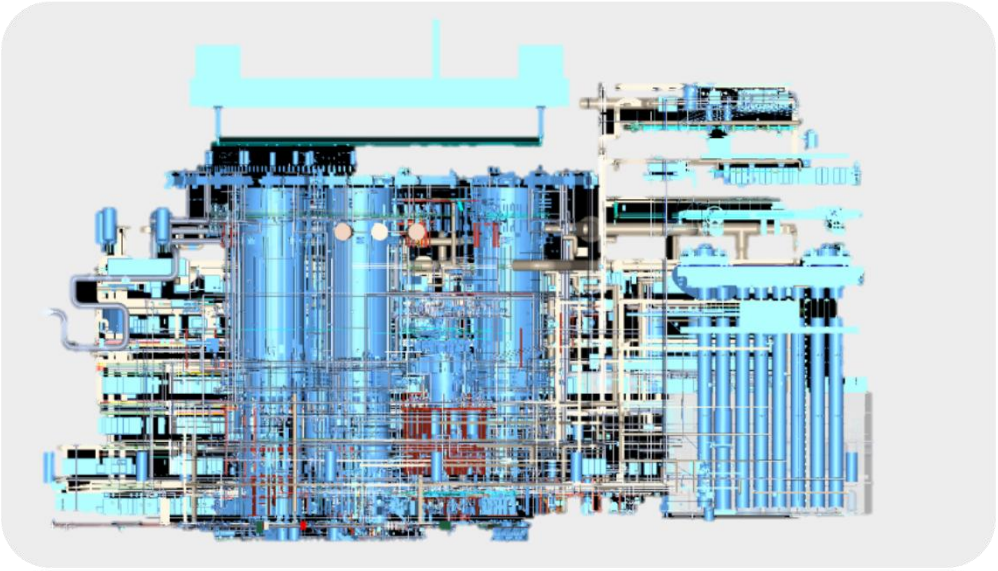


- Main businesses
  - R&D, promotion and industrialization of nuclear energy
  - serving as the general contractor for projects associated with nuclear energy technology
  - consultancy service in the industries of nuclear energy, technology and engineering
- Main products
  - Modular High-Temperature Gas Cooled Reactor (MHTGR)
  - Nuclear Heating Reactor (NHR)
  - Chinergy holds the exclusive business rights for these two products

Company Introduction

Good capabilities for engineering management procurement and design of HTGR

- **Patents:** 198 items（including：invention patents 109items；oversea patent 36items）
- **Software copyright:** 33 items
- **Standards：** Four national standards（participation）；Group standards 32 items
- **Proprietary tech:** 62items



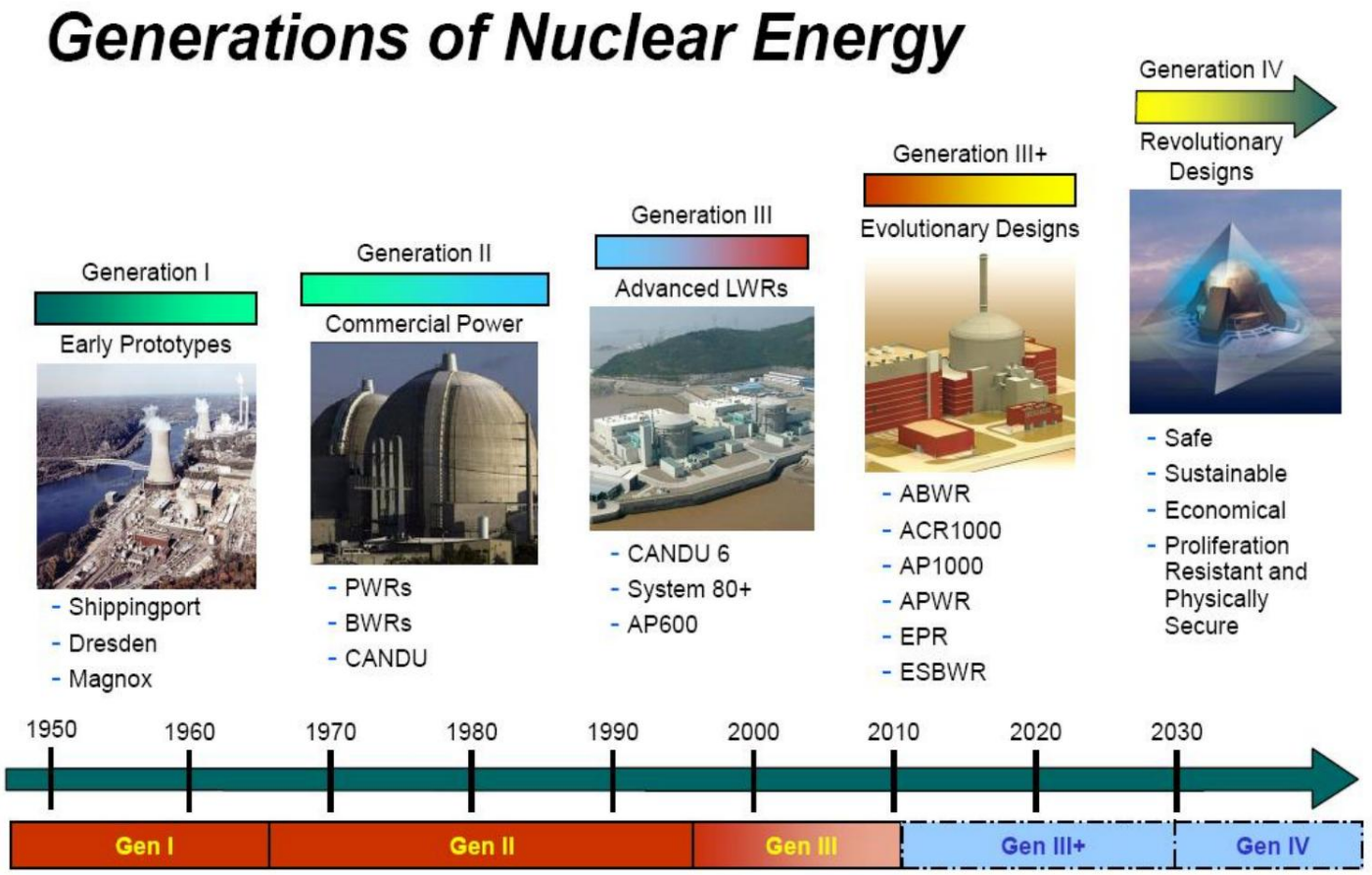
- **Obtain complete engineering data of the world's first pebble-bed modular HTGR**
- **The platform of digital integrative 3D design, the platform of modular design and construction, the platform of EPC data management, design capabilities significantly improved and constantly extend to the leading edge of design, undertake core design work**
- **The leader of the HTGR industrial chain, cultivate the industrial chain of equipment manufacturing and engineering construction, lay the foundation of the sustainable development for HTGR**

中核能源科技有限公司
CHINERGY CO.,LTD.
中核集团 CNNC

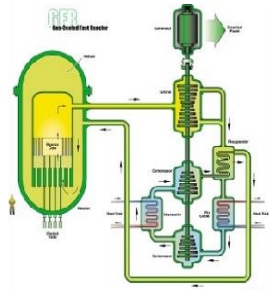
CONTENTS

History of Nuclear Power Development

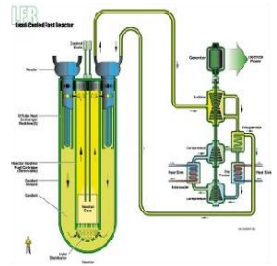
- High Temperature Gas-Cooled Reactor（HTGR）: one of the fourth generation of advanced reactor technology



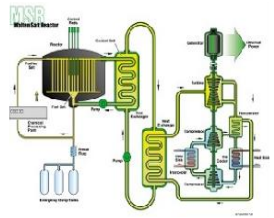
The Generation IV International Forum



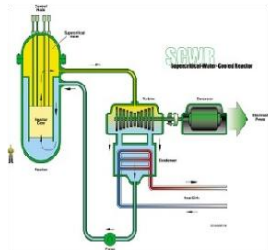
Gas-cooled fast reactor



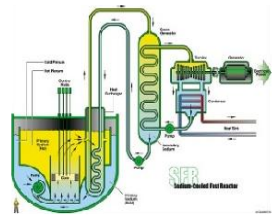
Lead-cooled fast reactor



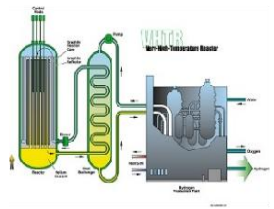
Molten salt reactor



Super-critical water-cooled reactor



Sodium-cooled fast reactor



Very/High temperature gas-cooled reactor

Definition of HTGR

- HTR / HTGR
  - ***H***igh ***t***emperature ***g***as cooled ***r***eactor
  - HTGR more frequently referred to prismatic (popular in USA)
  - HTR more frequently referred to pebble bed (popular in Germany)
  - In many cases, HTR and HTGR are equivalent
- Simple idea, excellent performance
  - High efficiency, safety, more application area
- Different stages, different name, increased performance, similar technology
  - Technical mature: High temperature gas cooled reactor (HTGR，HTR)
    - Helium coolant, coated particle fuel, in 1960s
  - Technical Improvement: Modular HTGR
    - Small size, modular, inherent safety, 1980s
  - New trend: Very high temperature reactor (VHTR)
    - Named by Gen IV International Forum, 21st century
    - Mature modular HTGR belongs to VHTR, GIF Technical Roadmap Update, 2014

Development history of HTGR in the world

Test reactor

PEACH BOTTOM (US 1967)

AVR (GEM 1967)

DRAGON (UK 1966)

Prototype reactor

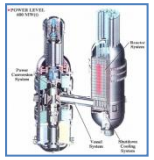
THTR (UK 1986)

FORT ST. VRAIN (US 1976)

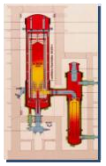
MHTGR Test reactor

HTR-10 (CHINA 2000)

HTTR (JAPAN 1998)



GT-MHR (US)

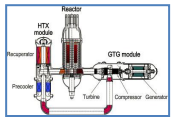


HTR-MODUL (GEM)

Demo reactor

HTR-PM (CHINA 2021)

Xe-100 (US)

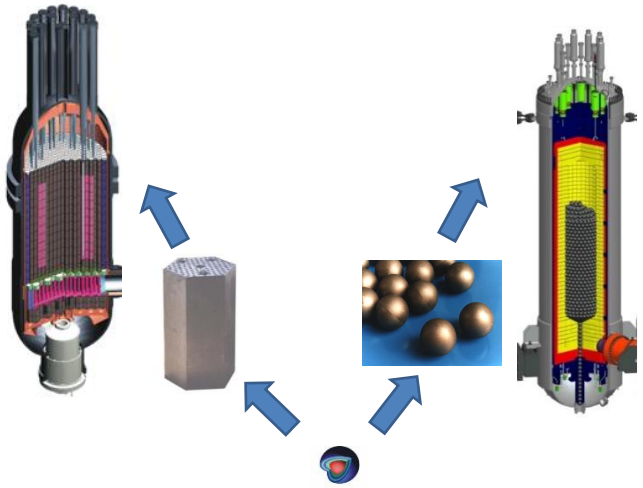


GTHTR300 (JAPAN)

NGNP (US)

棱柱 *Prismatic*

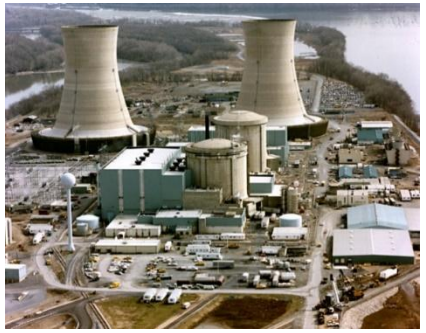
球床 *Pebble Bed*



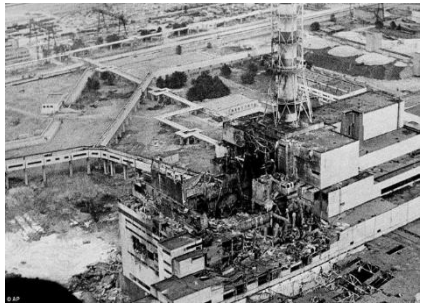
Common in ceramic coated fuel particles

Modular HTGR

- Proposed by Siemens/Interatom in the 1980s
- Inherent Safety
  - Reactor core meltdown and large-scale radioactivity release will not occur
  - Technically no need for offsite emergency measures
- Projects
  - HTR-Module（Germany）、PBMR (South Africa)、HTTR（Japan）、GT-MHR （USA）、NGNP（USA）、Xe-100 (USA)
- China has been actively involved in the research and development of modular HTGR, particularly focusing on the pebble-bed modular design



1979, TMI 三哩岛



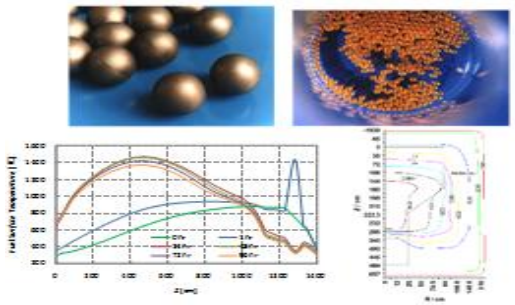
1986, Chernobyl 切尔诺贝利

2011, Fukushima 福岛

Development history of HTGR in China

➢ The development of HTGR in China can be divided into four stages

- Fuel
- Reactor physics
- Thermohydraulics
- Reactor structure etc.



Fundamental research
(1980s)

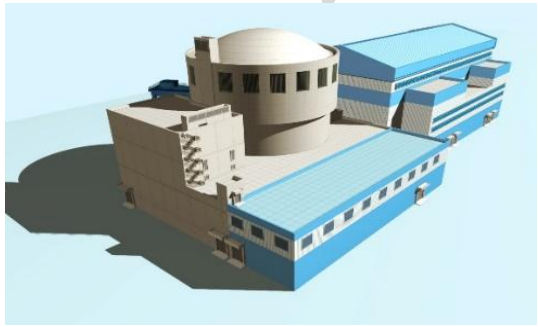
- Know-how
- verified Inherent safety features
- Fuel tech
- Thermal application

Test reactor
(HTR-10, 1986)

- Fuel quantity production
- Modular reactor
- Engineering validation
- Equipment manufactures capacity
- Safety review tech
- Economic feasibility

Demonstration plant
(HTR-PM, 2006)

- Inherent safety features
- Mature tech
- Modular and quantity production
- Economic competitiveness
- Achievable multi-use



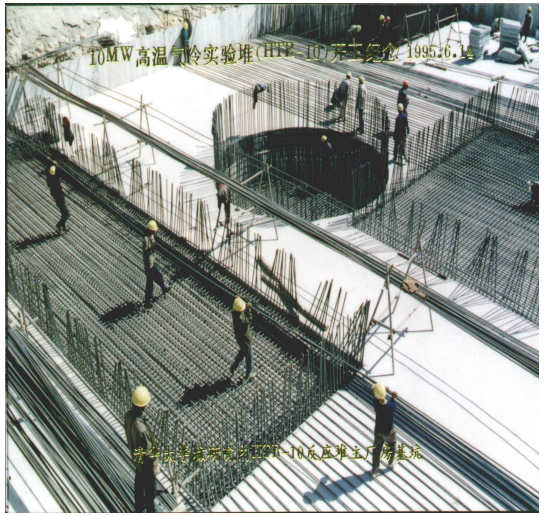
Commercial plant
(HTR-PM600, 2014)

10MW high temperature gas-cooled test reactor（HTR-10）

- **1986**: R&D on design and component technologies
- **1992**: Approved to construction
- **1995**: FCD Construction started
- **2000**: First criticality achieved
- **2003**: Full power operation

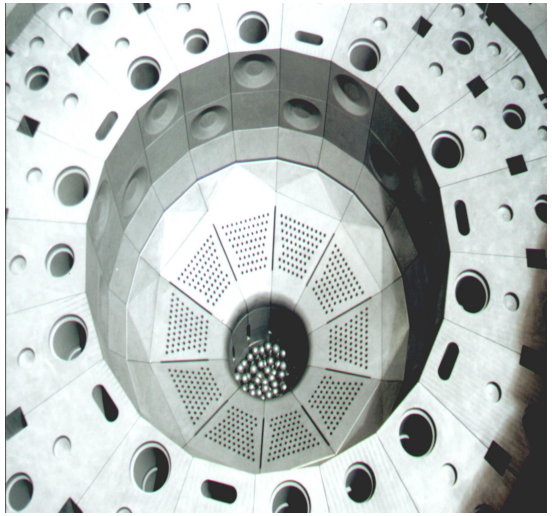
Main achievements

- Develop TRISO fuel elements technology
- A fully digital protection system was firstly used in China
- Have good grasp of HTR system design, i.e. fuel handling
- verified the Inherent safety features of Pebble Bed Modular HTR
- Follow-up R&D platform of HTR

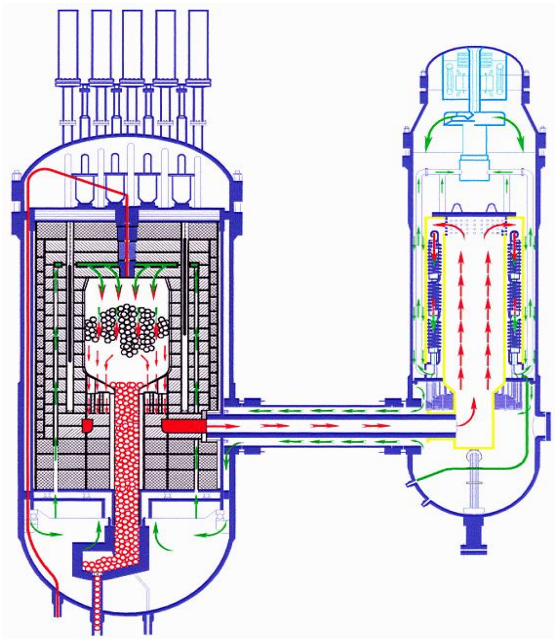


1995

Main control room

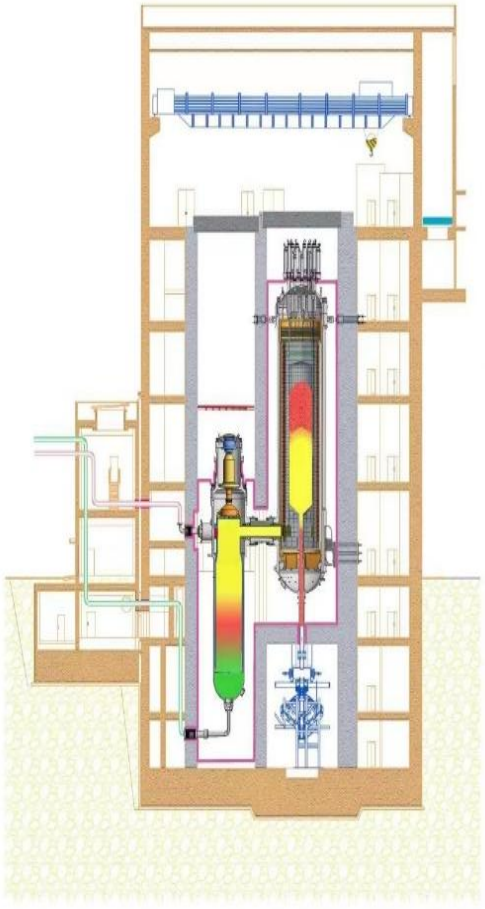


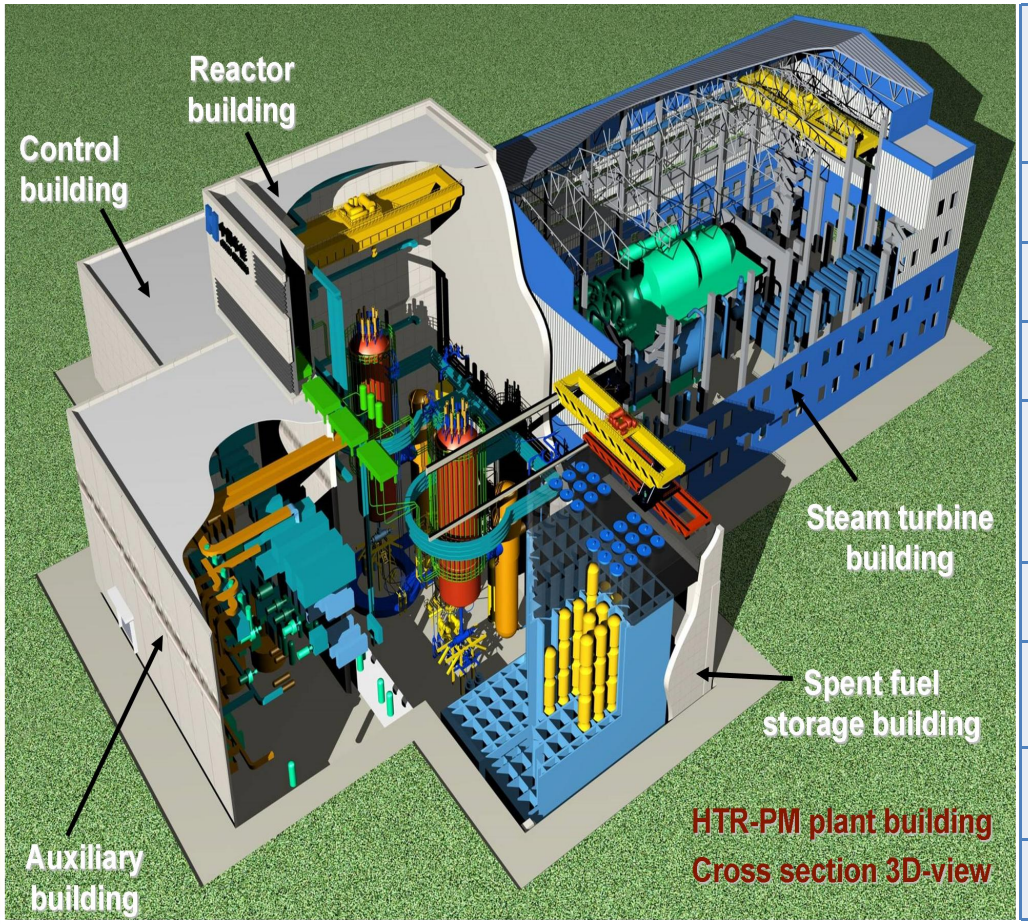
Reactor core structure



200MW HTGR demonstration project (HTR-PM)

- Based on the successful construction of HTR-10
- The world‘s first fourth-generation nuclear reactor
- Use two reactor modules to connect one steam turbine to achieve a power generation level of 200 Mwe





参数 Parameter	单位 Unit	数值 Value
电功率 Electricity power	MW	200
热功率 Thermal power	MW	2*250
冷却剂压力 Coolant pressure	MPa	7
反应堆入口/出口平均氦气温度 Reactor inlet/outlet helium average temperature	℃	250/750
冷却剂质量流量 Coolant mass flow	kg/s	96
反应堆平均热功率密度 Average power density	MW/m^3	3.22
堆芯等效直径 Diameter of core	m	3
堆芯等效高度 Height of core	m	11

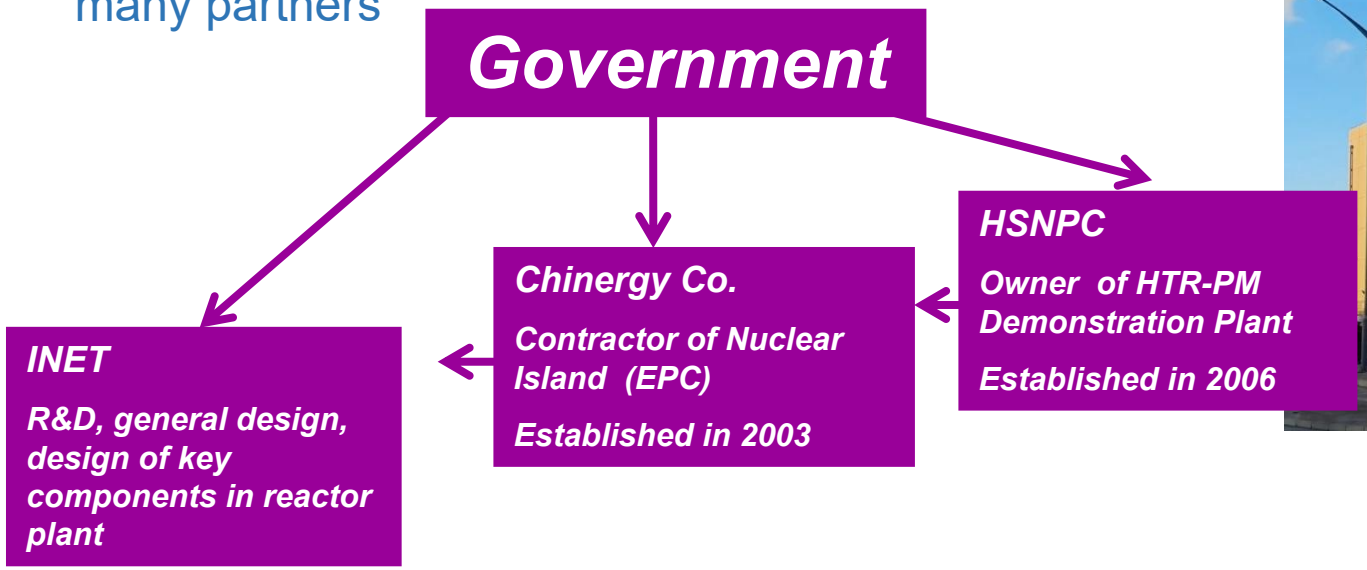
200MW HTGR demonstration project (HTR-PM)

- HTR-PM demonstration power plant in Shidao Bay, Shandong

200MW HTGR demonstration project (HTR-PM)

HTR-PM development team

As one of Chinese National Key Science and Technology Project (1 of 16 projects, including research, design, licensing, manufacturing, construction, fuel fabrication, operation, …, with many partners



200MW HTGR demonstration project (HTR-PM)

- HTR-PM Preparation
  - 2003: finished pre-concept design and decided to use steam turbine
  - 2004: signed industry investment agreement
  - 2006.01: became a key government R&D project
  - 2006.09: decided to use 2×250 MWt reactors with a 200 MWe turbine
  - 2008.02: government approved the HTR-PM project
  - 2008.10: issued procurement contracts of the lead components
  - 2008.4-2009.9: PSAR review
  - 2012.12: government issued construction permit and we poured the first concrete

Milestones of Construction(HTR-PM, Shidao Bay, Shandong)

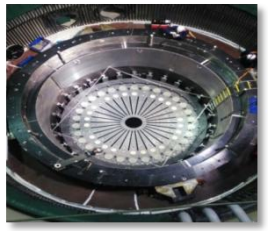
Dec 9th 2012 — FCD

Apr 25th 2015 — Sealed roof atop of main building structure

Mar 20th 2016 — First RPV lifting

Oct 16th 2016 — 110kV inversely feeding

Jun 8th 2017 — First Ceramic Internal installation

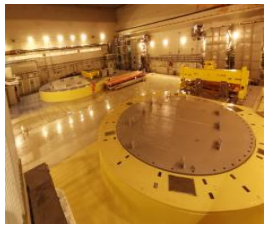


Jul 27th 2019 — Final SG positioned

Mar 18th 2020
Apr 29th 2020 — 2#NSSS Primary enclosure
1#NSSS Primary enclosure

Nov 3rd 2020
Oct 19th 2020 — 1#NSSS CFT
2#NSSS CFT

Feb 15th 2021
Mar 29th 2021 — 1#NSSS HFT
2#NSSS HFT



Aug 21st 2021 — The first spherical fuel elements loaded

Sep 12th 2021
Nov 11th 2021 — 1#NSSS Initial criticality Experiment
2#NSSS Initial criticality Experiment

Dec 14th 2021 — Combined to the Grid

Dec 9th 2022 — Both two reactors initial full power operation

Dec 6th 2023 — Commercial Operation

200MW HTGR demonstration project (HTR-PM)

Dec 6th 2023, the first modular HTR-PM nuclear power plant

has been put into commercial operation and commissioning in the world

200MW HTGR demonstration project (HTR-PM)

中核能源科技有限公司 CHINERGY CO.,LTD.
中核集团 CNNC

wnn world nuclear news

China's demonstration HTR-PM enters commercial operation

06 December 2023

Share

The world's first modular high temperature gas-cooled reactor nuclear power plant has entered commercial operation, China's National Energy Administration has announced.

The nuclear island of HTR-PM Demo (Image: Tsinghua University)

It follows a successful 168-hour demonstration run for the High Temperature Gas-Cooled Reactor - Pebble-bed Module (HTR-PM) in Shidao Bay (also known as Shidaowan), in Shandong Province, which is currently operating at 2×200 MWt power.

The HTR-PM features two small reactors (each of 250 MWt) that drive a single 210 MWe steam turbine. It uses helium as coolant and graphite as the moderator. Each reactor is loaded with more than 400,000 spherical fuel elements ('pebbles'), each 60 mm in diameter and containing 7 g of fuel enriched to 8.5%. Each pebble has an outer layer of graphite and contains some 12,000 four-layer ceramic-coated fuel particles dispersed in a graphite matrix. The fuel has high inherent safety characteristics, and has been shown to remain intact and to continue to contain radioactivity at temperatures up to 1620°C - far higher than the temperatures that would be encountered even in extreme accident situations, according to the China Nuclear Energy Association.

First concrete for the demonstration project was poured on December 2012, with the operating permit granted in August 2021 and the plant connected to the grid in December 2021. The plant has more than 2200 sets of first-of-a-kind equipment, including more than 660 sets of innovative equipment. The supporting fuel element production line has the largest production capacity in the world.

The project is a collaborative effort involving Tsinghua University as a technical leader, responsible for research and development and main components and systems design, with China Huaneng Group as the owner and operator of the plant, and China National Nuclear Coorporation as the engineering, procurement, and construction contractor and fuel manufacturer. Professor Zuoyi Zhang, director of the Institute of Nuclear and New Energy Technology at Tsinghua University, is the chief scientist and chief engineer for the project.

HTR-PM is a Generation IV nuclear energy technology and a small modular reactor. Two safety demonstration tests were conducted on the reactor modules, each at a power of 200 MWt, on 13 August and 1 September, respectively.

A Tsinghua spokesperson said: "The normal energy transfer driven by power was stopped during the tests. The measured nuclear power and temperatures within the different reactor structures, described how the reactors were naturally cooled down, without intervention of humans or emergency core cooling systems. The tests confirmed that commercial-scale reactors could be cooled down naturally without emergency core cooling systems for the first time in the world. It is the so-called inherently safe reactor.

"The major purpose of HTR-PM is to co-generate high temperature steam up to 500°C and electricity. It is cost effective currently in the Chinese market to supply steam and electricity for the petrochemical industry to substitute the burning of natural gas and coal. This breakthrough technology is recognised to play a positive role in optimising energy structure and achieving China's 'dual carbon' goal. Several commercial projects are under preparation in China."

China's National Energy Administration, in announcing the start of commercial operation, said: "The commissioning of the demonstration project is of great significance and has a positive impact on promoting the safe development of nuclear power in our country and improving our country's nuclear power power scientific and technological innovation capabilities."

In an interview last year for World Nuclear Association's *World Nuclear Performance Report 2022*, Lu Hua Quan, chairman of the Nuclear Research Institute, Huaneng Company, explained: "HTRs have the highest operating temperatures of all existing reactor types, and are also the only reactors that can provide very high-temperature process heat." He said there was export potential, especially to countries and regions where freshwater resources were scarce, adding that "HTRs could in the future provide a source of high-quality high-temperature process heat for various industries,

THE WALL STREET JOURNAL.

UNDERSTANDING CHINA News & analysis | Great Power Conflict | Tensions With U.S. | Taiwan Relations | China End

WORLD | CHINA

Atomic Power Is In Again—and China Has the Edge

A next-generation reactor that is safer and more efficient began commercial operation in eastern China

By Sha Hua Follow

Updated Dec. 7, 2023 7:55 am ET

Save | AA | Listen (6 min)

The first-ever fourth-generation nuclear power plant began commercial operation in China's Shandong province. PHOTO: ZHANG MANYI/ZUMA PRESS

SINGAPORE—China's push to reduce its use of fossil fuels and imports of oil and gas has put the country at the forefront of civilian nuclear technology, as climate change is bringing nuclear power back into vogue.

The country became the first in the world to put the latest generation of nuclear power technology into use, China said Wednesday, as a power plant with two new reactors started commercial operations in the eastern province of Shandong.

Learn more about LSEG

REUTERS®

My View | Following | Saved

China

China starts up world's first fourth-generation nuclear reactor

By **Colleen Howe**

December 8, 2023 4:57 AM EST · Updated 2 days ago

Aa

BEIJING, Dec 6 (Reuters) - (This Dec. 6 story has been corrected to change the timing and reason for NuScale's plant termination in paragraph 5)

China has started commercial operations at a new generation nuclear reactor that is the first of its kind in the world, state media said on Wednesday.

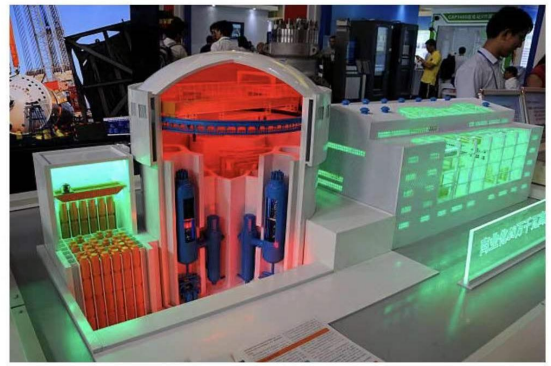
Compared with previous reactors, the fourth generation Shidaowan plant in China's northern Shandong province is designed to use fuel more efficiently and improve its economics, safety and environmental footprint as China turns to nuclear power to try to meet carbon emissions goals.

Bloomberg Subscribe

Green

China's First Next-Gen Nuclear Reactor Enters Commercial Operations

- Shidao Bay is China's first high temperature gas reactor
- China is building more nuclear plants than any other country



Model of the Shidao Bay high temperature gas-cooled reactor. *Photographer: VCG/Getty Images*

By Bloomberg News

2023年12月6日 at GMT-5 01:18

Copy Link

Save

1:31

Status of HTR-PM project

- HTR-PM: High temperature gas cooled reactor—pebble bed module
  - Mission of HTR-PM in China
    - Supplement to PWRs
      - for power generation, especially to replace coal-fired power plant in population region
    - Co-generation
      - of steam and electricity
      - & Hydrogen production in future
    - Technology Innovation
      - Supported as one of National Key Science and Technology Projects
      - Establishment of whole supply chain

Status of HTR-PM project

- China has achieved a leading position in the field of modular HTGR industrialization
- *Many achievements have been made in this process* : the world's largest helium test loop R&D platform; production line with annual output of 300,000 spherical fuel elements; complete HTGR industrial chain; engineering construction and operation experience etc.
- Provide strong support for the subsequent large-scale commercial promotion of HTGR

Achievements

- Verifiable and demonstrable HTR steam power plant
- Verifiable and demonstrable of operational and safety features
- The standardized nuclear steam supply system modular
- Verifiable and demonstrable for operation technology of two reactors driving a turbine
- The production capacity of industrial fuel element
- The complete development and construction experience, mature development team
- cultivate an industrial chain, important equipment achieve domestic production
- Engineering Experience Feedback

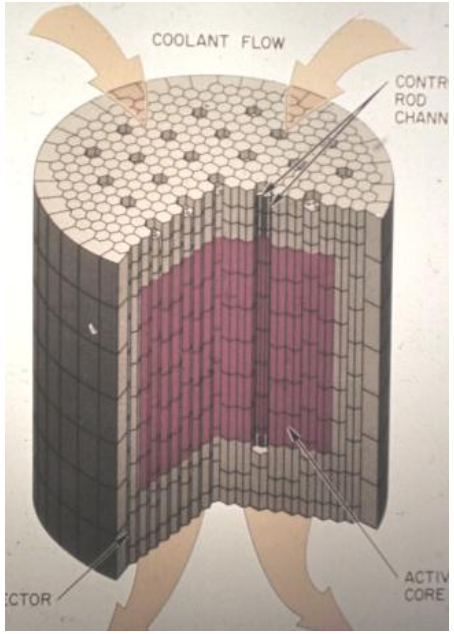
The largest helium test loop in the world

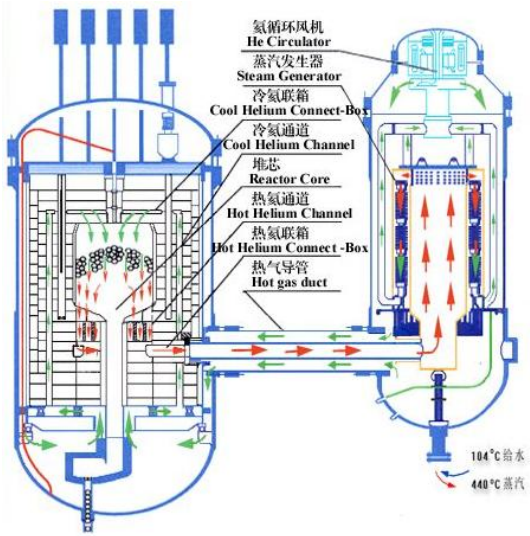
Production capacity of industrial fuel element

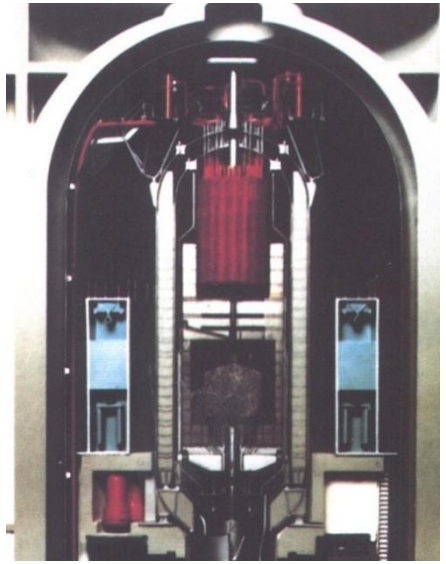
中核能源科技有限公司
CHINERGY CO.,LTD.
中核集团 CNNC

CONTENTS

Prismatic & pebble bed HTR



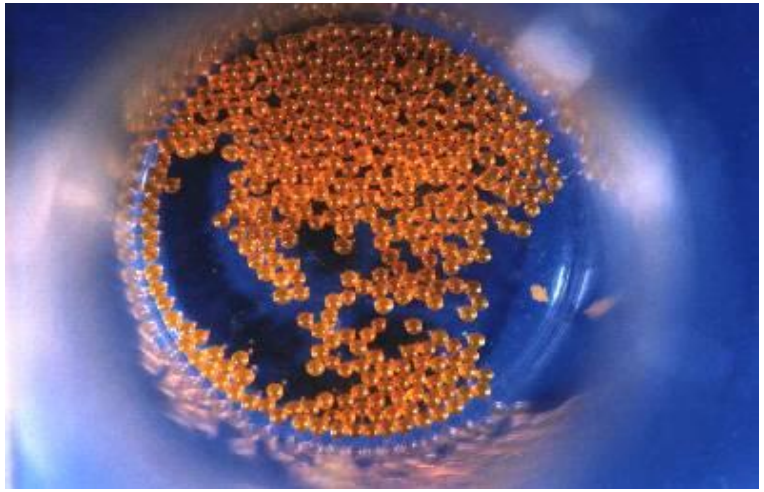




Simple idea

Coal stoves

Same TRISO coated particle fuel
Same inherent safety features



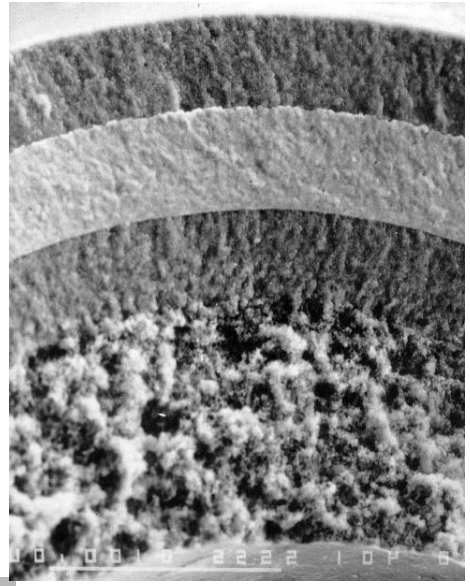
Dense PyC

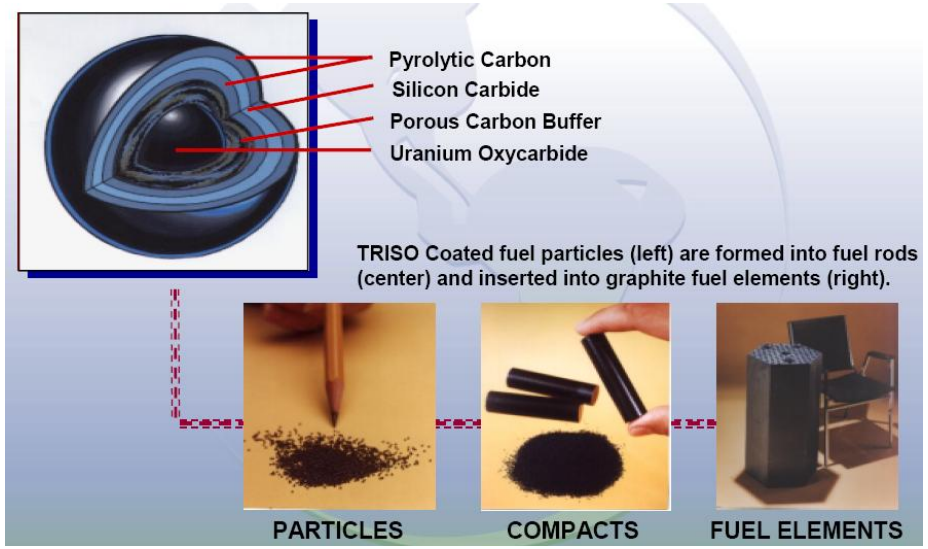
SiC

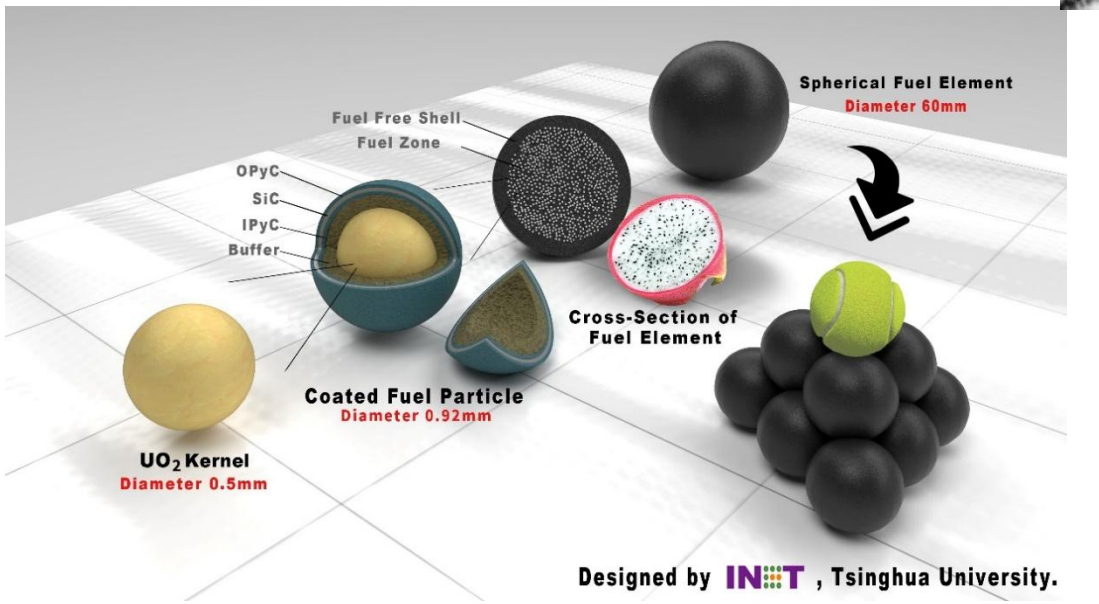
Dense PyC

Porous PyC

Fuel kernel



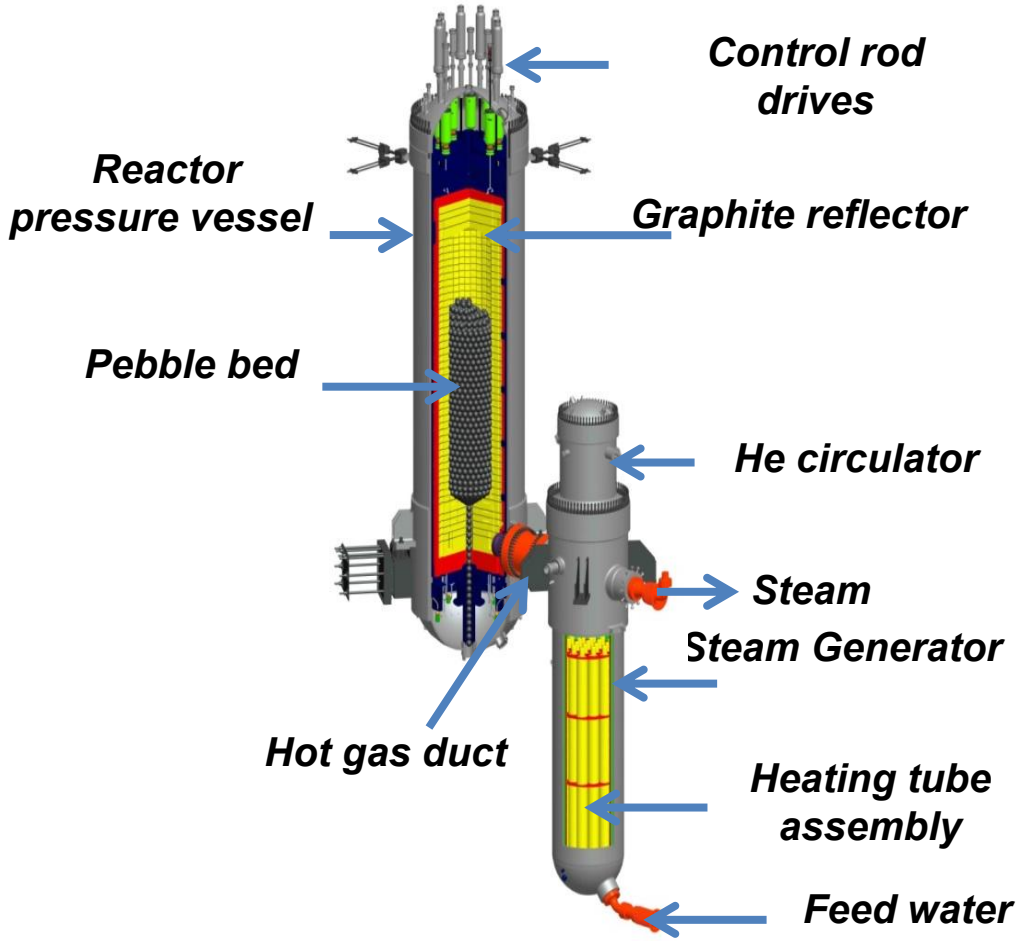




- **Performance of TRISO fuel**
- ***Failure fraction in manufacturing: <6×10^{-5}***
- ***Failure fraction resulted by irradiation under normal operation: <2×10^{-4}***
- ***Additional failure fraction since heat up to 1620 °C after target burnup: <5×10^{-4}***

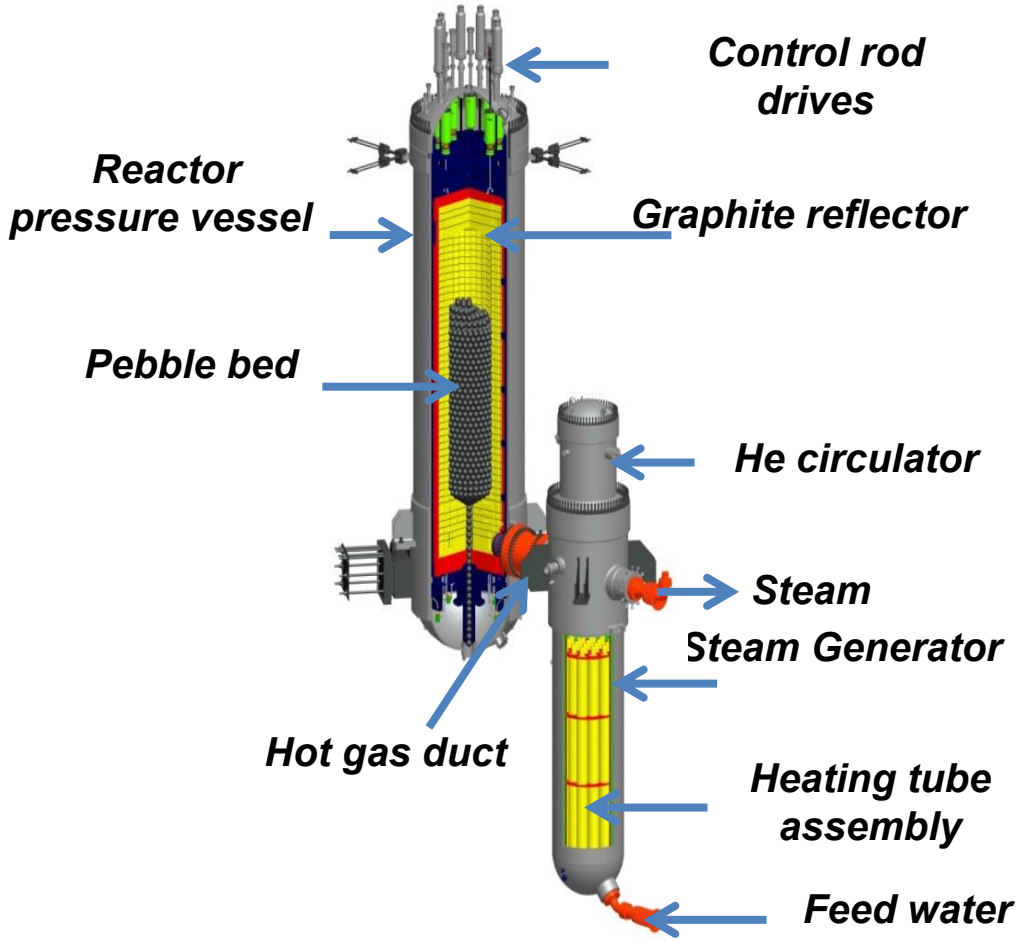
Technical features of Pebble-bed Modular HTR-PM

- An ideal inert gas of helium is used as coolant
- The temperature of the reactor outlet coolant in HTGR can be up to 750°C
- The graphite is used as moderator and reflector constructive materials
- The reactor uses all-ceramic TRISO-coated spherical fuel element
- Each reactor contains 420,000 spherical fuels in the core



Technical features of Pebble-bed Modular HTR-PM

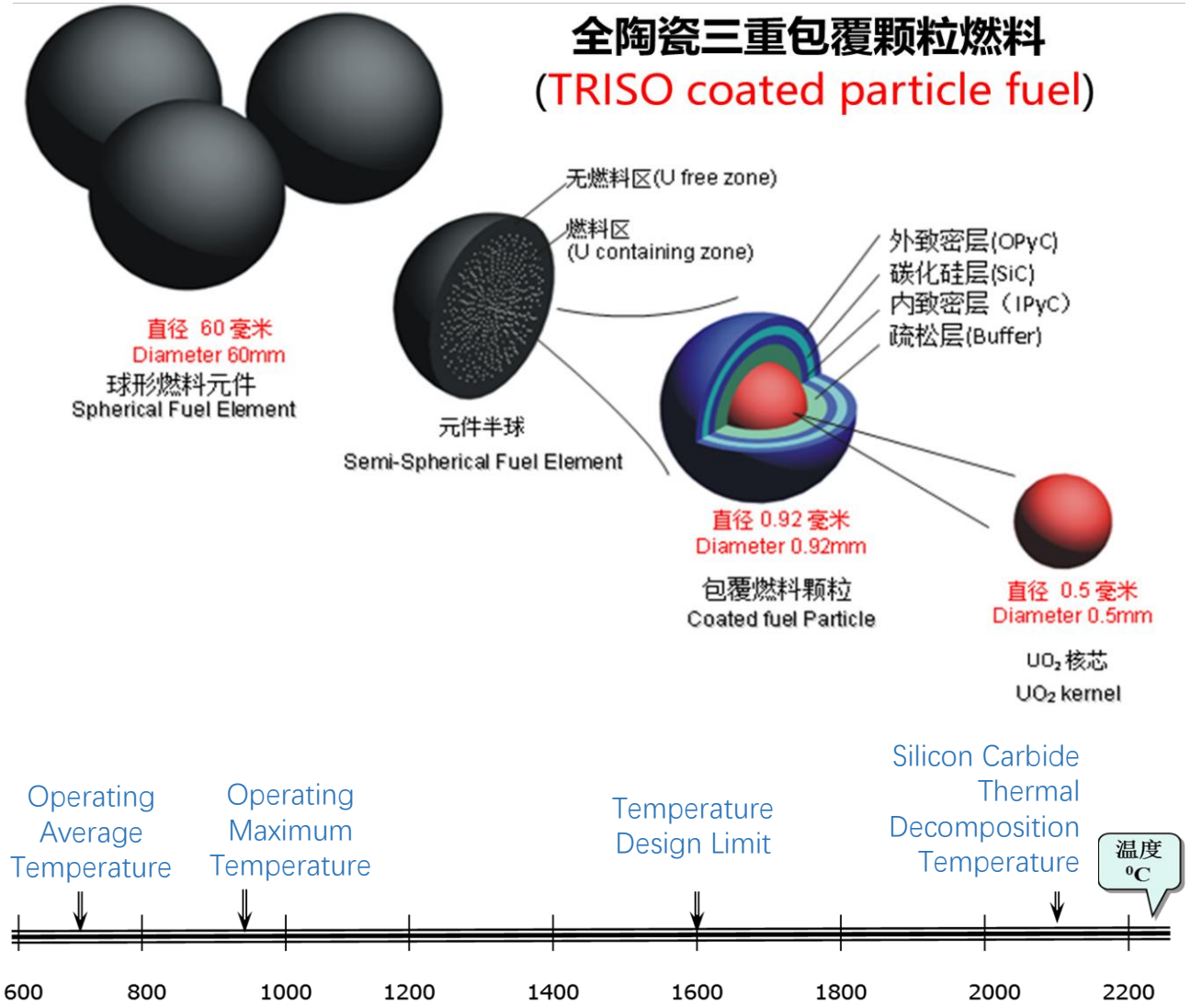
- Once-through steam generator with process heat
- Confinement/Vented Low Pressure Containment without leak-tight requirement



Technical features of Pebble-bed Modular HTR-PM

Inherent Safety Features

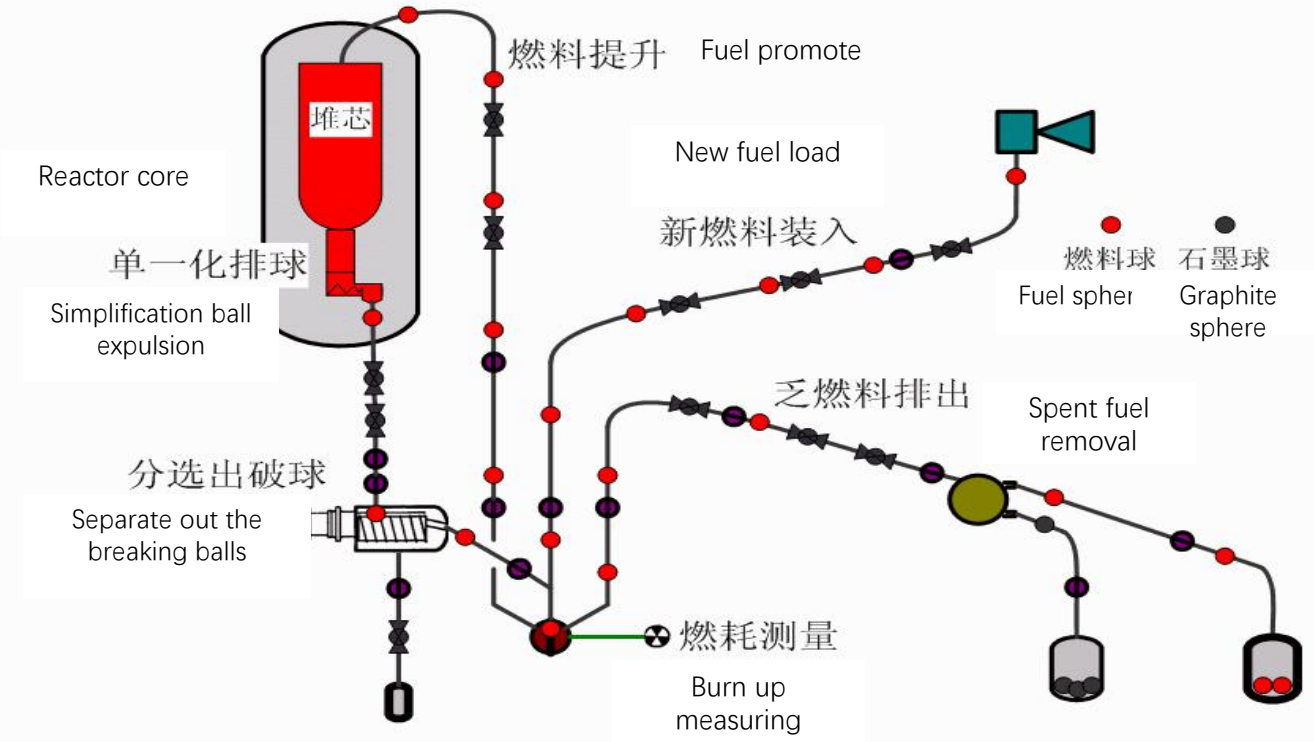
- The TRISO-coated fuel particles are considered a key safety feature of HTGRs， each coated particle can be treated as a “containment”, of which the failure fraction is very low
- Retention of fission products in coated particles for normal operation, DBAs and BDBAs
- In case of any accident, the maximum fuel element temperature will not exceed the limit value 1620 °C
- The reactor core meltdown and large-scale radioactivity release will not occur in any normal operating and accident conditions



Technical features of Pebble-bed Modular HTR-PM

- On-line refueling
- Main technical features
  - Inherent safety features
  - High Temp Multi-role
  - Modularization

Fuel handling schematic diagram



Technical features of Pebble-bed Modular HTR-PM

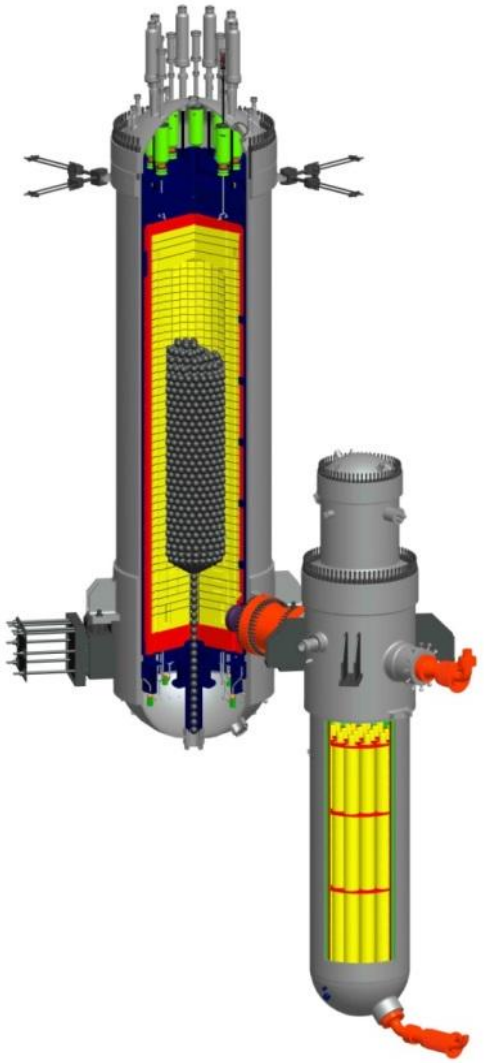
Inherent Safety Features

- To ensure the safety of the reactor, three things must be done well: shut down the reactor; remove the residual heat that continues to be generated after shutdown; ensure that radioactive materials are not released into the environment
- The modular HTGR achieves these objectives through innovative design, achieving inherent safety

Key issues for the reactor safety	Inherent safety design of Modular HTGR	safety goals
Reactor shut down	• Negative feedback • Large temperature margin	• Shut itself down
Decay heat removal	• Low power density • Slim core • Large heat capacity	• Inherent heat removal • Core meltdown free
	• TRISO particle • Below 1620° C	• Radioactivity retention

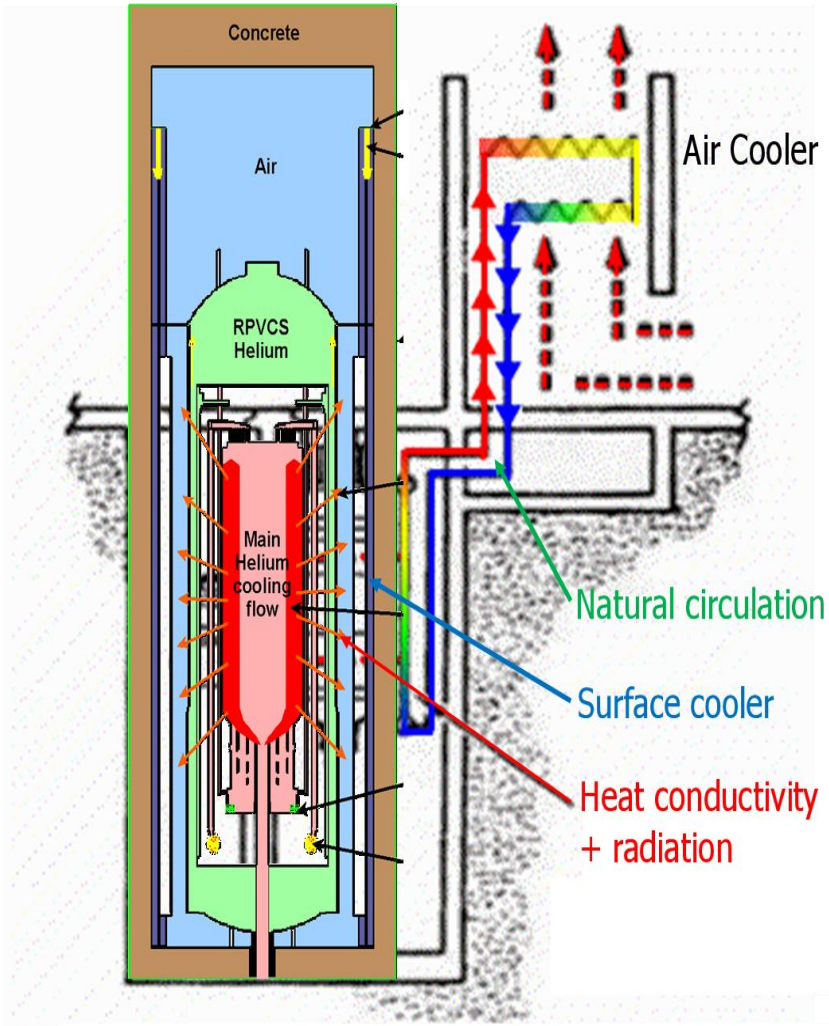
Inherent Safety Features : **reactor shut down**

- HTGR has a large negative reactivity coefficient and a large fuel temperature margin
- Two independent shutdown systems are designed: a control rod system and a small absorber sphere system. In the event of an accident such as a power failure, the rods and the small absorbers are released and drop into the reflector borings by gravity automatically to shut down the reactor （We use only one shutdown sysytem in our newest project, due to the inherent safety features of MHTR）



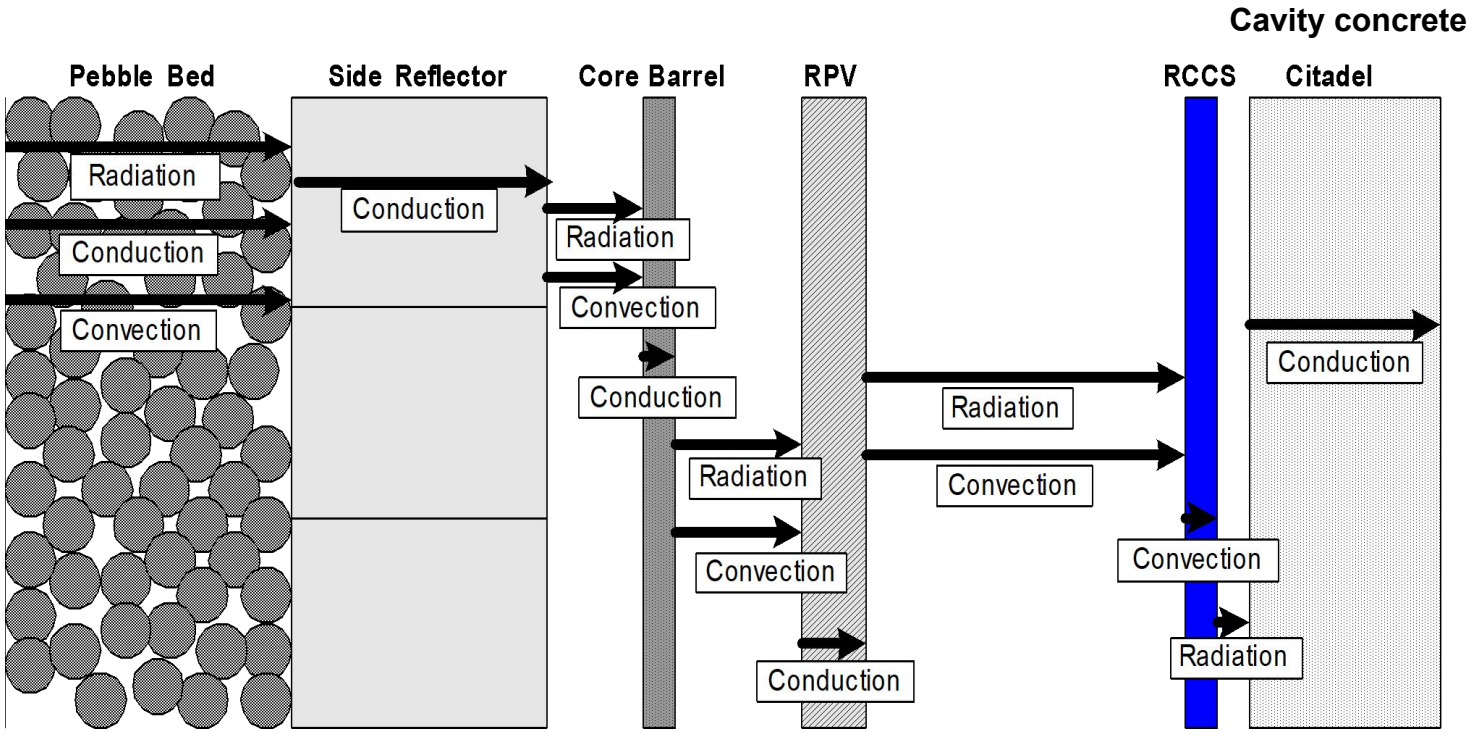
Inherent Safety Features : **decay heat removal**

- HTGR uses a design of low power density and the power density is only 1/30 of the PWR reactor, thus the absolute number of heat generated and decay heat are small
- The base of the fuel balls and the reflector surrounding the reactor core is made of graphite, the heating process following an accident can be effectively mitigated
- HTGR sets passive residual heat removal system



Decay heat removal by natural mechanism

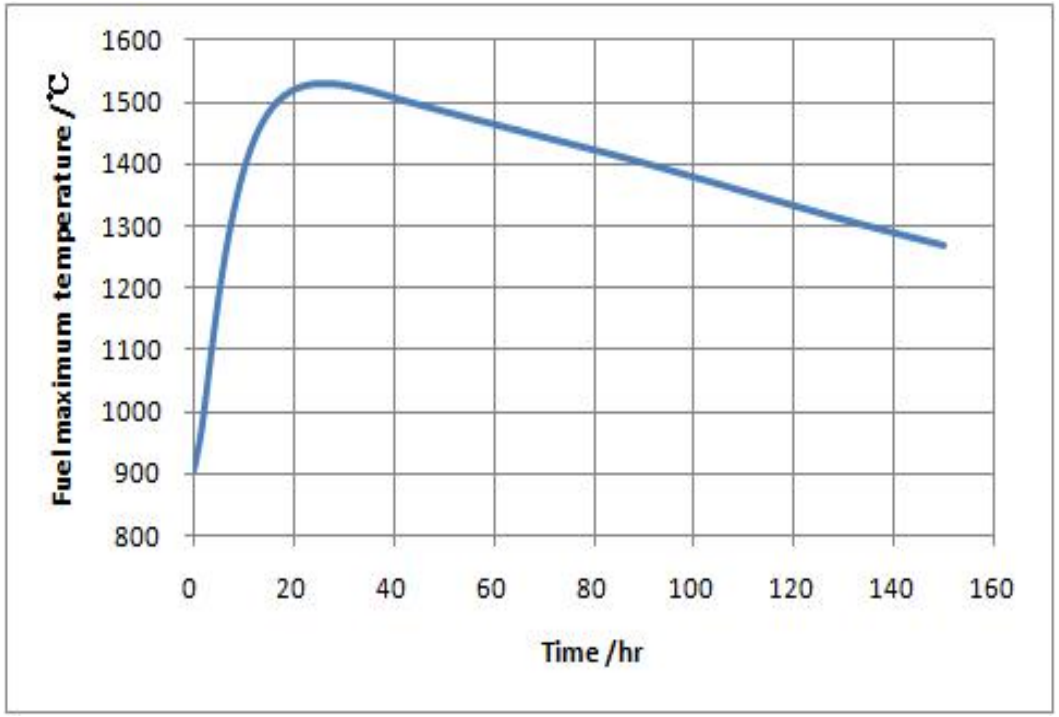
Decay heat transfer path based on temperature gradient



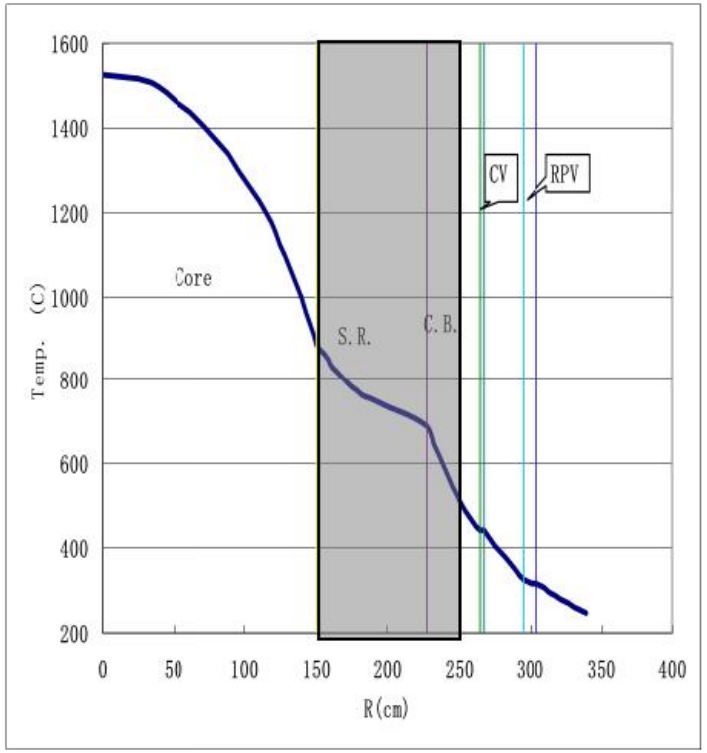
Inherent post-shutdown decay heat removal is achievable through conduction, natural convection and radiation heat transfer. Design choices include core geometry, low power density and high thermal capacity of the core structures.

Temperature for DLOFC(depressurized loss of forced cooling) accident

Even for total loss of coolant, no action, after long time, temperature less than limit, high temperature just in small area, small time interval



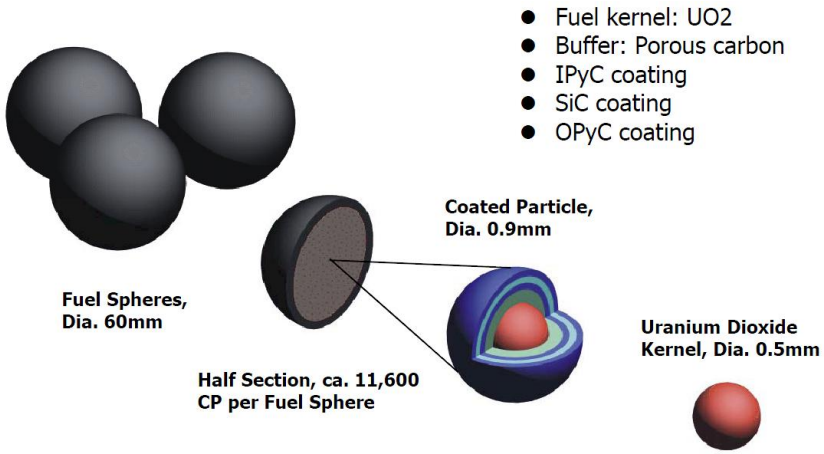
Total Loss of coolant can never be assumed in other reactors.



Technical features of Pebble-bed Modular HTR-PM

Inherent Safety Features: **radioactivity retention**

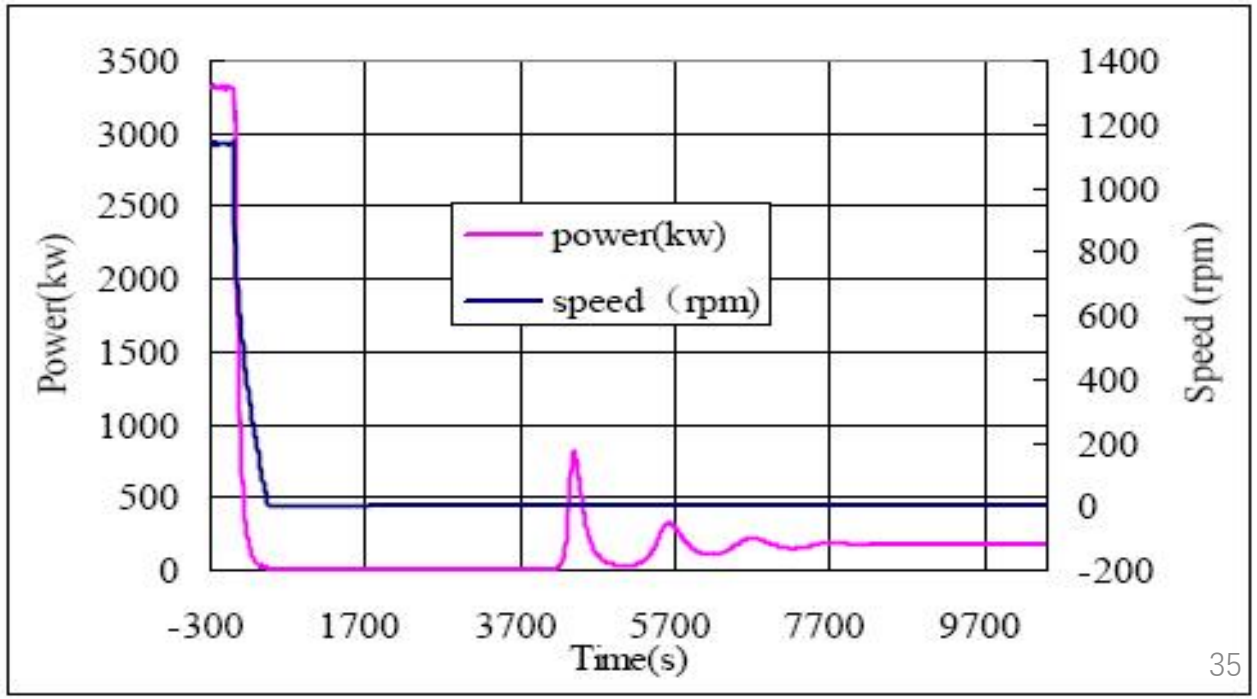
- HTGR is composed of all-ceramic fuel elements. It is able to prevent the release of radioactive fission products at temperatures not higher than 1620°C
- The reactor core meltdown and large-scale radioactivity release will not occur in any normal operating and accident conditions



Inherent Safety Features: test on HTR-10

- In 2004, 60 scientists from 24 countries organized by IAEA witnessed the inherent safety verification test carried out on the HTR-10 on the spot
- Verified the large negative temperature coefficient of reactivity of the reactor and that decay heat removal totally guaranteed by natural mechanisms can keep the reactor in safe state

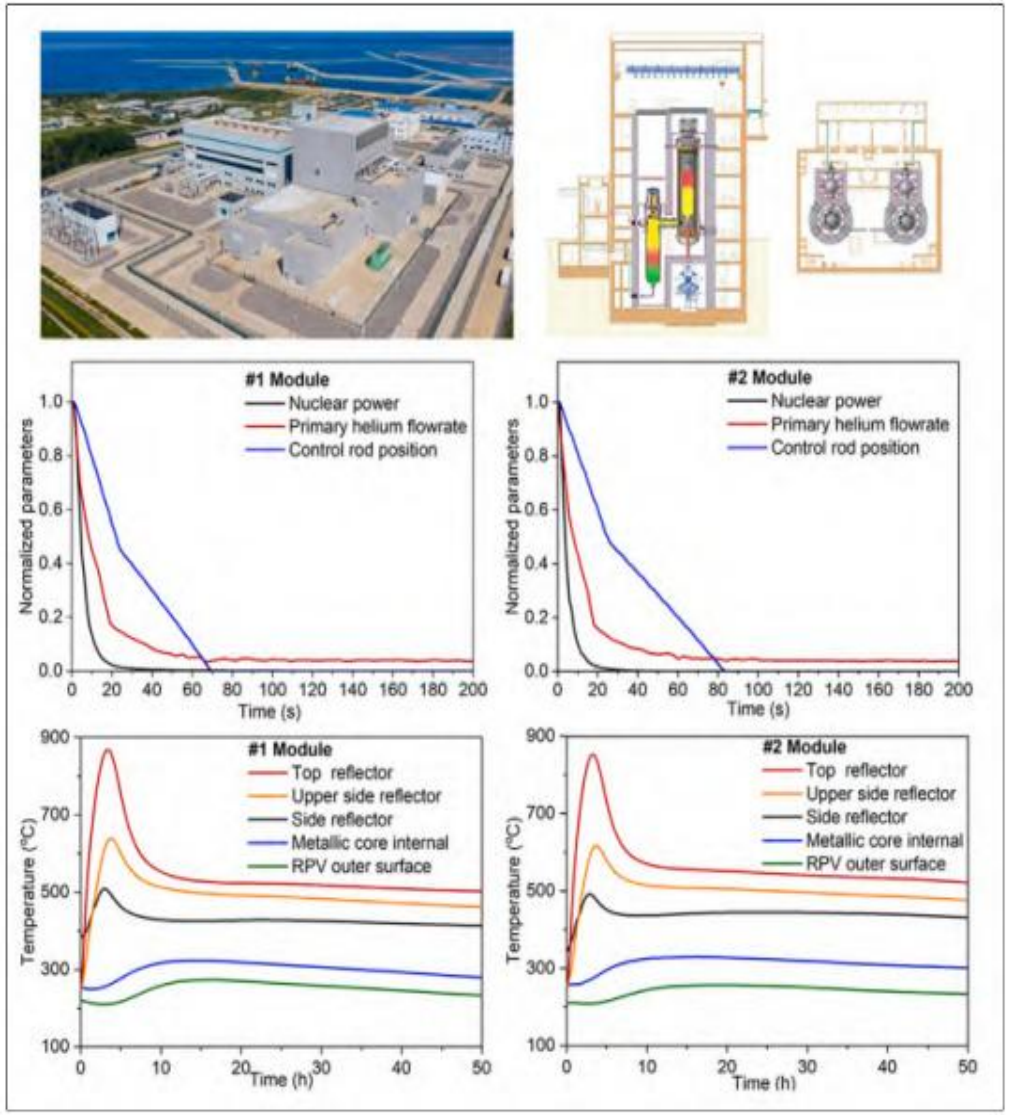
Safety demonstration test of helium circulator trip ATWS test



Technical features of Pebble-bed Modular HTR-PM

Inherent Safety Features: test on HTR-PM

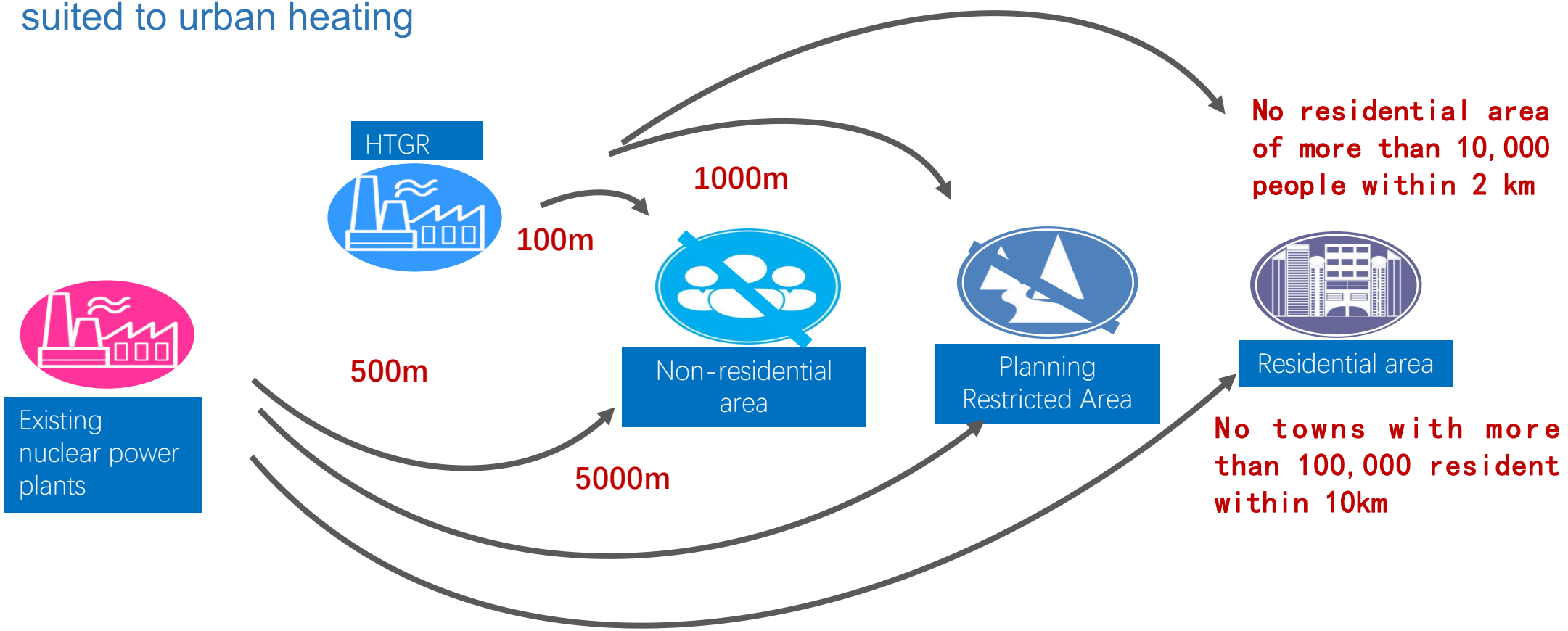
- In August and September of 2023, The first world's verification experiment of power outage combined with loss of cooling accident was carried out on HTR-PM nuclear power plant
- First time that commercial-scale nuclear fission reactors can be cooled down naturally without emergency core cooling systems
- HTGR technically eliminate the need for off-site emergencies and can built close to the users



Technical features of Pebble-bed Modular HTR-PM

Close to the user

- According to the “Principles and Requirements for the Delineation of Non-residential Area and Planning Restricted Area for Small Nuclear Power Plants (Draft for Public Comments)”, HTR-PM sites can be closer to users, are more environmentally friendly, and are better suited to urban heating



中核能源科技有限公司
CHINERGY CO.,LTD.
中核集团 CNNC

CONTENTS

Future of HTR-PM

HTGR Technology Development Route

Commercialized Improved HTGR

Construction of multi-module commercialized units based on reactor modules validated in HTR-PM

Reactor outlet temperature 750 °C

Cogeneration or Industrial Steam

Supercritical HTGR

Combined with supercritical steam turbine for higher power generation efficiency

Multi-module

Reactor outlet temperature 750 °C

Supercritical power generation

Utilization of decommissioned thermal power plant sites

Very High Temperature Gas-Cooled Reactor (VHTR)

Increasing reactor outlet temperatures to enable hydrogen production

Reactor outlet temperature reaches 900°C, Intermediate heat exchanger developed

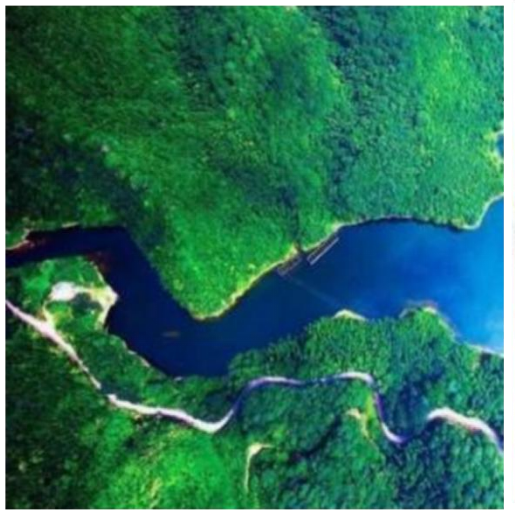
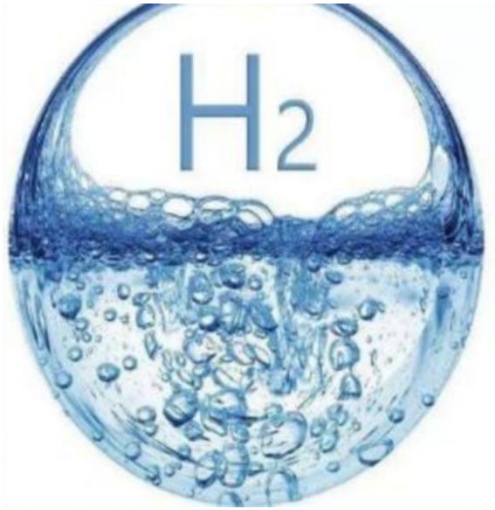
Hydrogen production from nuclear energy

Multi-use applications of HTR-PM

■ Carbon Peaking and Carbon Neutrality goals present significant opportunities for HTGR

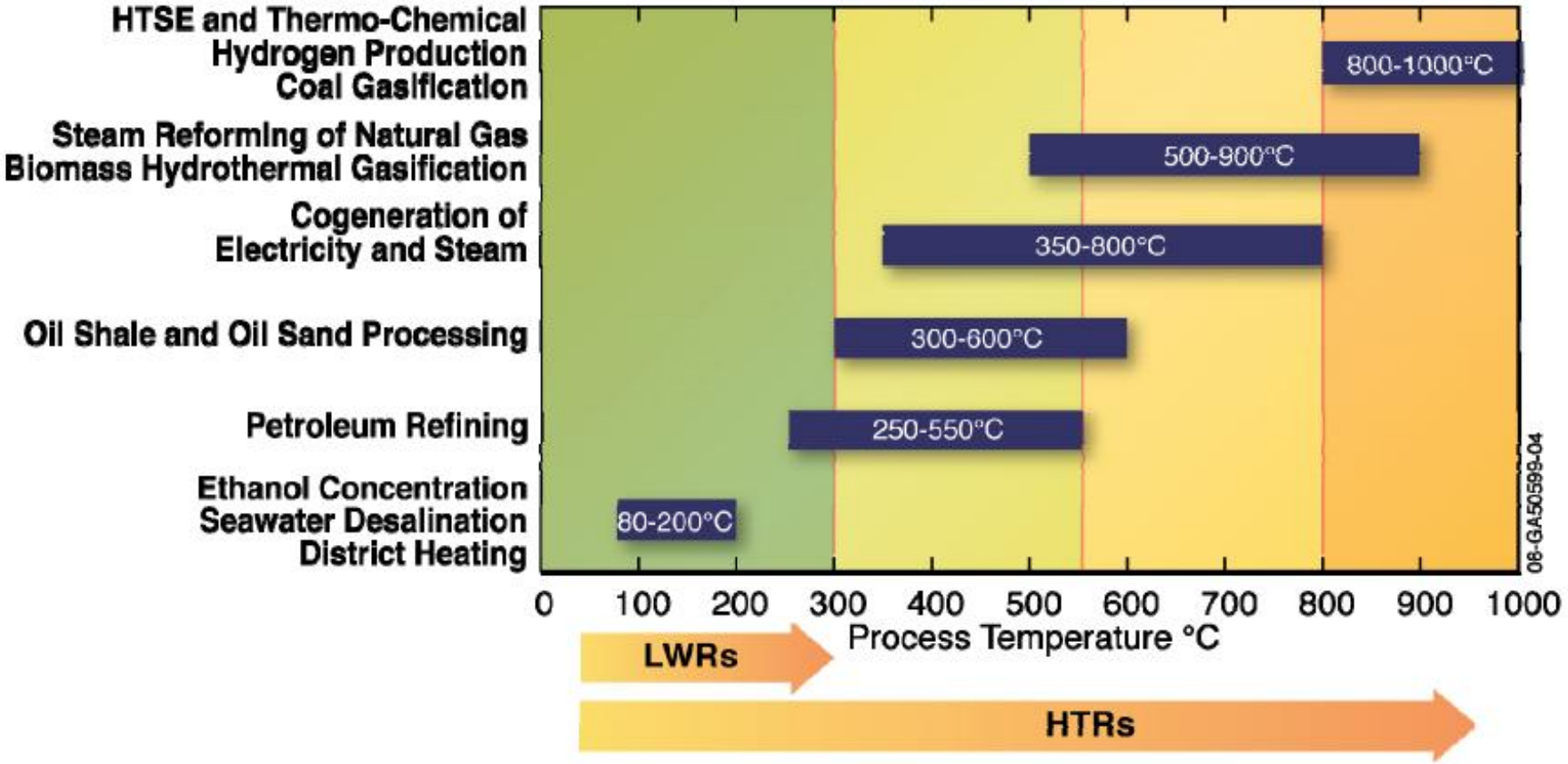
- Implementing a dual carbon strategy, which aims to achieve carbon peaking and neutrality, will impact various industries, particularly those with high carbon emissions,such as steel, cement, chemicals, and heavy machinery manufacturing, etc.
- HTGR as a green low-carbon, safe and efficient advanced nuclear energy technology can provide a variety of products, including "hydrogen, steam, water, heat, electricity" and other products, has a huge market potential and development opportunities



Multi-use applications of HTR-PM

- HTGRs have a wide range of potential applications
  - HTGRs can operate at temperatures up to 950°C or even higher, which can cover most of industrial thermal demand, such as hydrogen production, petrochemical industry, electricity production, seawater desalination etc.



Multi-use applications of HTR-PM

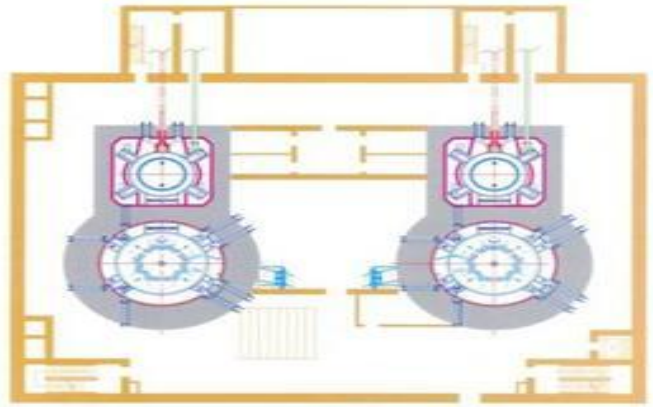
Modularization: built as needed

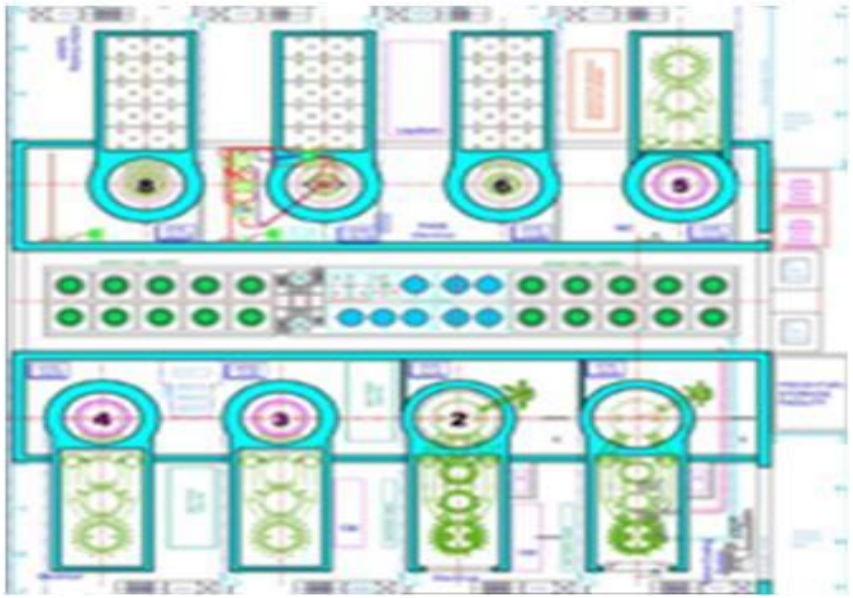
➢ Flexibility to adapt to market demand

- Small and medium power grids/remote areas
- Slow growth/substitution
- The scale of process heat application

➢Construction flexibility

- Partial construction and operation
- Reduced pressure of investment
- Standardization/Economies of scale/learning curve ……



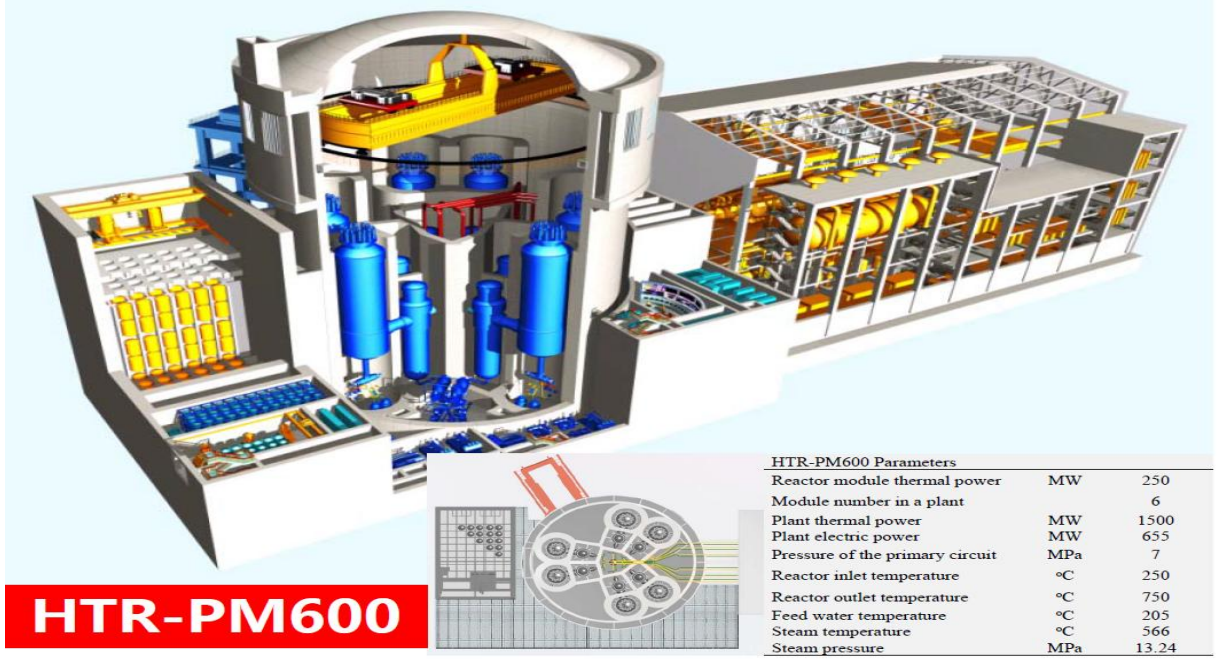


Efficient Power Generation

- HTGRs can be used to generate electricity directly, similar to conventional nuclear power plants
- Affected by carbon peak and neutrality policies, a large number of fossil fuel power plants will gradually be shut down and retired
- HTGRs have advantages of inherent safety and flexible scale, they can be built close to users. It is a promising option to reuse retired fossil fuel power plant sites to construct HTGRs,which can offer several benefits:
  - **Infrastructure Utilization:** Existing infrastructure such as transmission lines, substations, and water supply systems can be repurposed, reducing the need for new construction and associated costs
  - **Land Availability:**The sites typically have land, which can expedite the development process and minimize land acquisition challenges

Efficient Power Generation

- As a follow-up commercial version of the HTR-PM, 600MWe HTGR(HTR-PM600) have been further researched and developed for power generation
- HTR-PM600 is based on the technology of the HTR-PM project. It utilizes proven HTR-PM reactor and steam generator modules. Six modules are compact arranged in a circular factory building and connected to a steam turbine, form a 600-MWe nuclear power plant. HTR-PM600 achieves the same level of inherent safety as the HTR-PM and a power generation efficiency of 43.7%
- The industrialization project is currently progressing



HTR-PM600 Parameters		
Reactor module thermal power	MW	250
Module number in a plant		6
Plant thermal power	MW	1500
Plant electric power	MW	680
Pressure of the primary circuit	MPa	7
Reactor inlet temperature	ºC	250
Reactor outlet temperature	ºC	750
Feed water temperature	ºC	**205**
Steam temperature	ºC	**541**
Steam pressure	MPa	**14.3**

HTR-PM coupled with petrochemical industry

Background: "carbon peaking and carbon neutrality"

- **HTR-PM coupled with petrochemical industry to provide highly efficient and stable electricity and steam as well as alternative coal consumption for petrochemical industry parks**

- The petrochemical industry is the basic industry of national economic development in China
- One of the industries with high energy consumption and high carbon emission
- Developing petroleum and chemical industries as large energy consumers are facing serious challenges

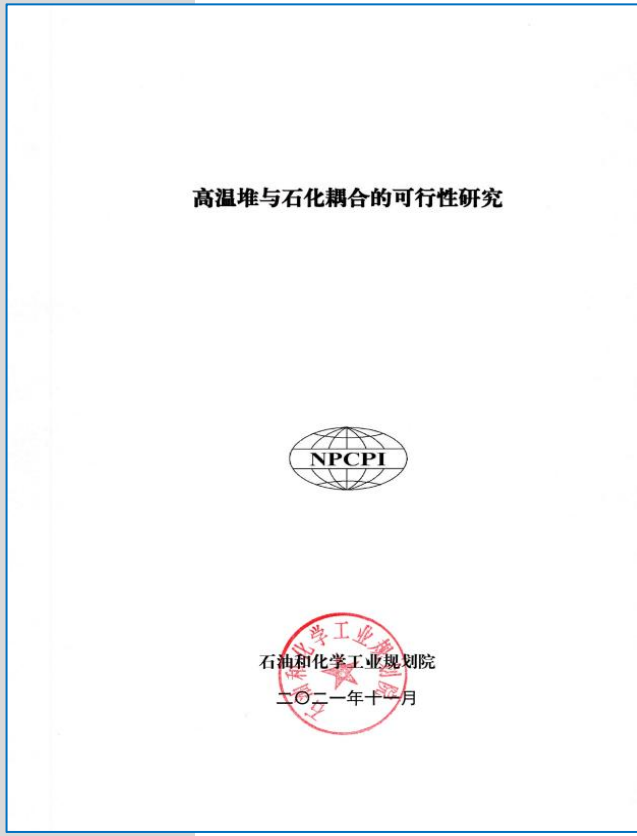
A feasibility study on how HTR-PM could be implemented for a petrochemical park with a specific design

□ Demand of energy to match Petrochemical parks

- The Petroleum and Chemical Industry Planning Institute has been commissioned to complete "Feasibility study of HTGR coupling with Petrochemical Industry"

  According to the development of 22 petrochemical parks in China's coastal areas to the planning scale:

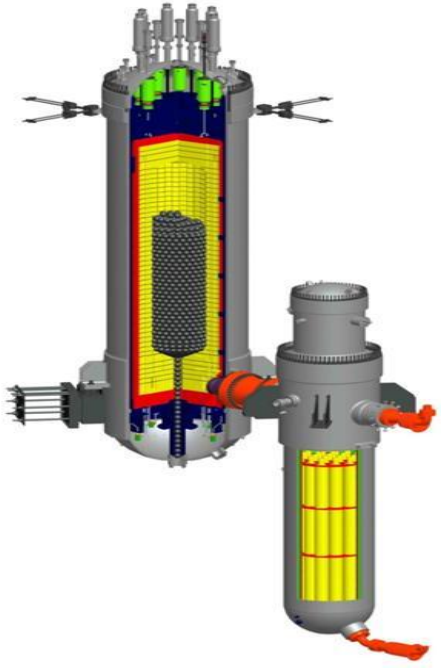
- Steam: The total demand is 135,000 t/h
- Electric: The total power consumption is about 40 million kilowatts
- Hydrogen: The total consumption of hydrogen in China is around 28 million tons (about 316.4 billion cubic meters), of which chemical hydrogen accounts for nearly 98.5%
- Desalination: Petrochemical parks are located in coastal areas islands etc., and all have demand for desalination



The energy demand is highly consistent with the HTGR "hydrogen, steam, water, heat, electricity" products

HTR-PM coupled with petrochemical industry

- It has a good match with the power and energy demand of the petrochemical park
- Can simultaneously meet the park's demand for "green hydrogen, steam, seawater desalination, heating, and electricity (hydrogen, steam, water, heat, and electricity)"
- At present, the main steam of HTGR is 13.9MPa and 540℃, which can cover the main steam demand of petrochemicals



electricity

steam

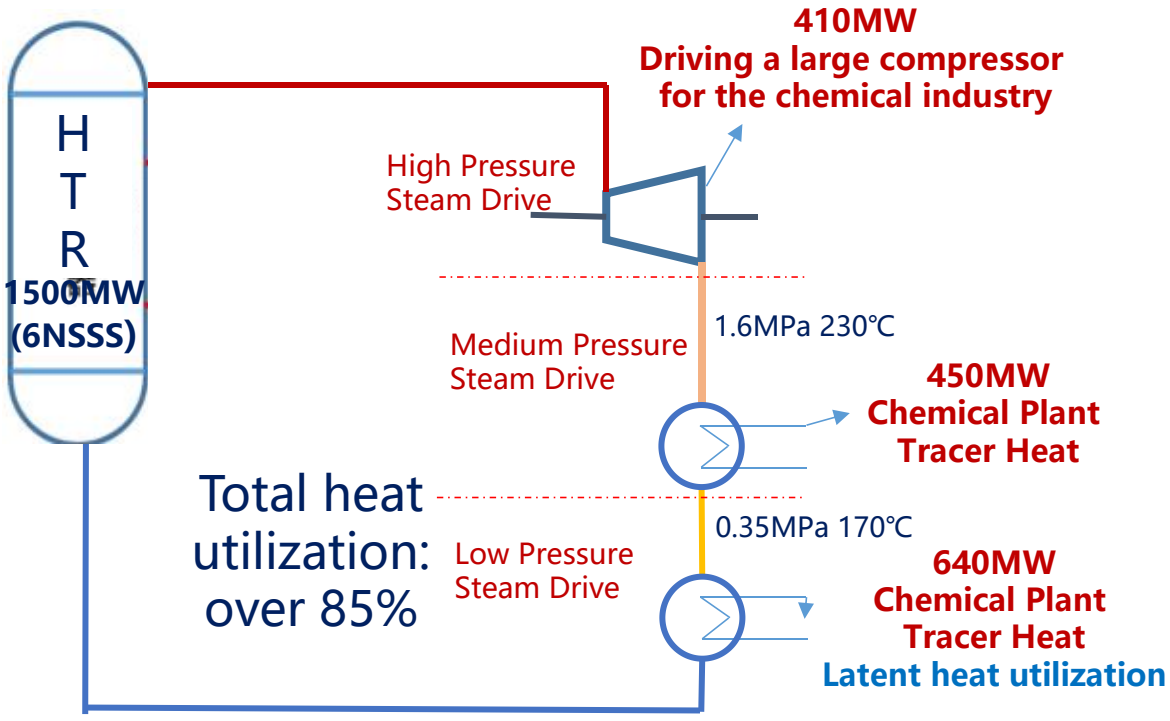
desalination

green hydrogen

HTR-PM coupled with petrochemical industry

Petrochemical coupling technology

- Ability to supply heat continuously:
  - independence of each module, mutual backup, any NSSS module, or even a module stopping, will not affect the overall heat supply;
- Directly apply the technology proven in HTR-PM;
- Give full play to the high-temperature and multi-purpose features and advantages of high-temperature gas-cooled reactors.



HTR-PM coupled with petrochemical industry

- HTGRs can provide industrial-scale, low-carbon, and stable high-temperature process heat for various industries such as petrochemicals, steel, heavy oil thermal recovery and so on, replacing the consumption of fossil fuels and reducing carbon emissions
- Companies like PetroChina and Sinopec have signed strategic cooperation agreements with the China National Nuclear Corporation (CNNC) to jointly promote the cooperation of HTGR in providing energy for petrochemical industrial parks and other areas

Steam consumption parameters for a certain petrochemical park	
Ultrahigh Pressure steam	11.5MPa/530℃
High Pressure steam	4.2MPa/400℃
Medium Pressure steam	1.3MPa/290℃
Lower Pressure steam	0.5MPa/210℃

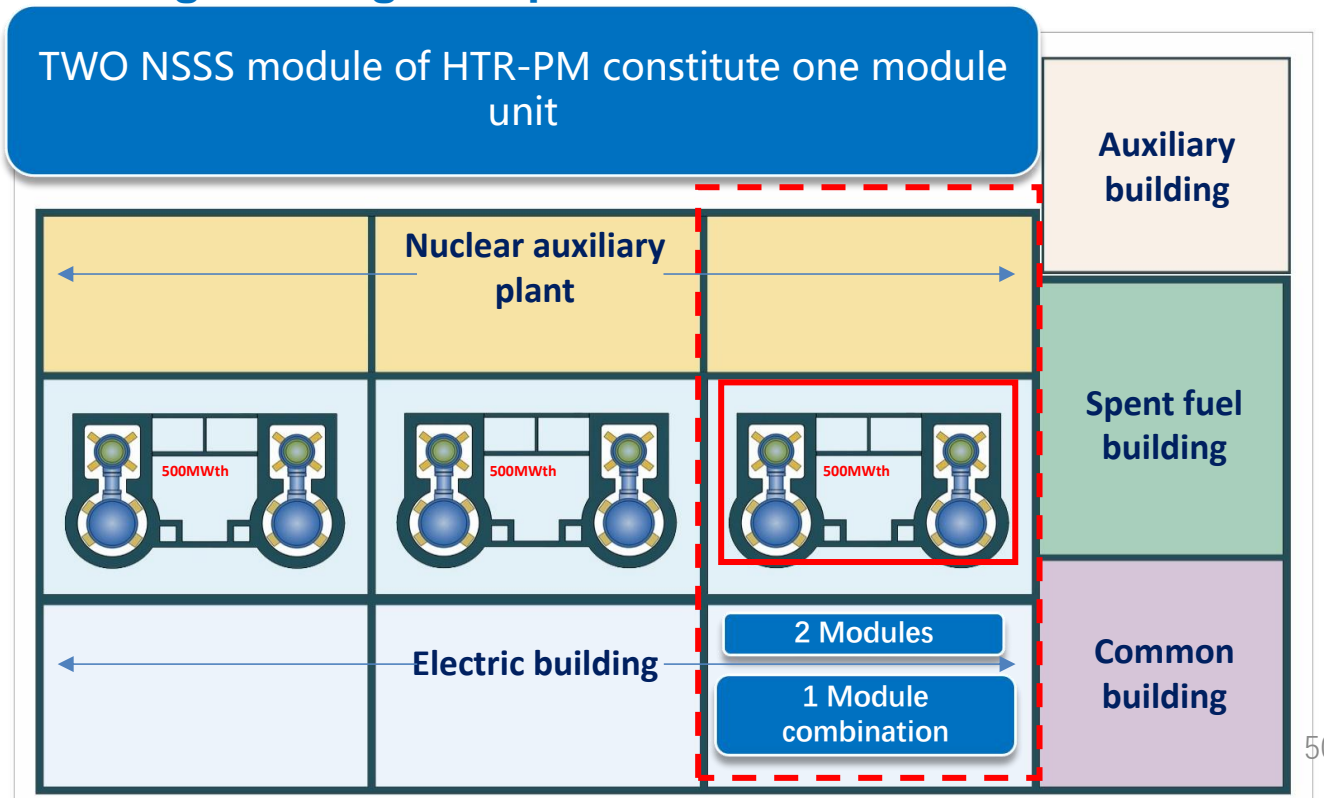
The main parameters of HTGR	
Thermal power of Reactor	2*250 MW
Reactors	two
Steam Generator outlet Temp	541 ℃
Steam Generator outlet Pressure	14.3 MPa
Supply quantity of steam	680t/h

Technology scheme of Petrochemical coupling HTGR

- **HTGR have continuous capability for steam supply： The independence of each module, any NSSS module or even a module stop, does not affect the overall thermal supply**
- **Direct use of two-module combination technology verified by HTR-PM demonstration power plant**
- **HTGR play a major role in characteristics and advantages of high temperature multi-roles**

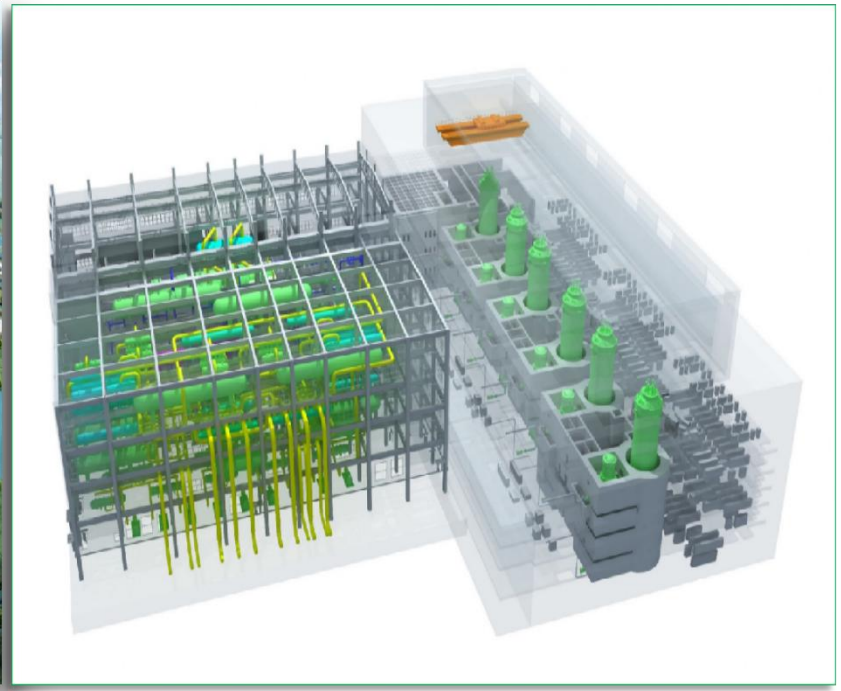
System Layout

HTR-PM600S nuclear plant of HTGR unit composed of three reactor plants, nuclear auxiliary building and electrical building in a straight line. Each module can be run independently and take turns to shutdown overhaul; The spent fuel building and common building are shared by three modules



Process Heat Application: **HTR-PM600S**

- We have developed the 600MW HTGR(HTR-PM600S), for steam supply it combines three “HTR-PM” module units together , each of them can operate independently , achieving high reliability and uninterrupted supply of high-temperature steam
- A project **get approved** in August 19th 2024： HTR-PM600S used for high efficiency electricity generation in a petrochemical industry park and heat sources of high temperature petrochemical technique process. can reduce the energy consumption and reduce around 3 million tons of CO_2 per year

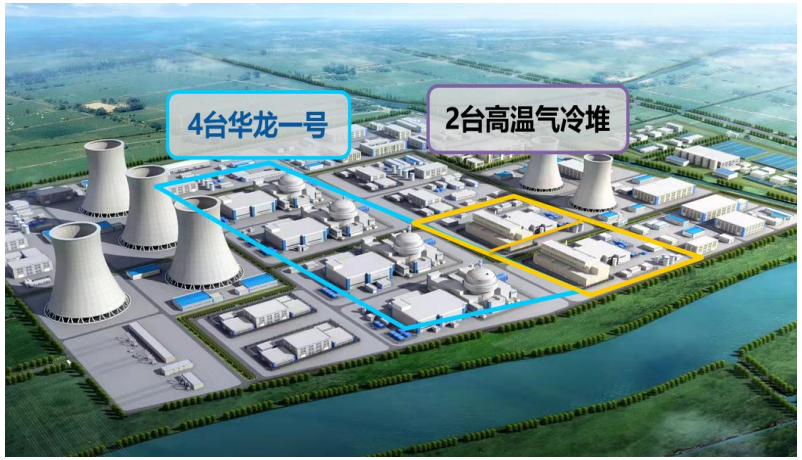


The main parameters of HTR	
Thermal power of Reactor	2*250 MW
Reactors	two
Steam Generator outlet Temp	541 ℃
Steam Generator outlet Pressure	14.3 MPa
Supply quantity of steam	680t/h

Demand of industry steam	
Thermal load	**Parameters**
Ultrahigh Pressure	11.5MPa/530℃
High Pressure	4.2MPa/400℃
Medium Pressure	1.3MPa/290℃
Lower Pressure	0.5MPa/210℃

Process Heat Application: **HTR-PM600S**

- Jiangsu Xuwei nuclear steam supply project is located at Lian Yungang City, Jiangsu Province, 17.5Km from the coastline.
- The project is commercial large-scale nuclear power heating project，Supplying industrial steam to the Lian Yungang petrochemical industry base. Simultaneously utilizes residual heat energy to generate electricity.
- 4 ACP1000 and 2 HTR-PM600S to be constructed on the site；2 ACP1000 and 1 HTR-PM600S to be constructed in the first stage.
- Approved in August 19th 2024; The First Concrete Date (FCD) has been provisionally arranged for Sep 2026, The planned construction period of HTR-PM600S is 54 months.



National green energy demonstration project

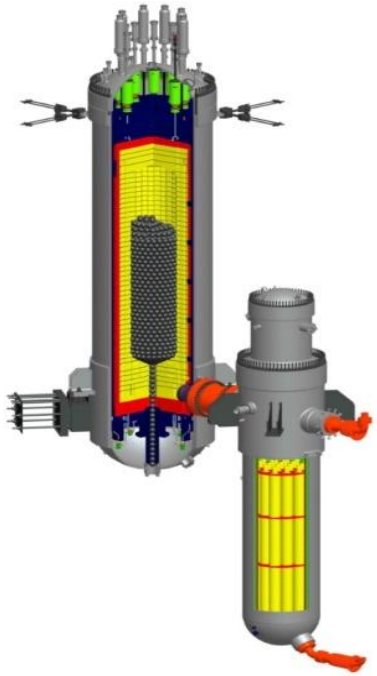
Multi-use applications of HTR-PM

Hydrogen production

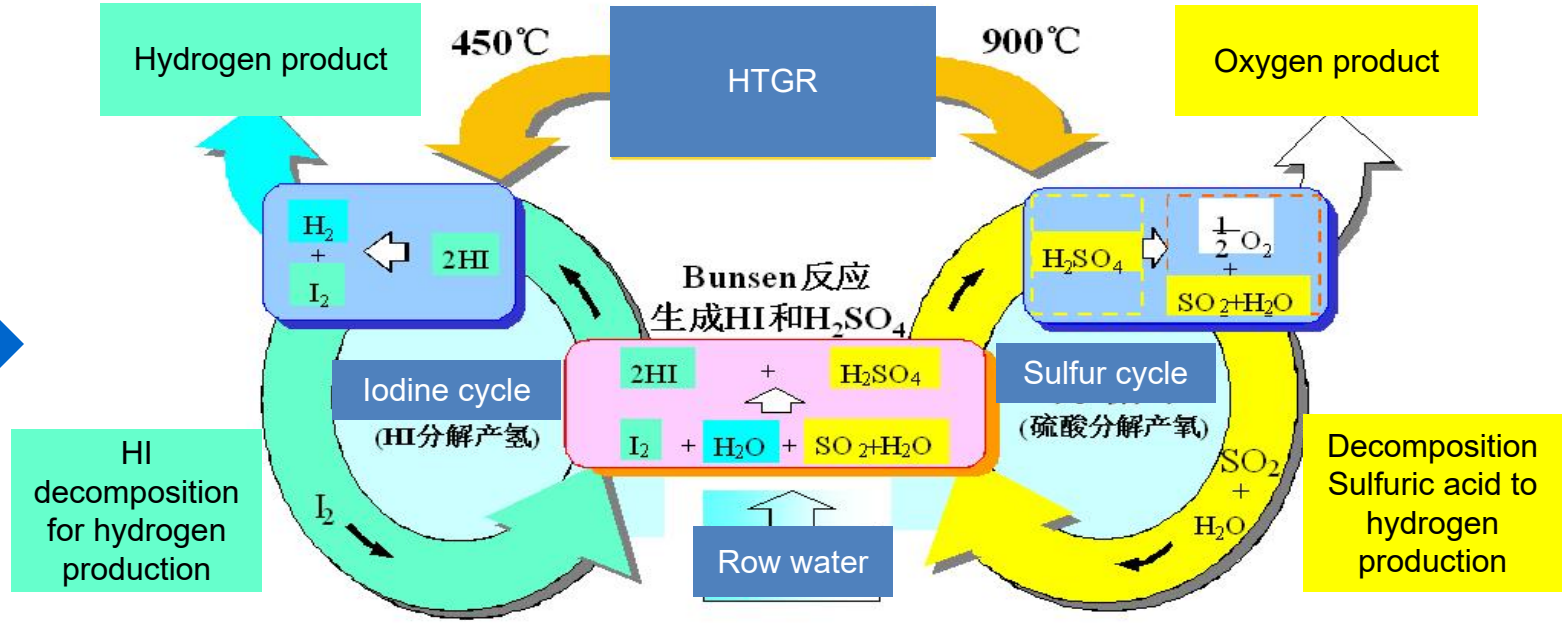
- At present, the hydrogen production is mainly based on petrochemical raw materials, it can not meet the demand of carbon-free hydrogen production in the future
- More than 95% of hydrogen is used as an industrial raw material, and the characteristics of industrial hydrogen demand are large scale and stable supply
- HTGR are considered the most suitable reactors for hydrogen production due to several key advantages: high-temperature output, inherent safety, absence of greenhouse gas emissions, potential for large-scale hydrogen production
- The main technical routes for application of HTGRs in hydrogen production include: nuclear thermal-assisted carbon-based fuel reforming, high-temperature thermochemical water decomposition, high-temperature steam electrolysis, nuclear power electrolysis of water etc

Multi-use applications of HTR-PM

Hydrogen production：**HTGR-IS**



Heat

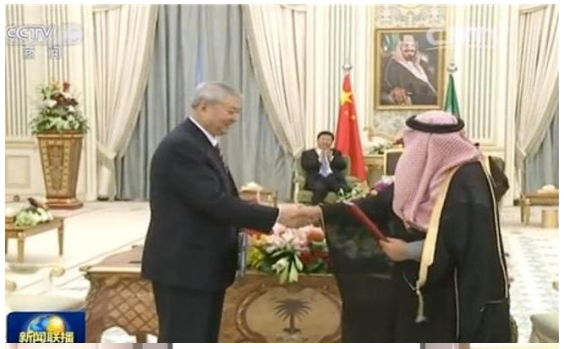


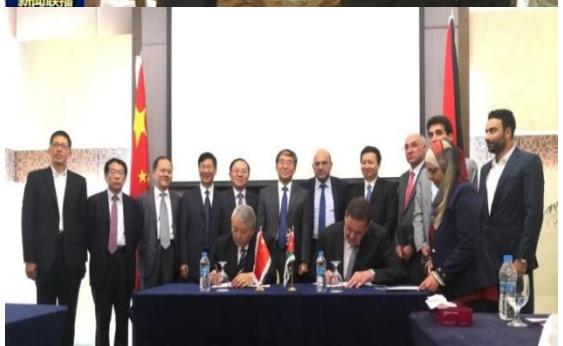
Iodine sulfur cycle

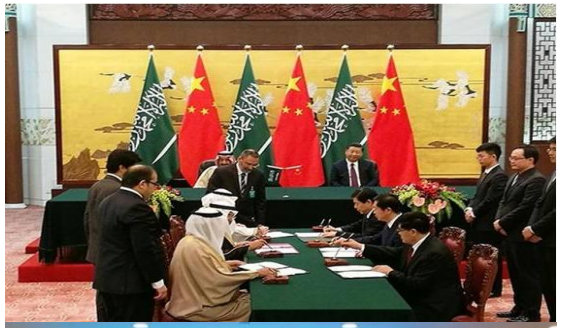
- **High efficiency (Efficiency >45%)**
- **Have good matching and it is easy to coupling with HTGR**
- **Full flow, pure chemical process, suitable for large-scale hydrogen production**
- **Clean and carbon-free, advanced technology**

The internationalization development of HTR-PM

- International Cooperation
  - HTGR has attracted the attention of numerous countries abroad. We has successively signed cooperation framework agreements on HTR-PM with Saudi Arabia, Jordan, Indonesia, Emirates and other countries
  - We are open to extensive cooperation with various countries to jointly advance the technology and application of HTR-PM, contributing to the sustainable development of human society by providing clean, low-carbon, safe, and efficient energy







中核能源科技有限公司
CHINERGY CO.,LTD.

中核集团
CNNC

THANK YOU

Email：dhwang@chinergy.com.cn

CHINA
NATIONAL
NUCLEAR
CORPORATION