DHR, A "CLEAN" DISTRICT HEATING REACTOR

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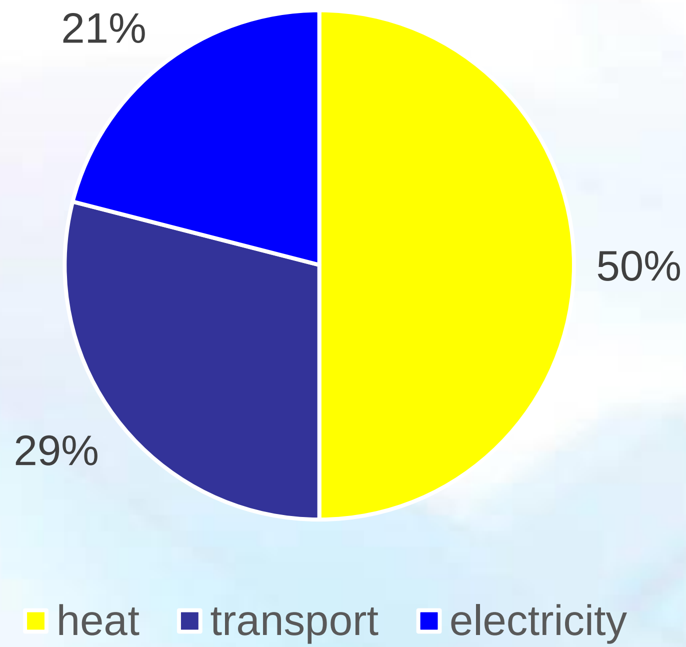
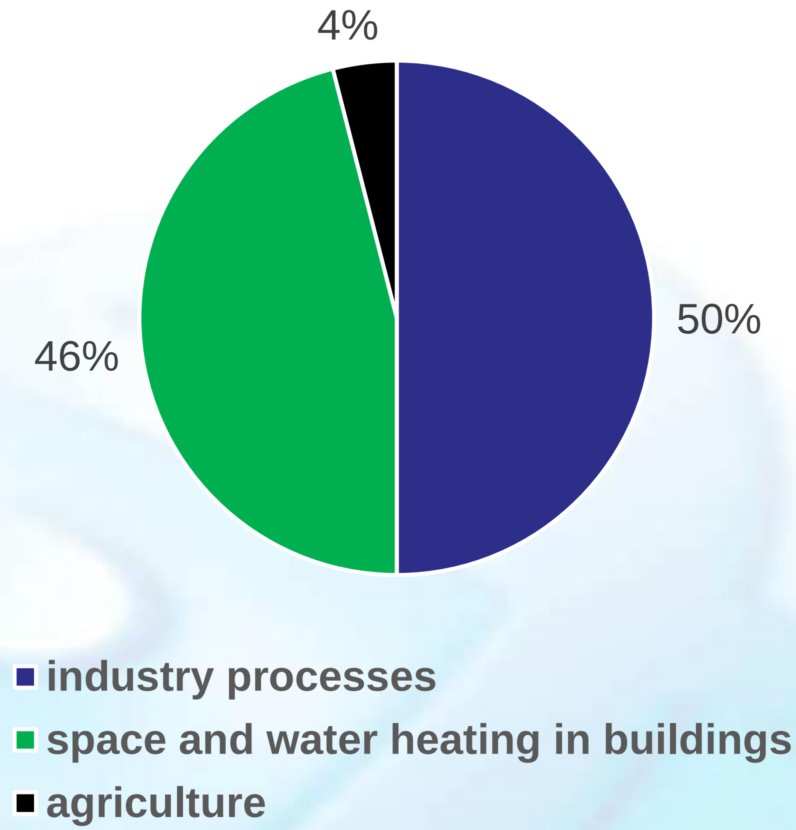
Heat demand worldwide

Global final energy consumption by sector, 2018



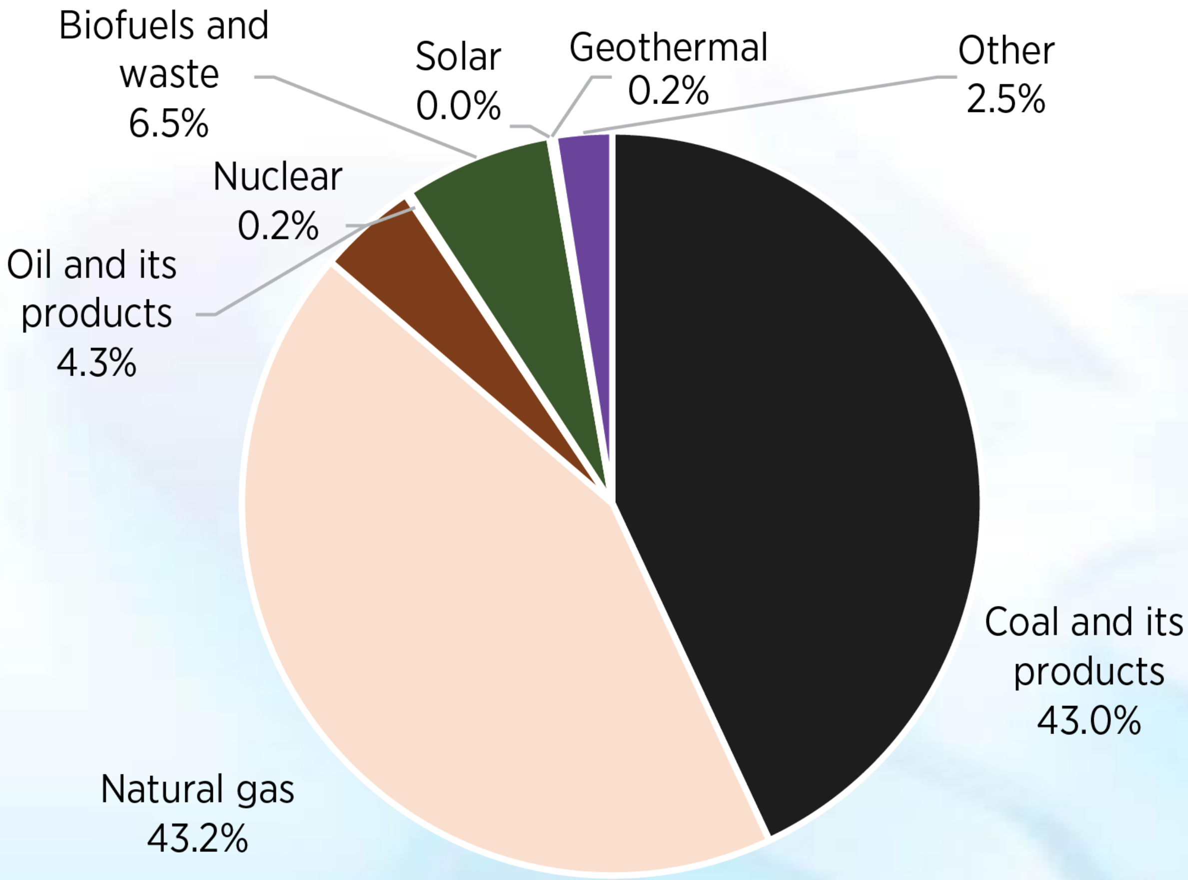
Global heat consumption by use, 2018



Source: IEA

Heat sources and carbon emission

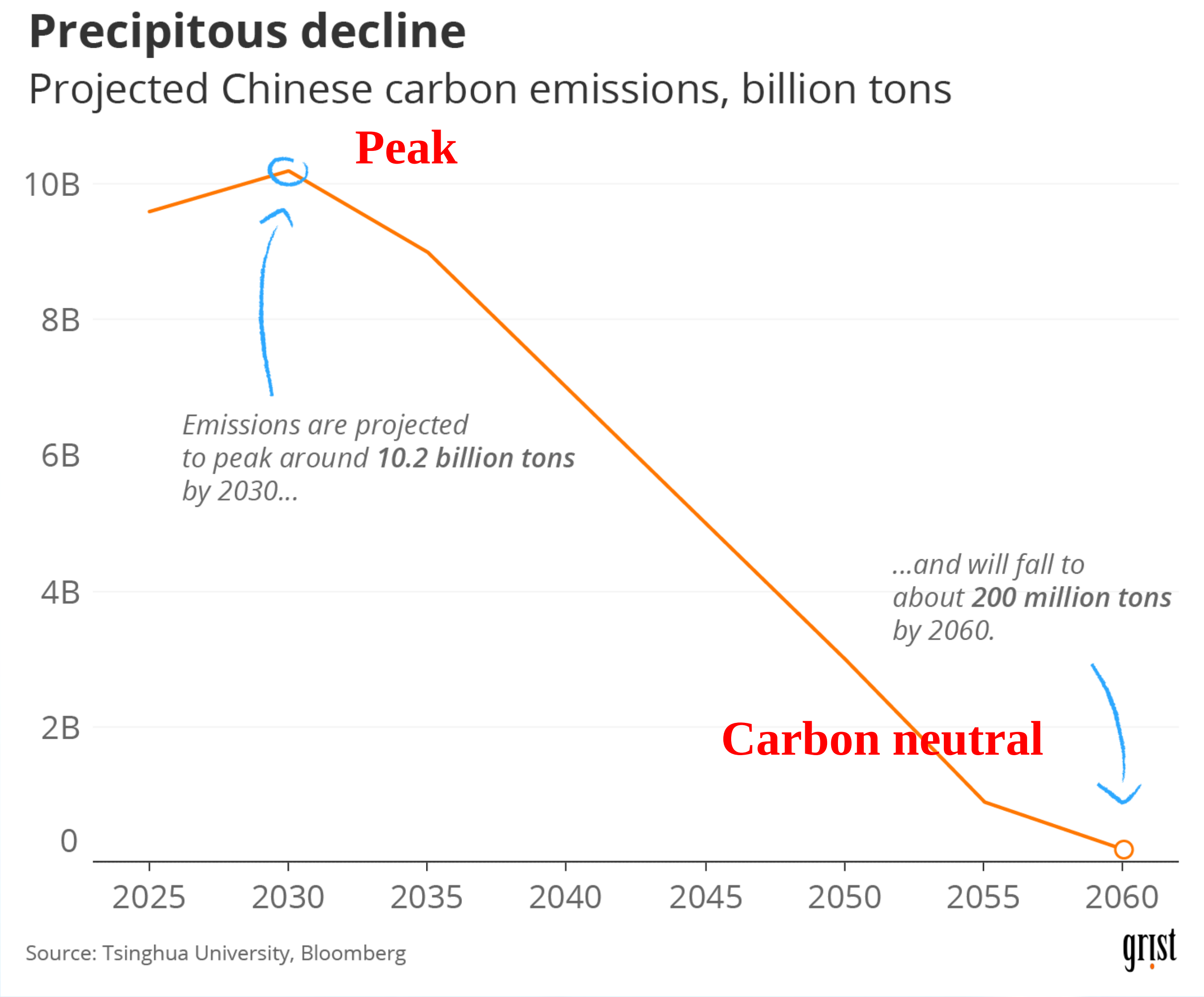
Breakdown of fuel use in district heating and cooling systems worldwide, 2014



Source: IRENA

- Most district heating and cooling system energy is currently provided by fossil fuels
- China's reliance on coal makes heat production particularly carbon-intensive, releasing around 400 gCO_2/kWh.
- The carbon intensity is typically 150-300 gCO_2/kWh in Europe for massive use of renewable energy sources

China's commitment to carbon reduction



- China aims to have CO_2 emissions peak before 2030 and achieve carbon neutrality before 2060
- China will scale up its Intended Nationally Determined Contributions by adopting more vigorous policies and measures

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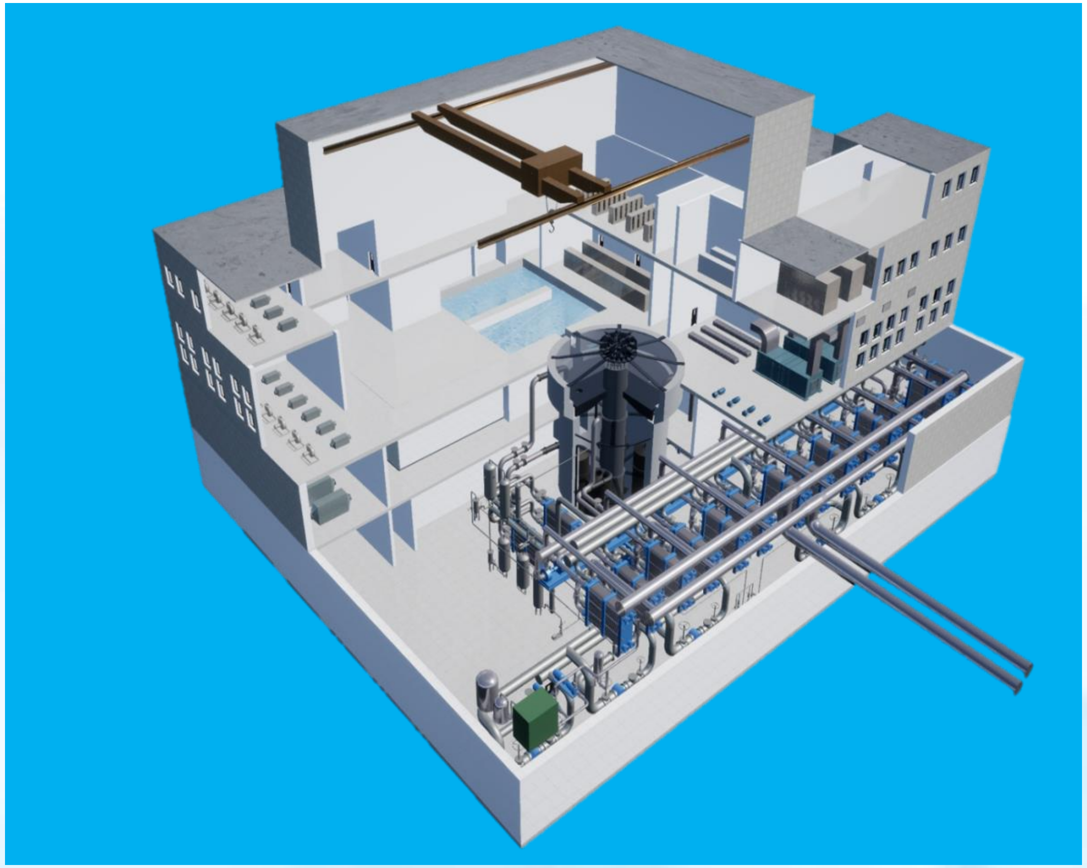
Deep-pool Low-temperature Heating Reactor (DHR)

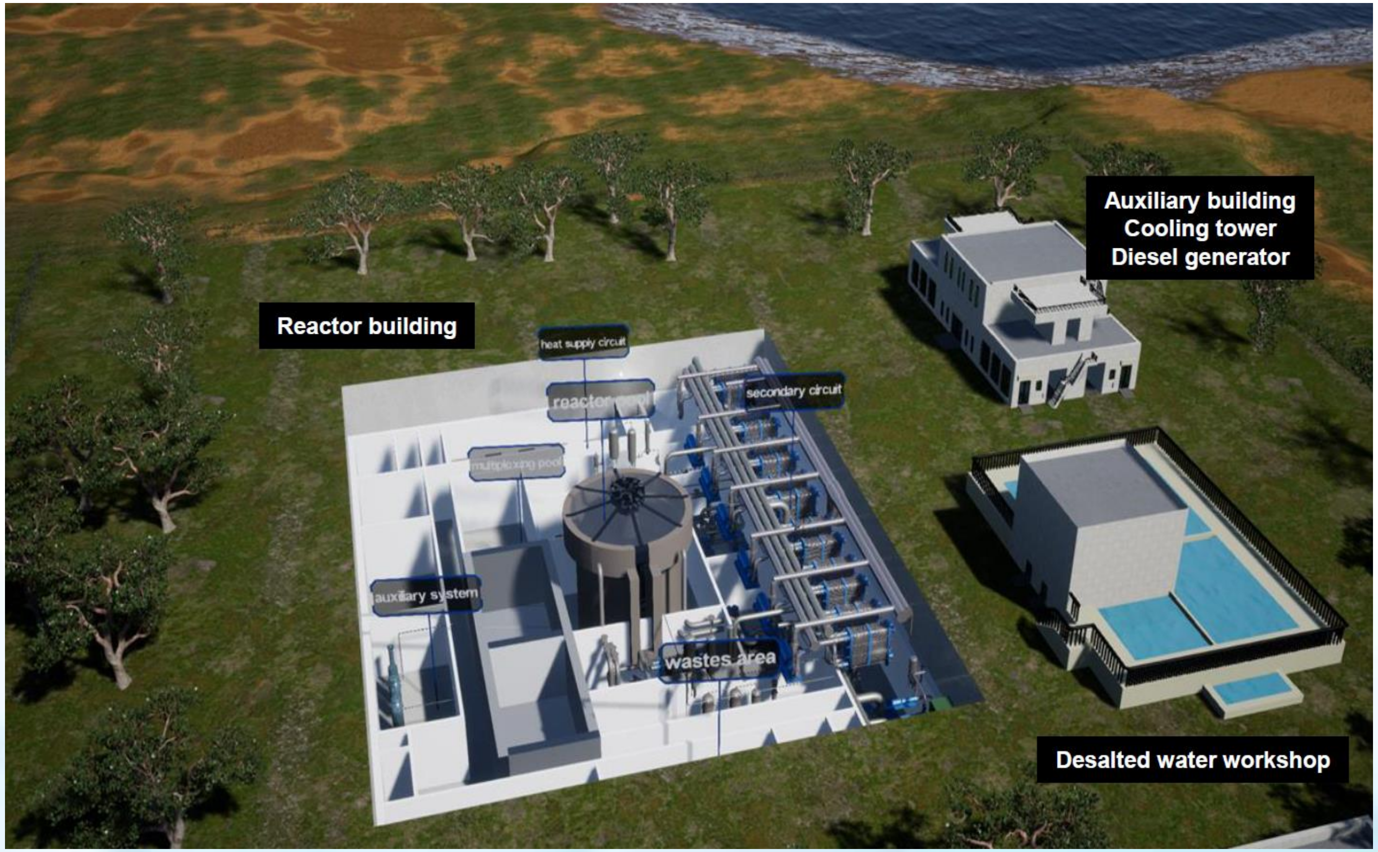


- **The reactor core is placed in the bottom of an atmospheric-pressure pool**
- **A proper core outlet temperature that can meet the requirement of district heating system is achieved by increasing the static pressure of the water layer**

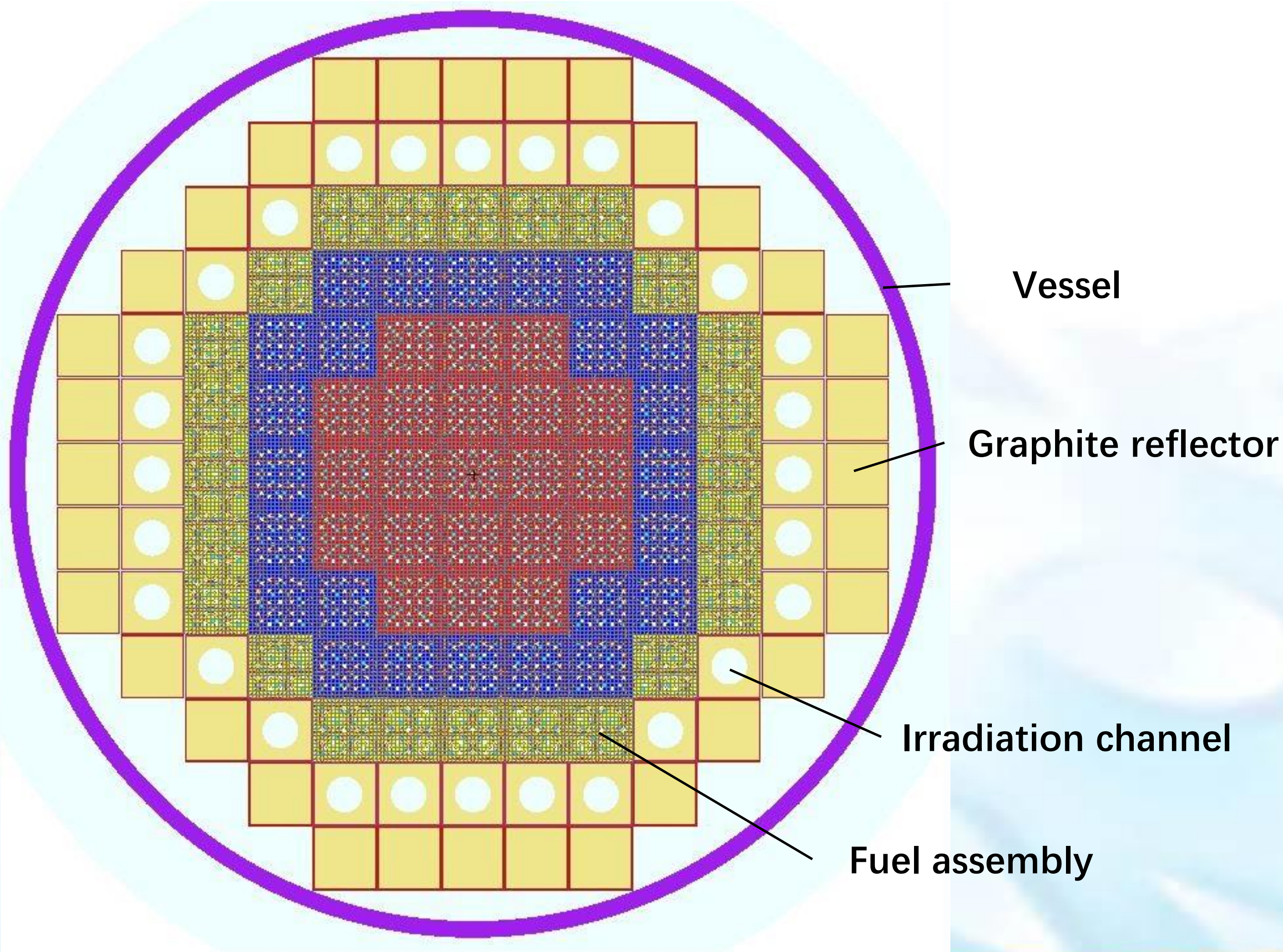
Main parameters

item	parameter
thermal power /MW	400
Life/year	>60
refueling period /EFPD	450
inlet/outlet of core /℃	68/98
O&M staff	35
Land area/ha	<0.4
Uses	Multipurpose

Overall layout of a DHR heating station

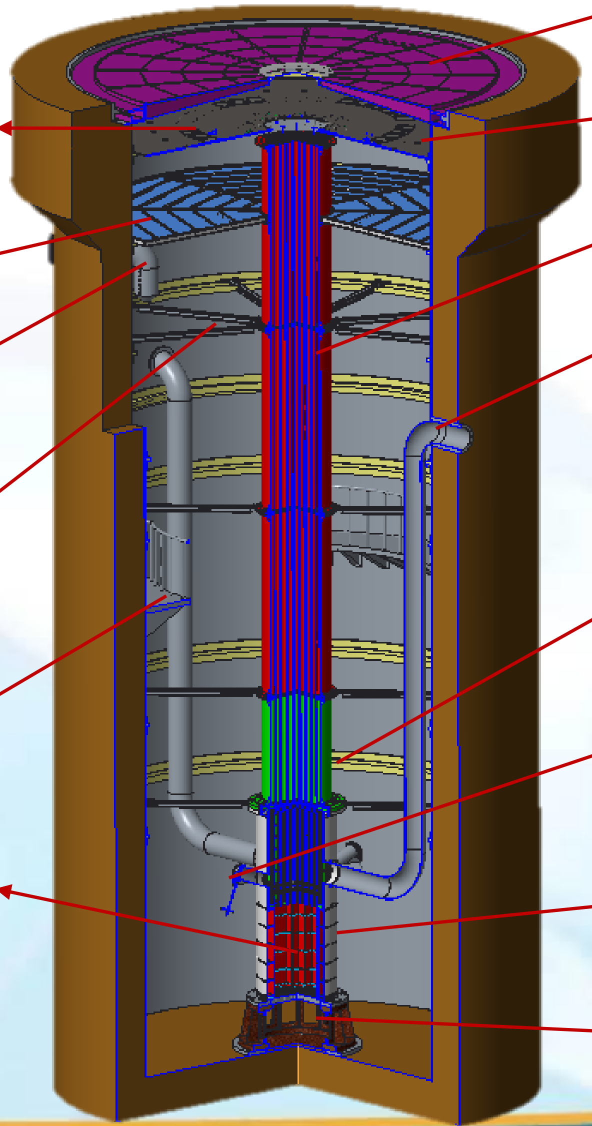


Core configuration and fuel



- No soluble boron, control rod is used for reactivity control
- Adopt PWR fuel assembly CF3-S , $17\times17_{-25}$, truncated, 8% Gd-loaded
- Average burnup~30GWD/tU

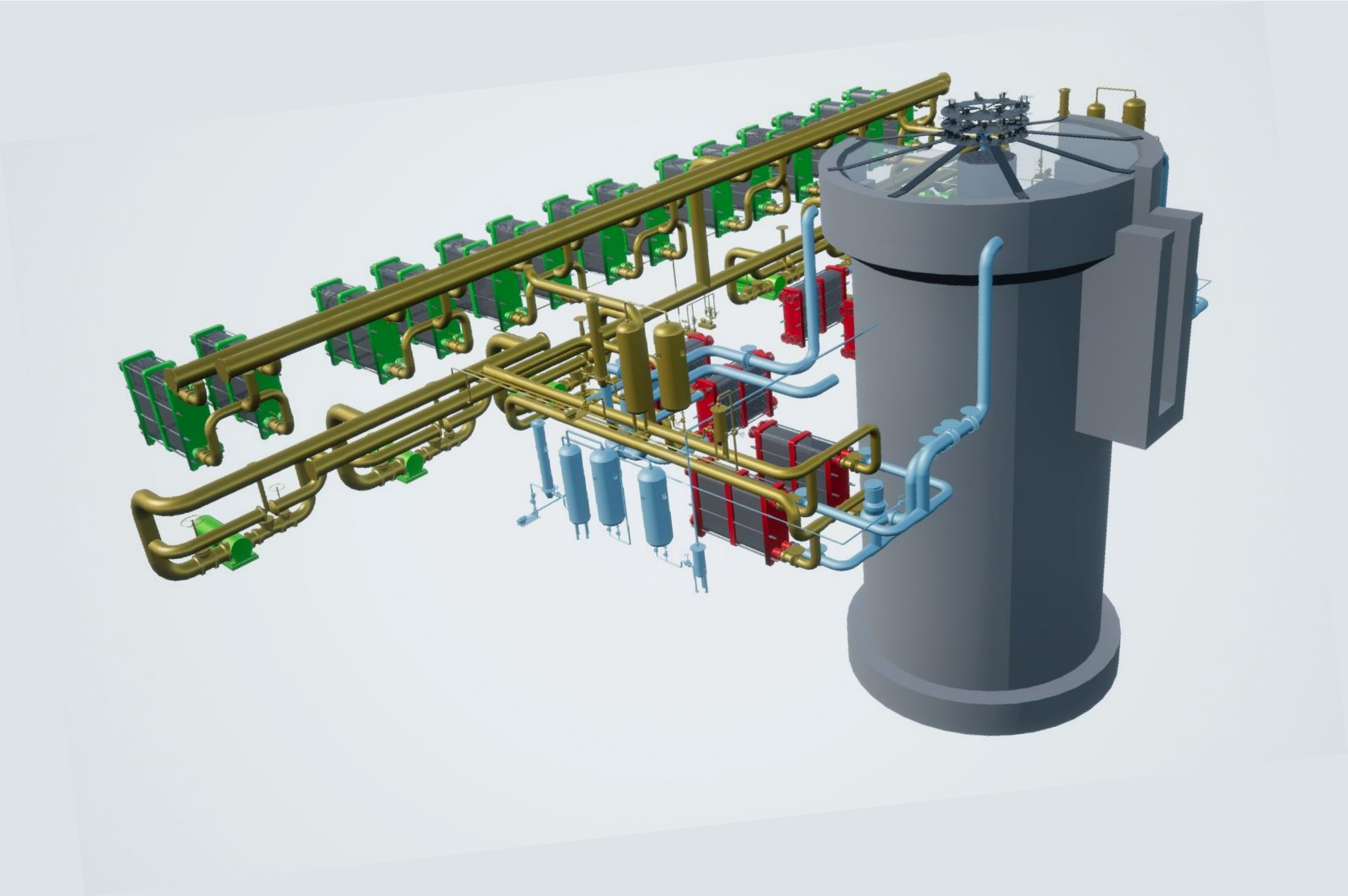
Reactor pool and in pool components



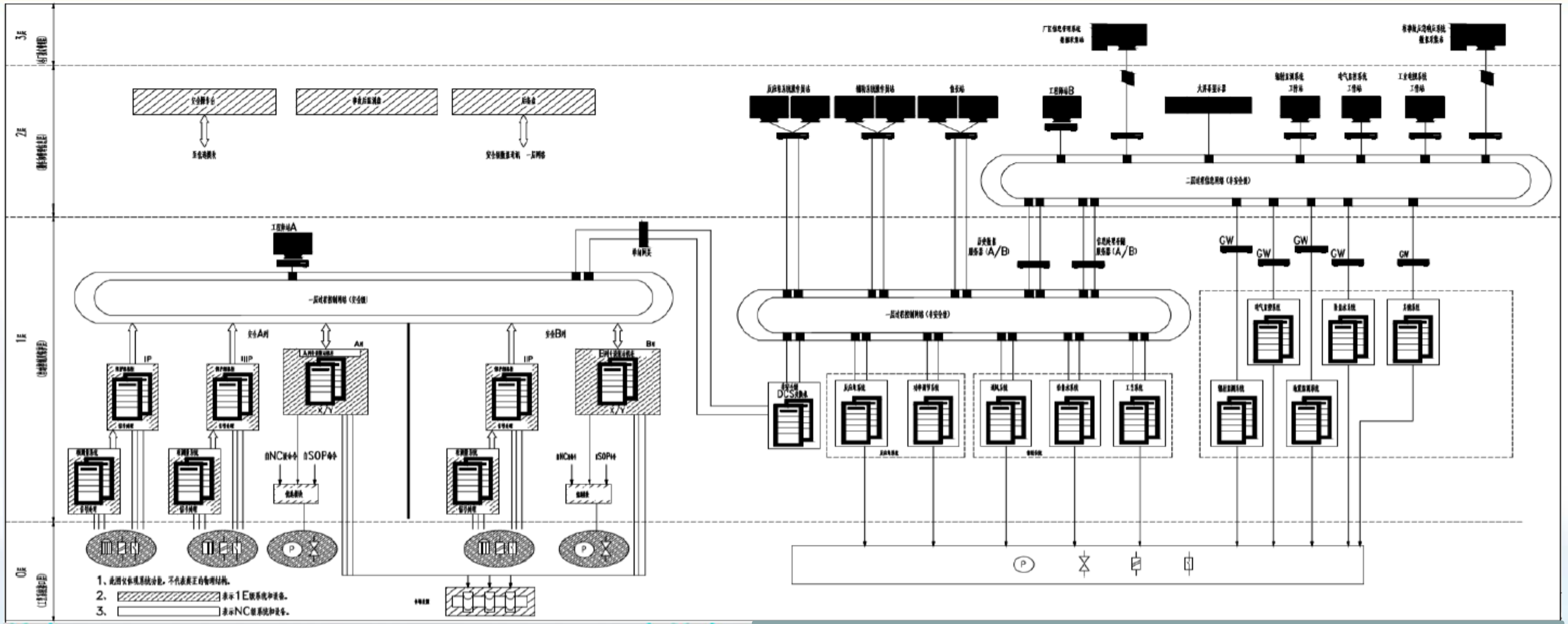
Item	Parameters
Diameter /m	10
Water Depth /m	26
Volume /m^3	1800

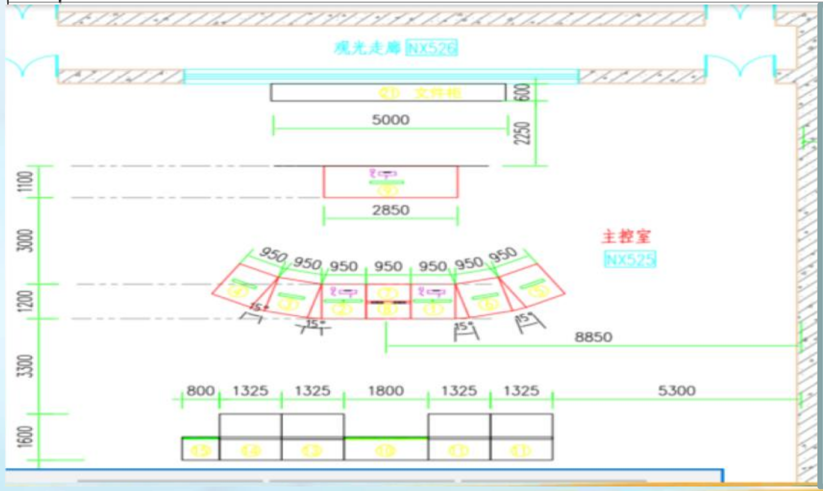
Circuit configuration

- **3 circuits design，2 stage heat exchange**
- **Take into attention to pump cavitation**
- **$P_{heating}$>P_2>P_1, to ensure radioactivity will not enter heating pipe**



Plant-wide integrated DCS





- One key start-stop
- Less person on duty
- Automatic tracking load

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Main Feature for YANLONG

Inherent Safety Reactor

01

Safe and environmentally friendly

"Plug-and-Play" reactor

02

Simple
Convenient
Mature

Multipurpose Reactor

03

Comprehensive Utilization
(Energy + Neutron)

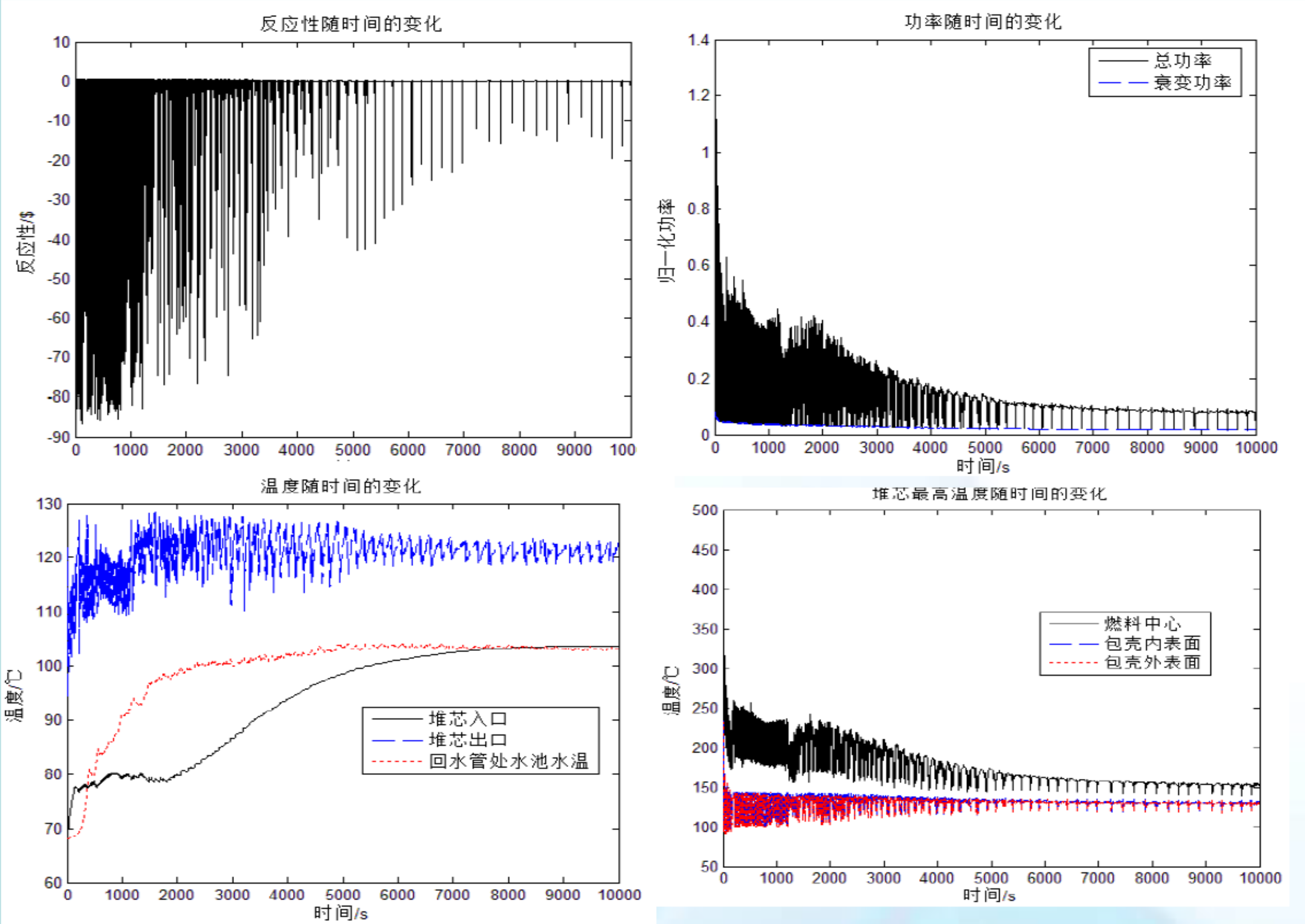
SAFE reactor

Inherent Safety

1. 1800 tons of water
2. Underground reactor
3. No overpressure, LLOCA, ejection of control rod, failure of safety valve, etc.
4. Large negative reactivity coefficient

"Zero" Meltdown

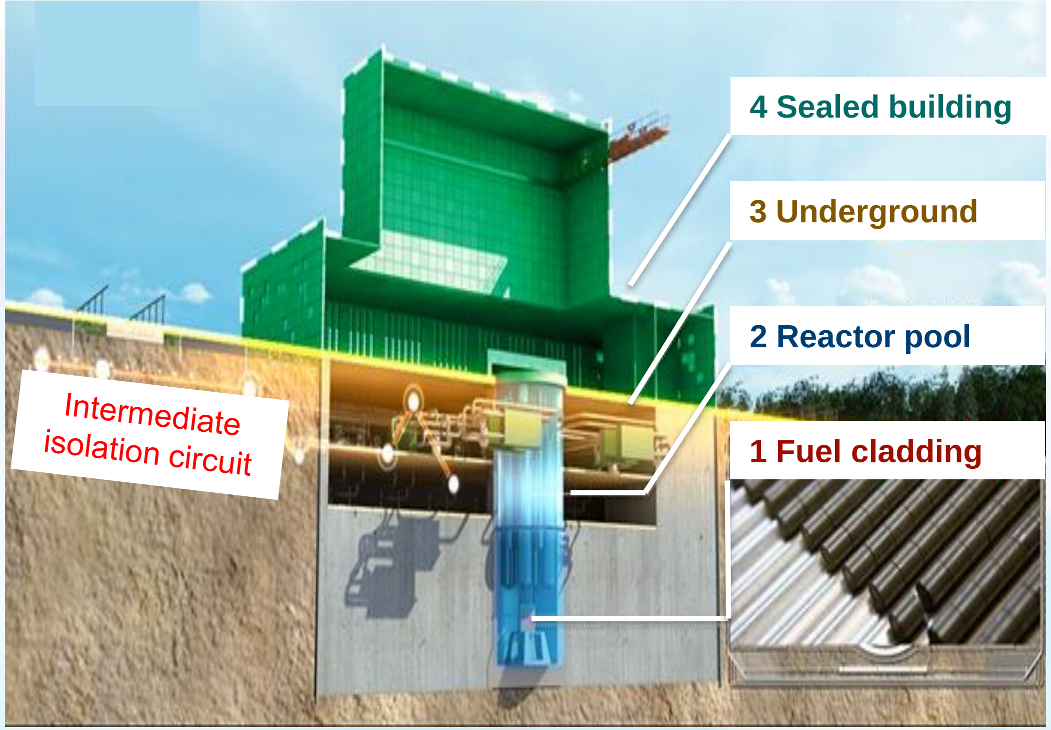
TIME	ACCIDENT SEQUENCE
0	SBO ATWS, FP
0~6000s	ρ, P, T_c, T_f oscillating, within the limit
6000s	Stabilizing at 10% P
10d	Core uncover



Automatic shutdown only relying on the negative reactivity feedback, without any intervention.

“Zero” radioactivity release

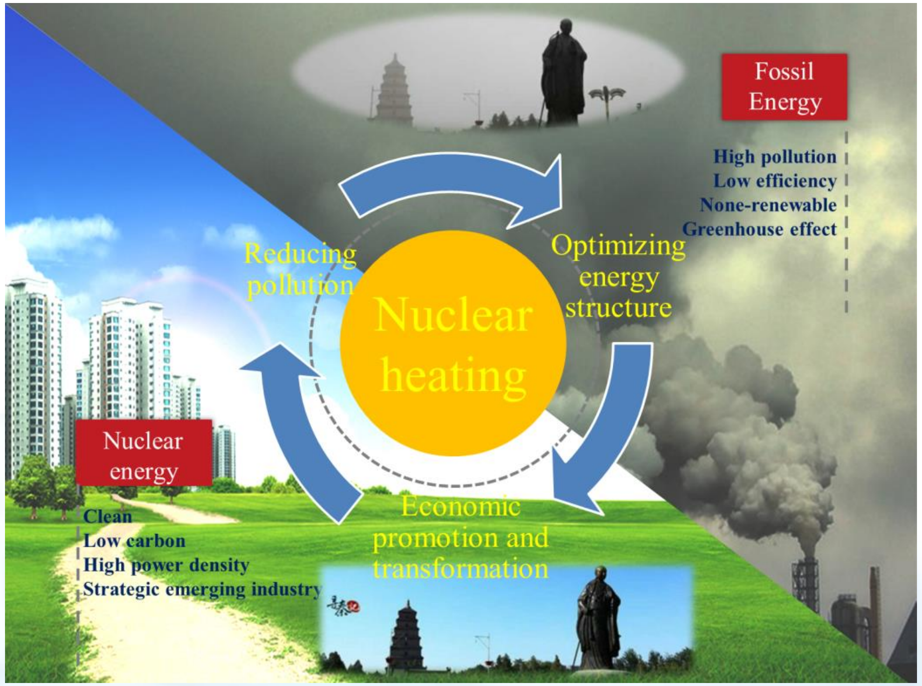
Multiple ways to reduce radioactive release



- An intermediate isolation circuit whose pressure is higher than that of the primary loop is set up to ensure that the water from the primary loop does not enter the heating loop.
- The reactor is equipped with four barriers, effectively isolating radioactivity
- Equipped with a gaseous and liquid effluence collection and treatment system

"Zero" pollutant release

No carbon emission, no emission of NO_X, SO_2, dust, ash, etc. DHR400 can reduce the use of about 320,000 tons of coal or 160 million cubic meters of NG per year, equivalent to 1300 hectares afforestation.



Heat source	CO_2(tons/y)	SO_2(tons/y)	NO_X(tons/y)	Dust(tons/y)	Ash(tons/y)	Radioactivity (mSv/person)
Coal	520000	6000	2000	3200	100000	0.013
Gas	260000		1000			
Nuclear	0	0	0	0	0	0.005

Convenient O&M and Decommissioning

Automatic Operation

One key start-stop

Automatic load-tracking

Easy Operation

No soluble boron, Normal pressure

Cold start, Up to full power within hrs

Convenient maintenance

Pump and heat exchanger all located outside the pool

Green reuse of site

Smaller source term

Decommission immediately

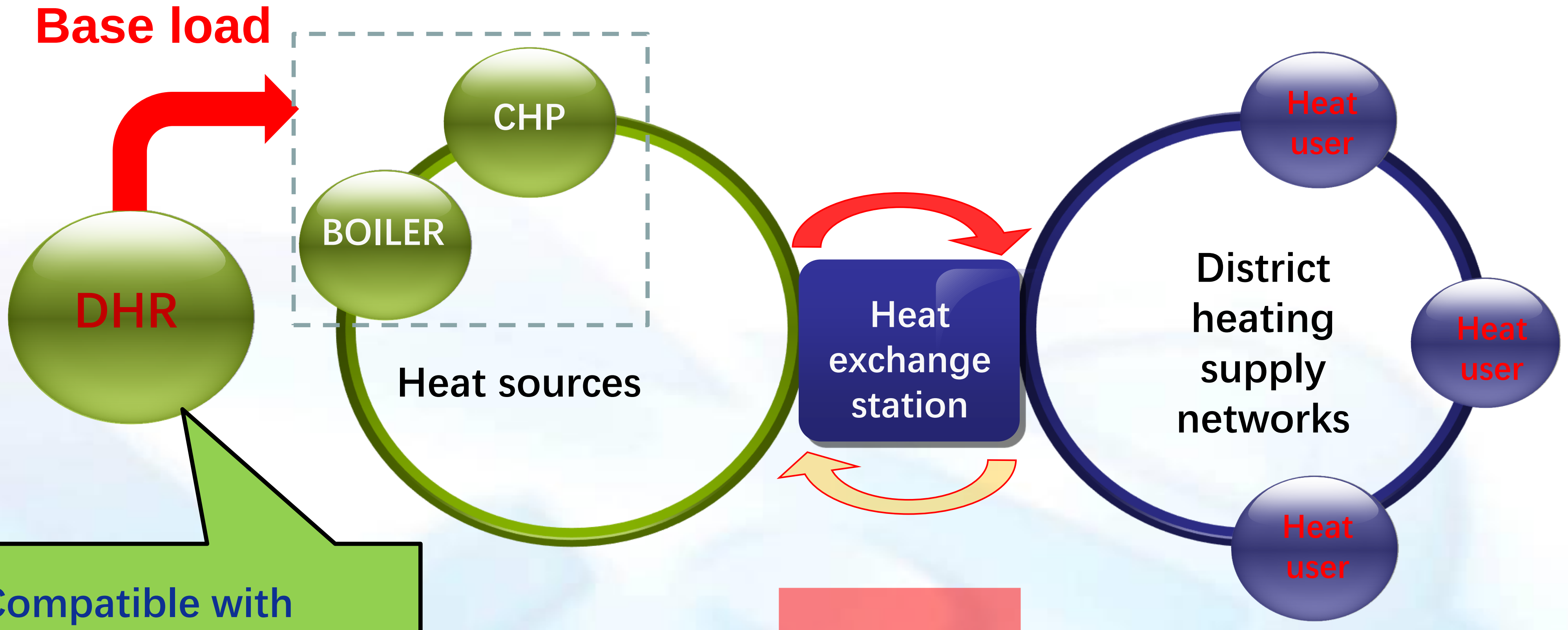
Easy siting

Less requirements for site location

- **No special RQMT for geological conditions**
  - **Bed rock site**
  - **Soft Foundation site**
- **No off-site emergency and small site area**
  - **Close to cities**
- **No special RQMT for water**
  - **Costal**
  - **Riverside**
  - **Inland**

- DHR can access to the existing heat network directly
- Possible to retrofit decommissioned fossil plants

Simple connection



- Compatible with existing networks
- Base load
- Operate full time during heating season

Multi heat sources, same network, Operation with low temperature

Multi-purpose

- **Energy application**
  - **District heating supply**
  - **Refrigeration**(lithium-bromide absorption-type refrigerating machine)
  - **Desalination of Sea Water**(low temp. multiple effect distillation(MED))
  - **Supply hot water** for green-house, farming, cultivation, etc.

} **Non-heating season**





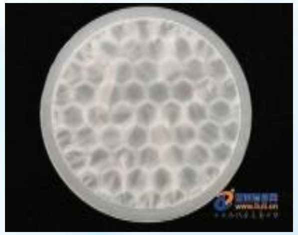
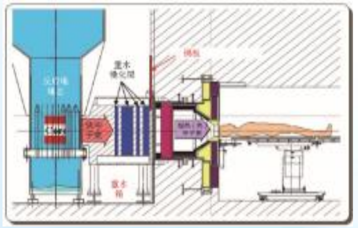
Multi-purpose

Neutron Application

- Production of radioactive isotopes, ^{99}Mo,^{125}I,^{131}I,etc.
- Material transmutation, NTD silicon, gem, topaz, pearl, etc.
- NAA, NRG, Neutron scattering, BNCT, etc.
- Production of nuclear pore membrane





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Principle verification

Project progress

- Preliminary design is accomplished
- Main equipment determined, all developed domestically, now being tested

Equipment	Fuel	Main pump	HX	DCS	In pool structure	Fuel handling	CRDM
Type	CF3-S	Centrifugal pump or Mixed flow pump	Plate HX	Similar to PWR			Wire rope
Status	CHF experiment	Engineering available			Engineering verification test needed		

- Exploring the regulations and standards for DHR, have made progress in communicating with Chinese regulatory authorities

Planned demonstration project

Liaoyuan, Jilin
Applying for project approval

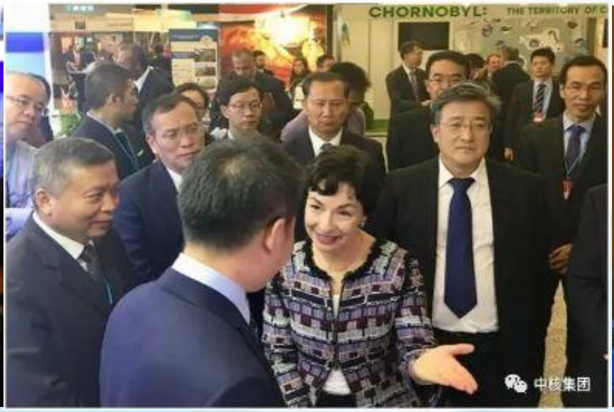
International cooperation

Meeting with Fortum Oyj from Finland, discussing nuclear district heating technologies and regulations.

Promotion and publicity

- DHR report on the IAEA annual meeting in 2018

- DHR report on the International Conference on Climate Change and the Role of Nuclear Power in 2019
    - The Chinese nuclear heating technology provides alternative to combat climate change
    - The DHR design is widely acclaimed by experts from worldwide



Conclusion

- Equipment and technology for DHR is mature and has high level of feasibility in engineering.
- DHR is safe , environment-friendly and economically competitive.
- DHR is an ideal alternative to coal-fired heating plant and would make an important contribution to worldwide goal on carbon emission reduction and environment protection.

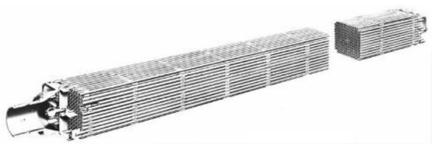
CNNC Nordic R&D Center

CNNC Nordic R&D Center on-site office at Studsvik Technology Park

Establish ceremony of CNNC Nordic R&D Center, Oct. 12th, 2020

- CNNC Nordic R&D Center preparatory work started in 2019.
- Managed by CNNC Technology Quality and Information Department. Operated by CIAE in China and by Studsvik internationally.
- CNNC planned to send staff there but delayed by the raging pandemic situation.

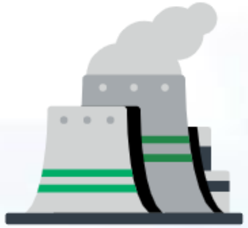
CNNC Nordic R&D Center



Nuclear fuel and material testing

Collaborating with STUDSVIK

Mechanical analysis and PCI of fuel cladding after irradiation



Pb-Bi cooled reactor

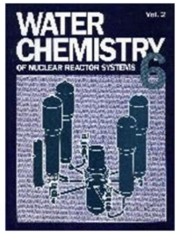
Collaborating with KTH

System analysis code development for residual heat removal after accident

Light water reactor severe accident

Collaborating with KTH

Research on molten core-water reaction



Reactor water chemistry

Joining the SMILE project (Structural Margin Improvements in aged-embrittled RPV with Load history Effects)

Advanced fuel Development

Collaborating with KTH

Nitride fuel fabrication, irradiation, testing, and fuel analysis model development

CNNC Nordic R&D Center

Ultimately build a Nordic Academy registered in Sweden

Establishment of CNNC Nordic R&D Center

Nuclear Heating for Future City

Thanks for your attention