华龙国际核电技术有限公司
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SMR: the Game Changer

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SMR Market Outlook

Climate Goals and Nuclear Energy

- **The Paris Climate Agreement**

  Aims to limit global temperature rise to 1.5°C, setting targets for human climate response activities.

- **China's "30-60" carbon reduction target**

  Achieve carbon peaking by 2030, and carbon neutrality by 2060

Clean, low-carbon energy will replace fossil energy as a core component of the world's energy mix.

Climate Goals and Nuclear Energy

- Under the "30-60 target", **the development of clean and low-carbon energy will be important on China's commitment to carbon emission reduction.**
- Nuclear, as a dispatchable power with high energy, **is possible to become an important basic energy source.**
- By the end of 2020, China has 5,102.7 kW of

Developing nuclear power has become a long-term stable strategy for China

2025: 70,000 MW nuclear power in operation.

2035: 200,000 MW Nuclear power in operation and under construction, generating about 10% of the country's electricity.(forecast)

China's policy and actions for SMR development

- China has included the development of SMR in the national top-level planning.
  The *14th Five-Year Plan* states **"promote the demonstration of small modular reactors".**
- Research institutions have carried out extensive research on small reactors and have preliminary R&D experience and technology reserves.
- China’s first small reactor **ACP100 demonstration project has started construction.**

Technical features of SMR

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- Low Power
- Inherent Safety
- Short Construction Period
- Need Policy Support from Government
- Modular Design
- Flexibility
- Easy Operation and Maintenance
- Stable Market & Batch Projects for Scale Benefit

SMR technology features and nuclear power market

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The technical features of SMRs are more compatible with the needs and markets of China's inland than conventional pressurized water reactors

- **Inherent Safety**

  SMRs significantly reduce meltdown risks, the need for cooling measures and off-site emergency response, and enable closer proximity to the demand side and densely populated areas.

- **Low power per reactor**

  Power between 10 MWe and 300 MWe, 1/3 - 1/100th of PWR, more adaptable of various

  ures.

SMR technically solves the key safety issue of PWR and can be a major complement of large PWR power.

SMR has an optimistic outlook for China’s nuclear energy market.

Changes on SMR Financing Model

Changes on SMR Financing Model

SMR will be a GAME CHANGER for nuclear power projects, changing the traditional design, procurement and construction model. This is reflected in the following areas:

- Shorter construction periods, which will allow for reduced financial costs.
- For an individual project:
  A decrease in construction and installation cost;
  An increase in design and equipment procurement costs.
- SMR R&D and equipment manufacturing costs will be incurred before the project starts, which may lead to earlier cash flow peaks, creating investment pressure and risk for the supplier.

Changes on SMR Financing Model

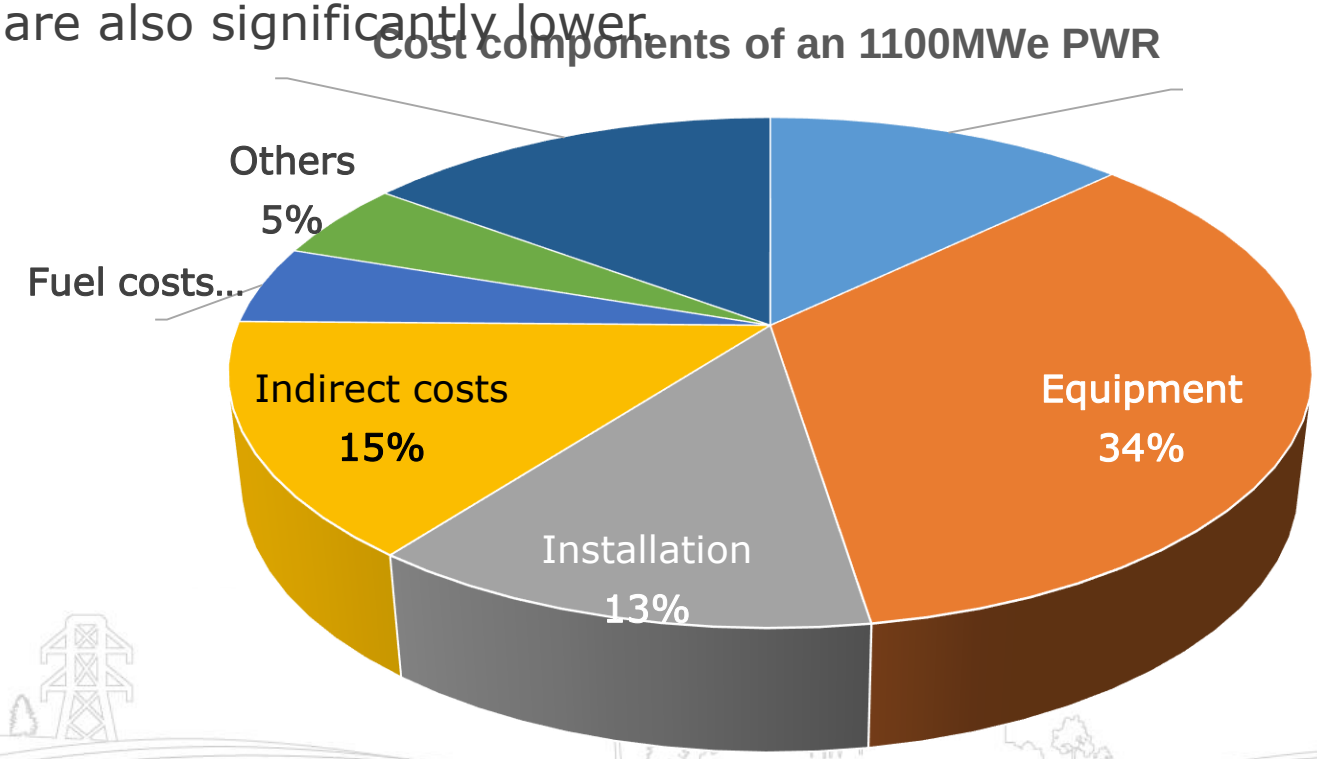
- Overall, **the total investment in SMR individual projects is much lower**, reducing investment risk and allowing for rolling development.
- But the investment risk and pressure is **shifted from the owners side to the suppliers side** and other stakeholders.

Changes on SMR Financing Model

- **In a typical PWR, the proportion of construction and installation costs are relatively high.**
- **SMR, on the other hand, has a much higher proportion of equipment costs.**

  Due to the shorter construction period, the cost of construction and installation activities are all lower.

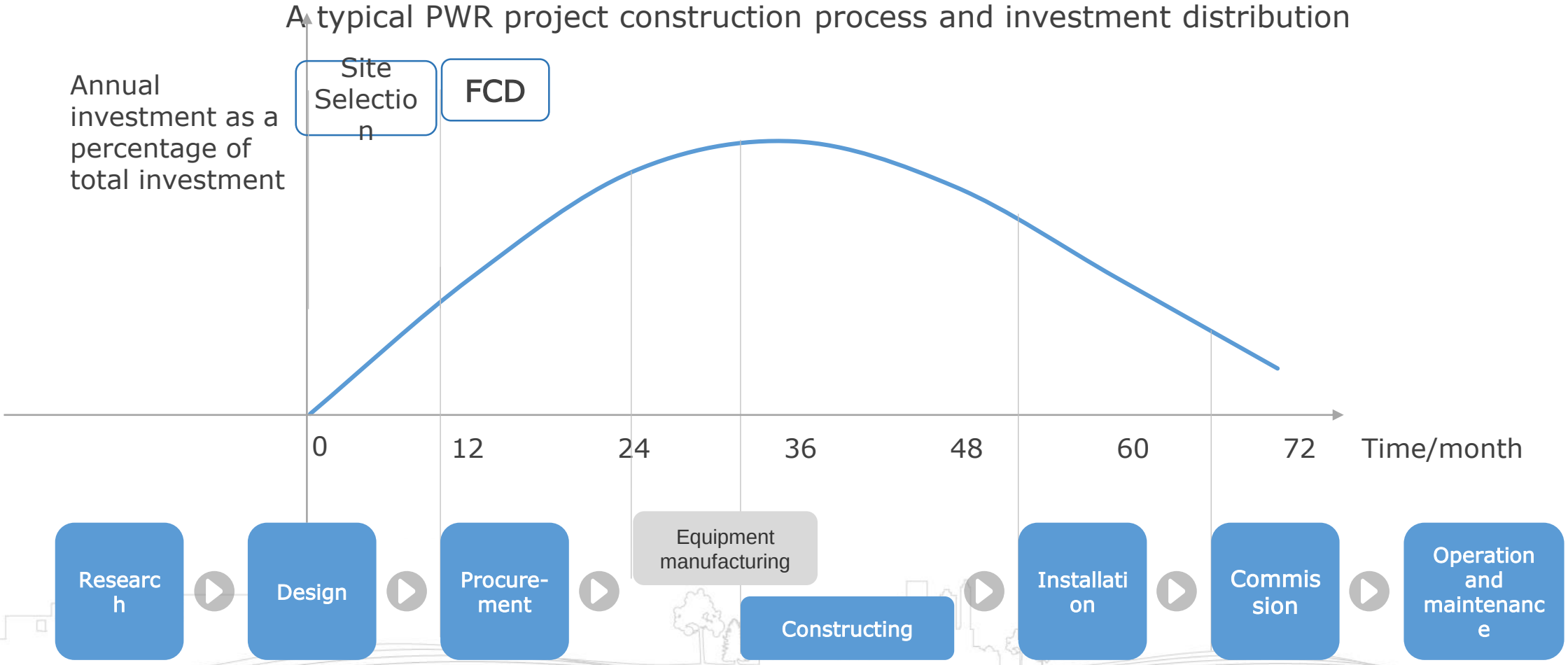
  Financial costs are also significantly lower.



Changes on SMR Financing Model

- Investment in a typical PWR is spread out more evenly from year to year, with the peak occurring during the construction phase.

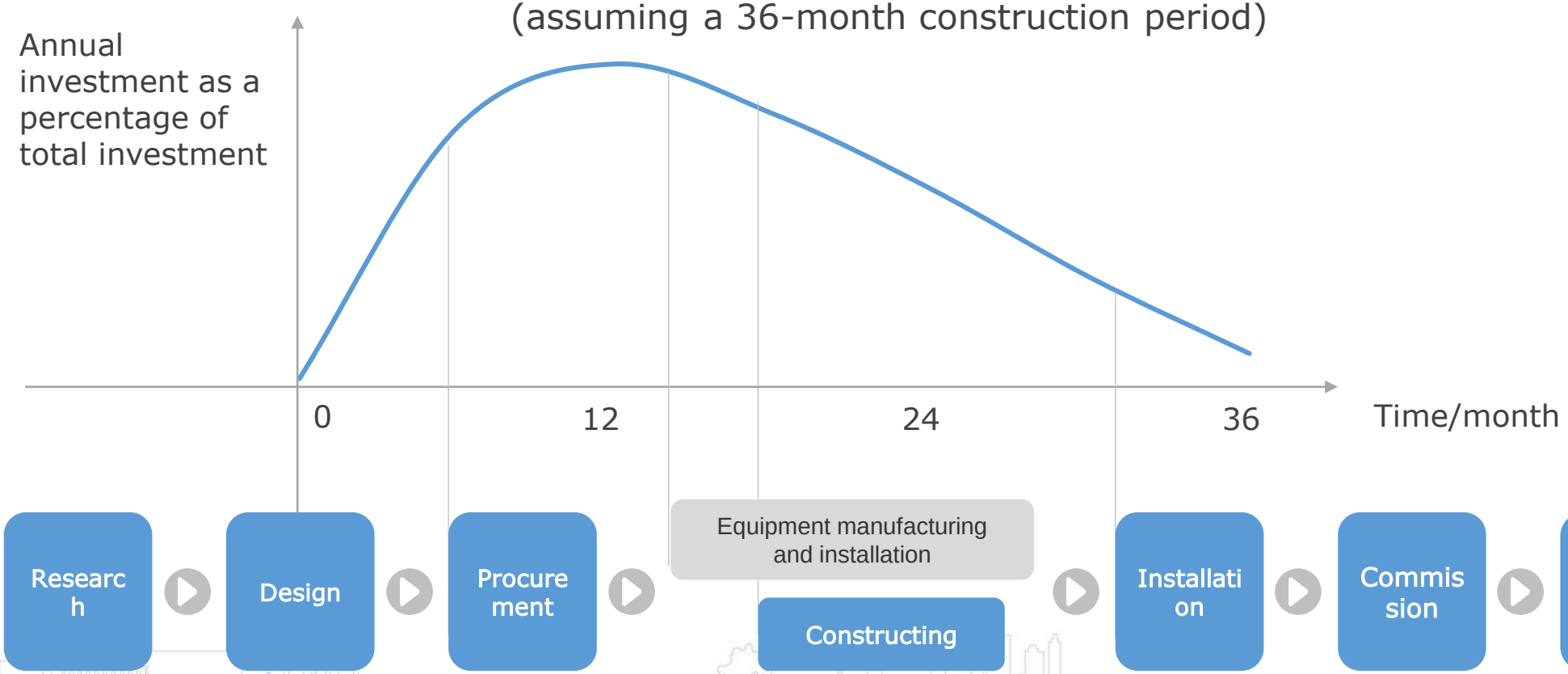
A typical PWR project construction process and investment distribution



Changes on SMR Financing Model

- SMR has higher equipment costs, bringing forward the peak investment.

Hypothetical SMR construction process and investment distribution
(assuming a 36-month construction period)

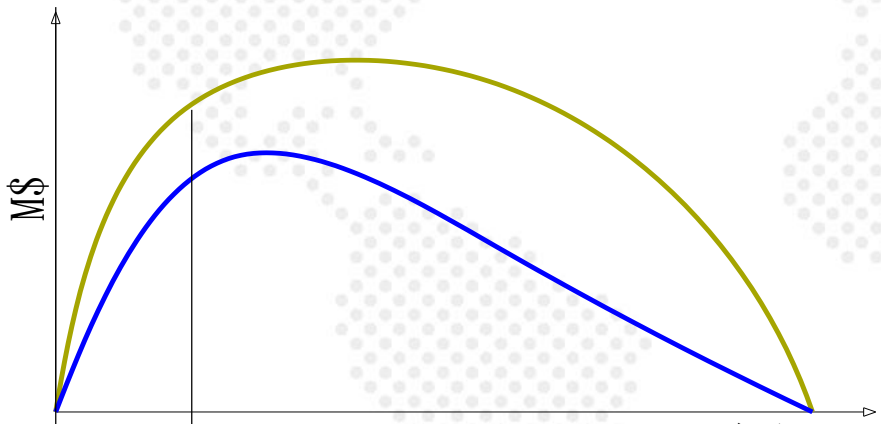


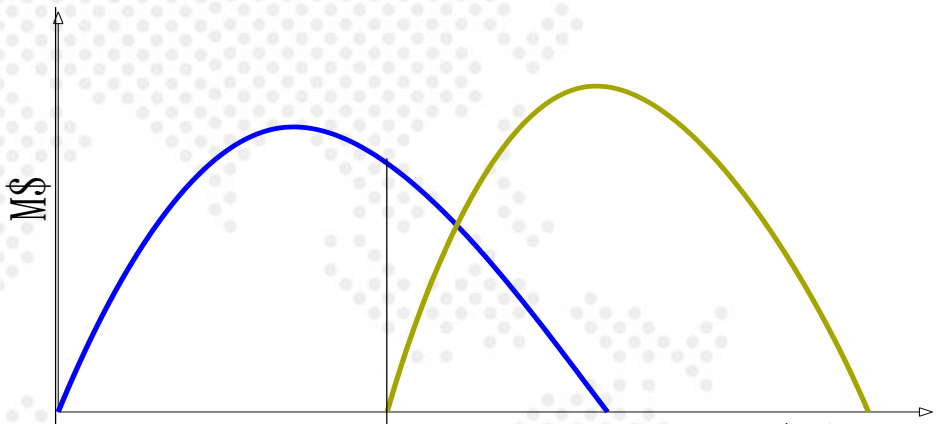
Changes on SMR Financing Model

In SMR projects, the upfront investment is mainly shifted to the supply side.

Total investment = Customer's investment + Supplier's investment – Payment by Customer to Supplier

Supplier : NSSS, AE, Industrial Network **Customer :** Owner, Investor, and other Stakeholders





Supplier Investment

Design → Procurement → Construction → Installation

Site Selection

FCD

Customer Investment

Pre-commissioning procurement → Contract Monitoring

Supplier Investment

Design → Construction & Installation → Installation onsite

up-front investment

Site Selection

Construction

Customer Investment

procurement → Contract Monitoring

Impact of SMR on Financing Models and Policies

SMR as a game changer for finance

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SMR is a game changer, that will change the traditional nuclear design, procurement and construction.

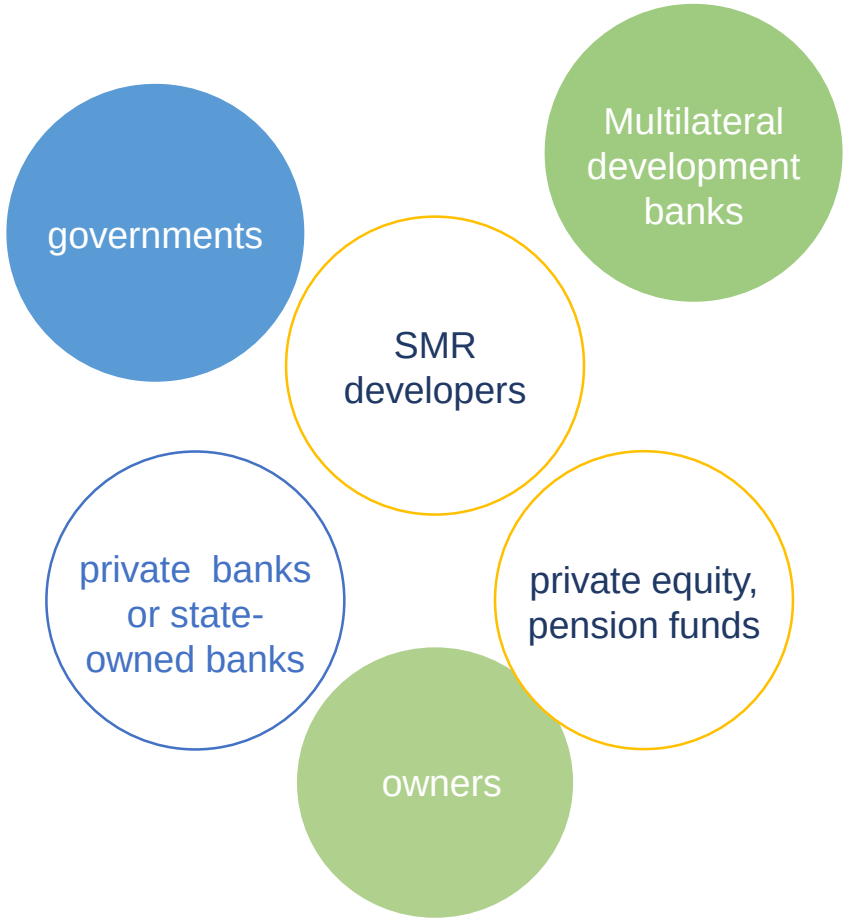
The changes and challenges would include:

- **Re-allocation of financing risks between the demand side, supplier side and supply chain**
  Compared with traditional nuclear investment and construction, the financing pressure on demand side would decrease, while the investment pressure is shifted to the supplier side and the whole supply/industrial chain. How will this redistribution happen – WHO and HOW?
- **R&D costs**
  SMR technology innovation requires massive investment on R&D. With current technical maturity, it's difficult for SMRs to attract capital with low risk appetite. WHO will pay for R&D costs?
- **Market size and stability of supporting policies**
  Sufficient users and stable policy support are necessary for maintaining investment expectations of the supply side and supply/industrial chain.

SMR's demand for financing model and financial policy support

SMR financing demands could be satisfied with appropriate financing approaches and financial policies. Financing approaches

- During the phase of SMR R&D and V&V, as well as SMR project demonstration, investment from the governments, state-owned investment institutions and consortiums should be introduced.
- In SMR project promotion phase, diverse investment will be introduced.
  - Supply-side investment : Stable and continuous policy supports on SMR development are necessary for the banks to grant long-term loans with low interests to the supply side.
  - Demand-side (utilities and end users) investment will be attracted by sufficient market size.



SMR's demand for financing model and financial policy support

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Financial policy

Financial policies are mainly formulated by the state and local governments in accordance with the needs of the development of SMR in various regions, and can include the following aspects: :

- Formulate policies, guide science and technology funds, and invest in early-stage R&D.
- Formulate tax preferential policies for the first batch of projects.
- The price protection and consumption mechanism for the products (electricity, heat, etc.) of the SMR project.
- In response to the flexible regulatory requirements of the SMR projects, the safety and the interests of investors should be both guaranteed.

Suggestions on SMR Financing Activities

Discussions and suggestions on SMR's financing methods

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The following game participants are required for cooperation and unified planning:

- National policy-making departments,
- Science and technology departments,
- Industry Management Authorities, Banks
- Innovative R&D institutions, industrial chain
- Project investors, owners, and operators

From R&D to SMR NPPs, it is necessary to formulate detailed game rules in every link, so as to clarify:

- Responsibilities and benefits
- Investment and risk
- Financial and cash flow needs and allocation
- Control of resources and return of value

Detailed and reasonable game rules will ensure that SMR's investment start-up, R&D, design, procurement, construction, installation, commissioning, operation, and maintenance are all interlocked and smoothly promoted, allowing users to get an early return on investment, thereby improving SMR's economical performance.

Summary

- **SMRs have better safety performances and scalability,** which determines that SMRs can adapt to the requirements of China's inland nuclear power and has a broad market prospect.
- **SMRs and large pressurized water reactors have significantly different capital investment characteristics.** Risks should be allocated through diversified financing approaches, and funds should be guided through financial policies such as national budgets, price concessions, and regulatory requirements.
- **Government support and guidance is an important force in the initial stage of SMR development.** Reasonable and detailed rules of the game should be designed to reduce investment risks and attract a wide range of funds to invest in the development of SMRs.

THANKS

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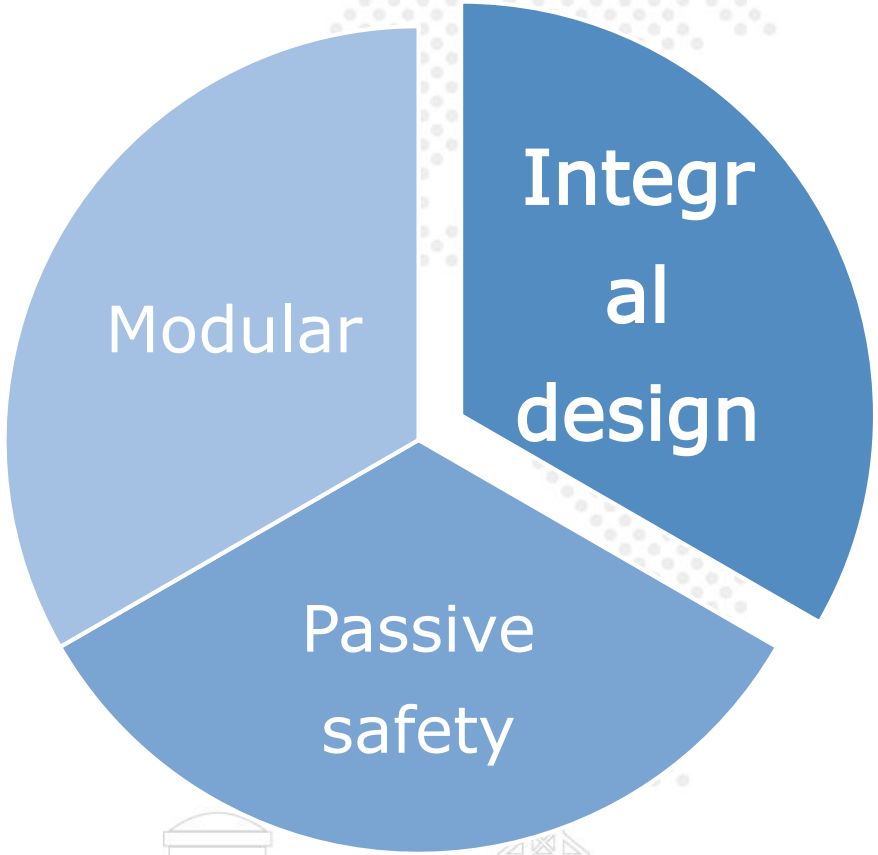
Backup Slides——SMR technical characteristics



The trend in SMR technology development has been towards the integral pressurized water reactor (iPWR) type.

There are about 11 iPWR-type SMRs concepts and designs that are in various phases of development in the world.

Main characteristics：

iPWR-type SMRs integrate the major primary system components in the RPV, such as the steam generator (SG), pressurizer (PRZ), and control rod drive mechanism (CRDM), to inherently eliminate or minimize potential accident initiators, and employ simplified PSSs to counter and mitigate the remaining accident initiators.

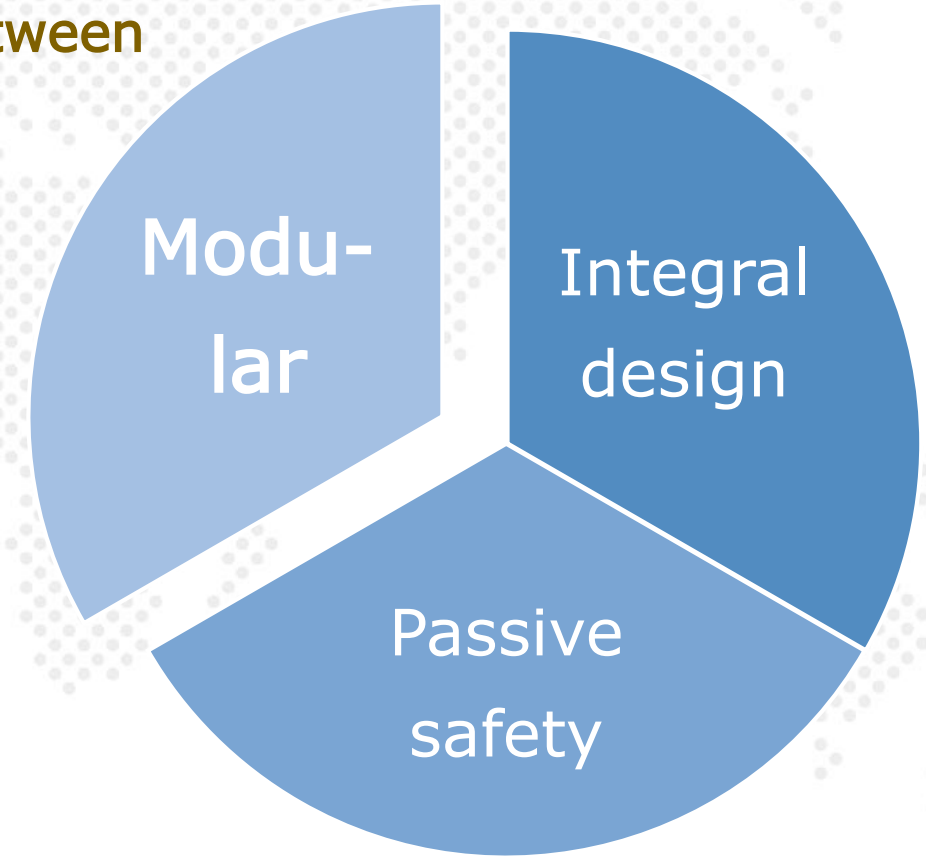
Backup Slides——SMR technical characteristics

Modularity is the main difference between SMR and large reactors.

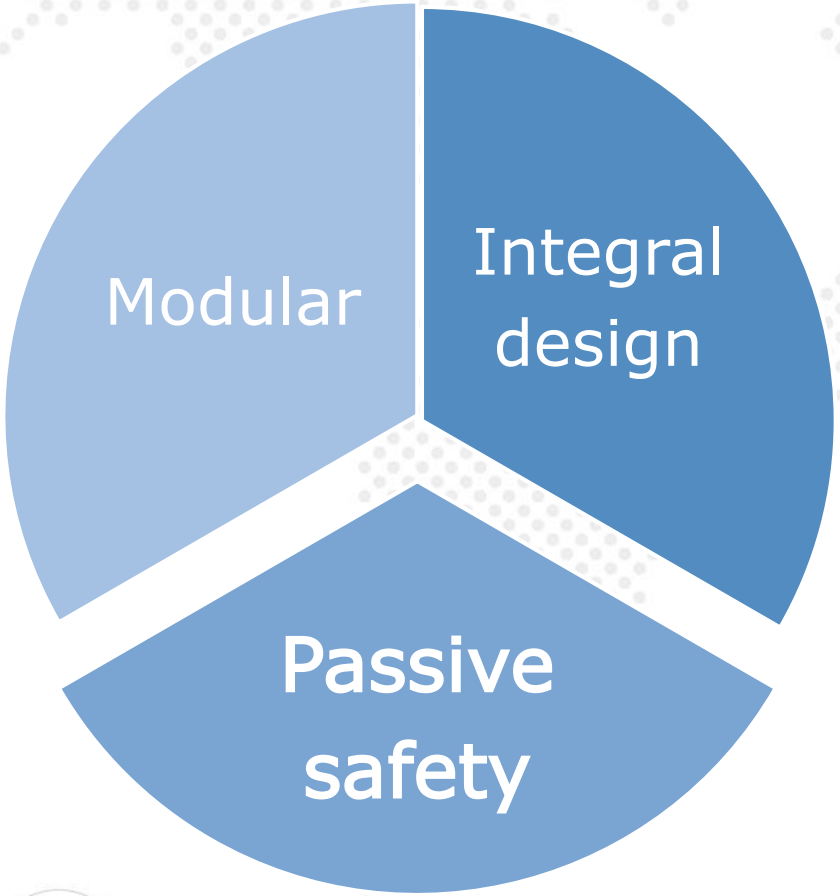
Main characteristics：

SMRs mainly use passive safety systems. In some advanced SMR designs, there are no rotating parts in the RPV. The coolant flows through the core by natural circulation. The entire reactor system (including all components in the primary circuit) can become a whole "module".

Modules can be prefabricated in the factory and then transported to the site for installation.



Backup Slides——SMR technical characteristics



Lower decay heat

- ✓ Small reactors have lower power and lower decay heat after shutdown.
- ✓ S/V of SMR is larger then LRs, therefore decay heat is easier to be removed in SMRs.

Smaller source term

- ✓ Compared with LR, the source term is reduced, which provides more flexibility in site selection.
- ✓ But when using multiple SMR modules to combine the source item may become larger.
- ✓ Reduce or cancel the emergency plan area.

Smaller site area

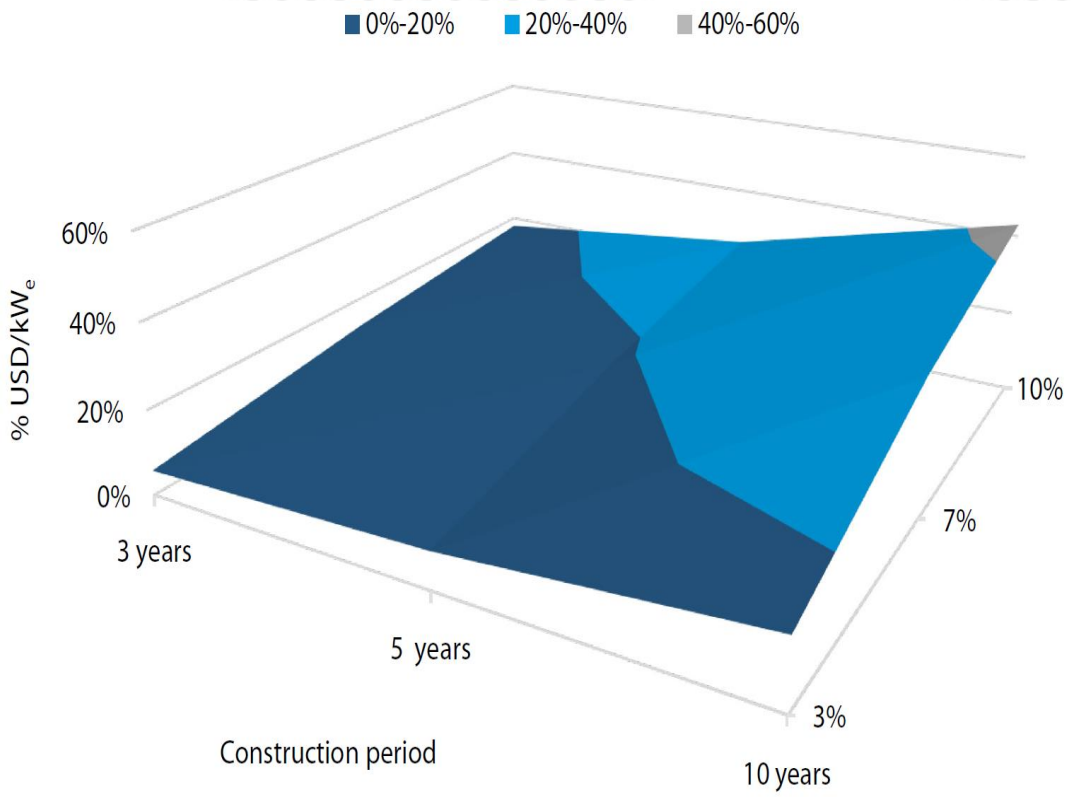
- ✓ The nuclear island occupies smaller area.
- ✓ Better seismic design or seismic isolation design.

Design simplification

- ✓ Smaller core size and lower power levels help simplify system design and reduce costs.
- ✓ The integral design, which means the main equipment such as SG and PRZ are in RPV, eliminates the possibility of large LOCA accident.
- ✓ Design simplification of safety systems.

Backup Slides—— Benefits of reduced construction period

Portion of IDC in total investment costs per kW_e as a function of capital costs and construction period



Cost of capital	Construction period		
	3 years	5 years	10 years
3%	5.8%	8.6%	15.3%
7%	12.8%	18.7%	32.4%
10%	17.6%	25.5%	43.0%

Source：OECD, Unlocking Reductions in the Construction Costs of Nuclear：A Practical Guide for Stakeholders, 2020

Backup Slides—— SMR benefits in financing

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Affordability:

reduced up-front investment

- SMR are expected to be more affordable as the overall capital outlay required per reactor will be lower than for large units, reducing the overall capital at risk for investors.
- This lower capital risk could attract new sources of financing (e.g. private equity, pension funds), lower the cost of capital and ultimately the levelised cost of electricity (LCOE) generated by SMRs.

Shorter payback:

Control of construction and costs

- Better control on shorter construction lead-time – leaner project management
- Lower supply chain risks – increased number of suppliers and reduced need of special and ad-hoc manufacturing and installations
- Better control on construction costs

Control over market risk

- For multi-unit SMRs, the ability to add modules and start generating electricity incrementally can reduce both upfront investment and capital risk.
- The ability to add modules incrementally could also allow investors to adjust to changes in electricity demand and cash flow/financing availability, thus improving the management of financial risks.

Backup Slides—— Financing approaches in different NEA countries

A number of NEA member countries are now supporting SMR development through different approaches by facilitating the development of a domestic programme and/or construction of demonstration and/or first-of-a-kind (FOAK) units.

US

- The United States Department of Energy (DOE), is providing cost-sharing support to selected SMR companies via public-private partnerships and granting these companies access to experimental facilities housed at national laboratories.

UK

- In UK, an SMR concept design is currently co-funded by the government and UK SMR consortium (the consortium is led by Roys-Royce).

China?

- Investment for the R&D from the government
- Tax reduction for FOAK, feed-in-tariff
- CNNC started construction of ACP100 as FOAK

How does the supplier side obtain government support in China:

- Suppliers should improve technology maturity and economical performances of SMRs while ensuring safety performances and the minimization of emergency planning zone;
- Suppliers should form an industrial alliance to balance and protect the interests of all parties. The industry should reach a consensus on SMR development roadmap and industrial development outline, and promotes the approval of the project, thereby leveraging the interest chain with SMR project;
- Promote standardization with modularization, promote batch production with standardization, and realize the scale benefits of SMR;
- Apply for national R&D fund support in the early stage of R&D;
- Apply for government tax reduction and exemption for FOAK and electricity price protection;
- Put forward reasonable demands. For example, when determining the number of SMRs that enjoy the FOAK subsidy policy, the number of SMRs should be more than the number of FOAKs for large reactors, and the specific calculation should be based on the power level.