Research Status and Prospect of Comprehensive Utilization Technology of Nuclear Energy

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Abstract. Nuclear energy is safe efficient zero carbon energy. With the proposal of the national double carbon goal, nuclear energy is developing from single power generation to multi-purpose utilization. The comprehensive utilization of nuclear energy will become an innovative breakthrough in nuclear energy development. This paper expounds on the development status of different energy sources in China and the development technical path of nuclear energy, lists the policy suggestions related to the comprehensive utilization of nuclear energy, focuses on the forms and key technologies of comprehensive utilization of nuclear energy, such as nuclear heating, nuclear desalination, nuclear steam supply, nuclear hydrogen production, nuclear and renewable energy coupling, and constructs a representative scenario of comprehensive utilization of nuclear energy. In addition, the opportunities and challenges faced by the current comprehensive utilization of nuclear energy and the future development direction are summarized and prospected.

Keywords: Nuclear · Comprehensive utilization · Heating · Seawater desalination · Hydrogen

1 Introduction

Climate change has become a common issue of global concern. Traditional fossil energy urgently needs to be replaced by clean and low-carbon energy. China's coal rich resource endowment determines that energy consumption is dominated by fossil energy. With the optimization and adjustment of the energy consumption structure, in 2021, the proportion of coal consumption in the primary energy consumption will drop to 56%, the proportion of non-fossil energy consumption will increase to 16.5%, and the proportion of clean energy consumption such as natural gas, hydropower, nuclear power, wind power and solar power generation in the total energy consumption will increase to 25.5%. In terms of installed capacity, the installed capacity of non-fossil energy has reached 1.12 billion kW, accounting for 47.0% of the total installed capacity, exceeding the installed capacity of coal-fired power for the first time. Nuclear energy is a stable reliable clean energy resource, which can play an important role in building a modern energy system, coping with climate change, and ensuring energy security [1].

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China's nuclear industry system started in the 1950s. After decades of unremitting efforts, the system has made remarkable development achievements and is ranked among the world's leading nuclear powers now. In the early stage, nuclear power technology was mainly based on introduced. After that, an independent development path of "introduction, digestion, absorption and re-innovation" has been embarked on. "Hualong 1" is the third-generation nuclear power technology with complete independent intellectual property rights in China, and its world's first nuclear power Fuqing unit 5 has been connected to the grid in 2020. By the end of 2021, there were 53 nuclear power units in operation in Mainland China, with an installed capacity of 53.26 million kW. In 2021, the cumulative generating capacity of nuclear power units in operation was 407.14 billion kW h, accounting for 5.02% of the cumulative generating capacity in China. It is estimated that by the end of the 14th Five Year Plan period, the installed capacity of nuclear power in operation in mainland China will surpass that in France, ranking second in the world.

Nuclear energy has great advantages in maturity, economy and sustainability. Compared with other renewable energy sources, it has the advantages of non-intermittency and fewer constraints by natural conditions. Nuclear power is mainly used for power generation. According to the report of the world nuclear power reactor (2021), by the end of 2020, among the 442 nuclear power units in operation in 32 countries around the world, 69 Units in 11 countries have also realized the comprehensive utilization of one or two of items, including regional heating, industrial heating and sea water desalination [2]. With the continuous development of nuclear energy technology, the scenarios for comprehensive utilization of nuclear energy will be gradually enriched. Comprehensive utilization of nuclear energy plays an increasingly important role in China's energy transformation. It can not only meet the diversified energy demands of high energy-consuming industries, but also provide decarbonization technology solutions for high carbon emission industries. Facing the "3060" goal, the comprehensive utilization of nuclear energy is an important starting point for the clean and low-carbon transformation of energy, which has great significance to ensure energy supply and security and achieve sustainable development.

2 Comprehensive Utilization of Nuclear Energy

Nuclear energy utilization is expanding from a single "power supply" to "clean energy, comprehensive utilization, multi-function" and other fields. Nuclear power generation has great advantages in technology maturity, economy and sustainability. At the same time, compared with hydropower, photoelectricity and wind power, it has the advantages of non-intermittency and fewer constraints by natural conditions [3]. It is a clean energy resource that can replace fossil energy on a large scale, which has been widely used in the field of nuclear desalination at present in China, in which has carried out demonstration applications in nuclear heating and integrated energy. Facing the transformation of clean and low-carbon energy, national and local governments have issued policies on comprehensive utilization of nuclear energy to improve the efficiency of nuclear energy utilization, accelerate the pace of comprehensive utilization of nuclear energy, and expand the scope and scenarios of nuclear energy application. Some nuclear energy comprehensive utilization policies are shown in Table 1.

Table 1. Summary of nuclear energy comprehensive utilization policies

Comprehensive utilization	Release time	Policy name	Key content
Comprehensive policy	2022.3	Modern energy system planning during the 14th Five Year Plan Period	Carry out comprehensive utilization demonstration of nuclear energy, actively promote advanced reactor type demonstration projects such as high-temperature gas cooled reactor, fast reactor, modular small reactor and offshore floating reactor, and promote the comprehensive utilization of nuclear energy in the fields of clean heating, industrial heating and seawater desalination
	2021.10	Action plan for carbon peak before 2030	Actively develop nuclear power in a safe and orderly manner, actively promote advanced reactor type demonstration projects such as high-temperature gas cooled reactor, fast reactor, modular small reactor and offshore floating reactor, and carry out demonstration of comprehensive utilization of nuclear energy
	2021.10	Opinions on completely, accurately and comprehensively implementing the new development concept to do a good job in carbon peak and carbon neutralization	In northern cities and towns, we will accelerate the central heating by cogeneration, accelerate the large-scale development of industrial waste heat heating, and actively and steadily promote nuclear waste heat heating
Nuclear heating	2021.8	The 14th five years plan for energy development in Shandong Province	The national energy and nuclear energy heating commercial demonstration project will be completed. The cross regional heat supply project from Haiyang nuclear power to Yantai city and Qingdao Jimo and the nuclear power heat supply project of Guohe No. 1 demonstration project were started
	2021.3	The 14th five years plan for national economic and social development of Heilongjiang Province and the outline of long-term objectives for the year 2013	Actively and steadily promote nuclear heating demonstration, focus on the construction of Jiamusi nuclear heating demonstration phase I project and SDIC (Keshan) nuclear heating demonstration project, and promote clean energy heating supply

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Table 1. (*continued*)

Comprehensive utilization	Release time	Policy name	Key content
Nuclear desalination	2021.4	The 14th five years plan for national economic and social development of Liaoning Province and the outline of long-term objectives for the year 2035	Actively explore the comprehensive utilization of nuclear energy for seawater desalination
	2021.8	The 14th five years plan for energy development in Shandong Province	Relying on the coastal nuclear power projects, accelerate the comprehensive utilization of nuclear heating and seawater desalination, and start the 300000 ton/day nuclear seawater desalination project of Haiyang and the 100000 ton/day nuclear seawater desalination project of Guohe No. 1 demonstration project
Nuclear hydrogen production	2022.3	Medium and long term plan for the development of hydrogen energy industry (2021–2035)	Promote the research and development of technologies for hydrogen production by solid oxide electrolysis cell, hydrogen production by photolysis of water, hydrogen production by seawater, and hydrogen production by nuclear energy at high temperature
	2021.4	The 14th five years plan for national economic and social development of Liaoning Province and the outline of long-term objectives for the year 2035	Promote nuclear waste heat heating and low-temperature reactor central heating, and actively explore ways to promote the comprehensive utilization of nuclear energy such as hydrogen production and seawater desalination
	2021.8	The 14th five years plan for energy development in Shandong Province	Explore the research and demonstration application of nuclear hydrogen production technology, and carry out the hydrogen production project of the national harmony No. 1 demonstration project

2.1 Nuclear Heating

Since the 1960s, Sweden, Canada and other countries have adopted nuclear heating. At present, there are about 57 commercial reactors in the world that generate hot water or steam for district heating while generating power. They are mainly distributed in Eastern Europe. The operation experience of these projects has exceeded 1000 reactor years [4].

The application of nuclear heating in China started late and took the lead in Shandong. In 2019, the Haiyang nuclear heating project was put into operation, marking the official implementation of the first commercial clean heating demonstration project of nuclear power units in China. In December, 2021, the first nuclear heating project in southern China - Zhejiang Haiyan nuclear heating demonstration project (phase I) was officially put into operation, with a heating area of 460000 m^3. While the heating quality was improved, the heating price was reduced by about 1\3 compared with the past. About 9 provinces and 23 cities in China have expressed their interest in nuclear heating, which is mainly distributed in the cold northern regions and areas with serious air pollution. China's nuclear heating has a broad space for development, especially in replacing coal-fired boilers and promoting clean energy heating. The nuclear heating demonstration project has verified the economy, safety, stability and scalability of nuclear extraction heating. Subsequently, several nuclear power generating units have incorporated extraction heating into the planning. In terms of the low-temperature heating reactor, Tsinghua University, China Nuclear Power Group and other units have developed NHR200-ii low-temperature heating reactor, Yanlong pool type low-temperature heating reactor and other reactor types respectively, and the construction of demonstration projects has also been included in the planning (Table 2).

Table 2. Key issues of nuclear cogeneration technology and low temperature pool reactor technology

Mainstream technology	Key issues needing attention
Nuclear cogeneration technology	1) Transformation of nuclear power unit in operation - unit power influence, steam extraction port layout, steam extraction load range, power control mode, safety and economy of the steam extraction system, etc 2) New nuclear power units - Research on the model of heat supply steam turbine, research on reactor matching with heat supply load change, utilization in non-heating seasons (seawater desalination, refrigeration, etc.)
Low temperature pool reactor technology	1) Special research on matching of reactor and heat supply network - analysis of reactor and loop parameters changes with the load of heat supply network 2) Research on building low-temperature heating reactor using retired coal-fired cogeneration plant site 3) Utilization in non-heating seasons (seawater desalination, refrigeration, etc.)

2.2 Nuclear Steam Supply

At present, industrial steam can only be provided by traditional fossil energy in China. Under the background of the "double carbon" strategy, the "double control" of energy consumption also limits the industrial development. Nuclear power steam supply has the characteristics of high quality, cleanness, large output and wide application range. It can meet the steam demand of most industrial enterprises and has a large market demand.

With the development of China's industry and the increasing number of nuclear power units, nuclear steam supply will become a new type of energy supply. At present, Tianwan nuclear power plant steam energy supply project, Fuqing nuclear power heating project and Lianyungang nuclear power heating demonstration project plan to use nuclear power to provide industrial steam for surrounding industrial zones. It is expected that more nuclear power plants will carry out nuclear power steam supply projects in the future (Table 3).

Table 3. Key issues of medium and low-temperature steam supply technology and high-temperature steam supply technology

Mainstream technology	Key issues needing attention
Medium and low temperature steam supply technology	1) Research on high efficiency steam conversion technology, including selection of steam conversion equipment and steam turbine equipment 2) Research on nuclear steam supply operation scheme and reliability 3) Research on reactor coordinated control scheme 4) Research on radiation safety, transient and accident conditions, ecological environment effect evaluation of nuclear steam supply system, etc
High temperature steam supply technology	1) Hualong 1 (Linglong 1) + high temperature reactor coupled steam supply technology 2) Hualong 1 (Linglong 1) + conventional energy (waste incineration unit/gas unit/coal-fired unit/electric heating)

2.3 Nuclear Desalination

Seawater desalination technology mainly includes the thermal method, membrane method and thermal film coupling seawater desalination technology. The main uses of seawater desalination in China are industrial water and domestic water. According to the 2020 national seawater utilization report, by the end of 2020, there were 135 seawater desalination projects in China, with a project scale of 1.651 million tons/day, which has a certain gap from the planned goal that the national total scale of seawater desalination will reach more than 2.2 million tons/day by the end of the 13th five year plan. According to the action plan for seawater desalination utilization and development (2021–2025), by 2025, the total scale of seawater desalination in China will reach more than 2.9 million tons/day, and the new scale of seawater desalination will be more than 1.25 million tons/day. At present, China's reverse osmosis technology and low-temperature multi effect technology account for 65.3% and 34.3% of the total project scale respectively.

In terms of nuclear seawater desalination, Kazakhstan, India, Japan and other countries have accumulated more than 150 heaps of nuclear seawater desalination experience after years of development. Japan has more than 10 seawater desalination facilities and pressurized water reactor nuclear power cogeneration projects, which have the characteristics of small scale and low output, with a fresh water production capacity of about 14000 m^3/day. The main desalination processes coupled with nuclear reactors for fresh water production are: 1) Multi-Stage Flash (MSF), 2) Multi Effect Distillation (MED) and 3) Reverse Osmosis (RO). From the perspective of foreign reactor types used for seawater desalination, the pressurized water reactor is the most commonly used reactor for MSF, MED and RO [5, 6].

At present, the seawater desalination process (see the following table for details) used in domestic built and under construction nuclear power plants mostly adopts membrane method, and its seawater desalination is mainly used for desalted raw water or service water of power plants (Tables 4 and 5).

Table 4. The seawater desalination process used in domestic built and under construction nuclear power plants

Project name	Design scale (m^3/d)	Adopted process
Fujian Ningde NPP	15000	RO
Liaoning Hongyanhe NPP	10200	RO
Zhejiang Sanmen NPP	17000	RO
Shandong Haiyang NPP	16800	RO
Fujian Xiapu NPP	6800	RO
Liaoning xudapu NPP	23000	RO
Hainan Changjiang ACP100	6000	MED

2.4 Nuclear Hydrogen Production

The current hydrogen production methods include chemical by-product hydrogen production, coal gasification hydrogen production, methane reforming hydrogen production, methanol reforming hydrogen production, and water electrolysis hydrogen production. In China's hydrogen production structure in 2020, coal-based hydrogen production accounts for 62%, natural gas hydrogen production accounts for 19%, industrial by-product gas hydrogen production accounts for 18%, and electrolysis of water for hydrogen production accounts for about 1%. It can be seen that hydrogen is mainly derived from fossil energy, and the proportion of hydrogen production from renewable energy and clean energy is extremely low, in China. Hydrogen production by electrolysis of water has three technical routes: proton exchange membrane electrolysis, alkaline water electrolysis, and solid oxide electrolysis. Alkaline electrolysis of water for hydrogen production was applied earlier, and its technology is relatively simple and mature. At present, the large-scale industrial hydrogen production by electrolysis of water adopts

Table 5. Key issues of Nuclear waste heat seawater desalination technology and Nuclear membrane seawater desalination technology

Mainstream technology	Key issues needing attention
Nuclear waste heat seawater desalination technology (mainly steam / hot water)	1) Coupling waste heat utilization technology with seawater desalination technology, combined with heat pump technology, steam turbine back pressure transformation, etc 2) Researching on technical optimization and economic improvement of hot film coupling mode
Nuclear membrane seawater desalination technology (main energy and power)	1) Key equipment such as energy recovery, high-pressure pump, and reverse osmosis membrane technology 2) Comprehensive utilization technology of concentrated brine

alkaline water electrolysis hydrogen production technology, but this technology has low hydrogen production efficiency and large power consumption. Moreover, the purity of hydrogen produced by this technology is not high enough to prevent potential safety hazards. The development of hydrogen production technology from water electrolysis has been relatively mature, and the present weakness is cost and life [7].

Under the constraints of the "double carbon" goal, low-carbon and zero-carbon hydrogen production processes have become the focus of attention. As a clean and efficient primary energy, nuclear energy is one of the important solutions for the large-scale supply of hydrogen in the future. The mainstream nuclear hydrogen production technologies developed currently include thermochemical cyclic hydrolysis and high-temperature steam electrolysis [8] (Tables 6 and 7).

Table 6. Typical technical route of different hydrogen production technologies

Hydrogen production technology	Typical technical route	Application field
Cold water electrolysis	Alkaline Water Electrolysis (AWE)	Nuclear power, hydropower
	Proton Exchange Membrane Electrolysis (PEM)	Nuclear power, hydropower, wind power, solar power
High temperature steam electrolysis	Solid Oxide Electrolysis (SOEC)	Nuclear power
Thermochemical hydrolysis	Iodine-Sulfur Cycle	Nuclear power (ultra-high temperature gas-cooled reactor)

Table 7. Main problems of two nuclear energy hydrogen production route

Technology method	Main problems of attention
Nuclear energy + thermochemical hydrolysis hydrogen production route	The research and development focus includes the improvement of the iodine-sulfur cycle and the mixed sulfur cycle, and the improvement of the primary circuit temperature of the UHT gas-cooled reactor
Nuclear energy + solid oxide electrolysis route	The research and development focus includes further improvement of electrolysis efficiency, improvement of single cell stack power, improvement of fuel cell life and cost reduction. The hydrolysis route, can also be coupled with conventional pressurized water reactors, and can be used with nuclear power peak shaving in the future

2.5 Nuclear Energy-Storage-Renewable Energy Coupling

Wind power, hydropower and solar power are developing rapidly and have broad application prospects. Renewable energy has the characteristics of intermittence and volatility, while nuclear energy is stable reliable clean energy. Energy storage can not only cut peaks and fill valleys, but also shift load fluctuations. It is an important technical support for the current large-scale consumption of renewable energy. Nuclear energy, energy storage and renewable energy are complementary, and their application of coupling can effectively reduce greenhouse gas emissions and improve system reliability.

Internationally, Malaysia has done a lot of work on the coupling of renewable energy and nuclear energy. In 2016, Malaysia introduced three types of feasible coupling systems: tightly coupled hybrid energy systems, thermally coupled hybrid energy systems, and loosely coupled hybrid energy systems. The coupled use of nuclear energy and renewable energy can produce electrical energy and thermal energy together, and dynamically distribute thermal energy and electrical energy through a synchronous control system to flexibly supply power to the grid. Ref. [9] demonstrated a nuclear and renewable energy coupling system (Fig. 1), in which nuclear and renewable energy co-produce electrical and thermal energy, and dynamically distribute thermal and electrical energy through a synchronous control system to flexibly supply power to the grid. The thermal energy generated by nuclear energy and the solar concentrating system is used for thermal power generation, and the generated electricity is fed into the low-carbon power grid together with the electricity generated by wind energy and photovoltaic solar energy. The wasted heat provides thermal energy for industrial production to produce low-carbon products, and the electrical energy required for industrial production is provided by nuclear energy, wind energy and photovoltaic solar energy. The rested heat energy is stored in the thermal storage system, and the rested electrical energy is stored in the battery.

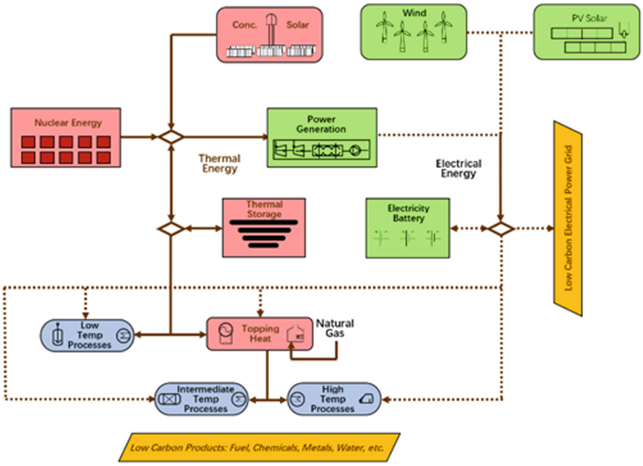

Fig. 1. Example of a nuclear and renewable energy coupling system

Chinese "Guohe No.1+" smart nuclear energy comprehensive utilization demonstration project will be put into operation in 2021. Relying on the "Guohe No.1" demonstration project, the project covers distributed photovoltaics, photovoltaic carports, distributed wind power, and reserved interfaces for hydrogen production and energy storage equipment, thus building a diversified energy complementary ecology of "nuclear, wind and hydrogen storage". In 2022, Haiyang Nuclear Power will put into operation of the "Nuclear Energy + Photovoltaic" project, and rely on the "Water and Heat Simultaneous Interpretation" project to build a "Distributed Photovoltaic Power Supply + Nuclear Energy Heating and Water Supply + Water Storage + Electric Energy Storage" four-in-one "hydrothermal power storage" comprehensive smart energy demonstration project in the dormitory area [10].

In addition to demonstration applications, domestic and foreign scholars have carried out extensive research on the nuclear energy-storage-renewable energy coupling system. Cheng [11] proposed a new type of nuclear and solar complementary power generation (NSCP) system. The nuclear energy module adopts a small modular lead-cooled fast reactor (LFR), and the solar module is a tower solar system. Zhang [12] proposed a hybrid nuclear-wind system with hydrogen energy storage, which consists of a nuclear power plant, a wind power plant, and a cluster of PEMs for energy storage. Through off-grid scheduling, excess electricity can be stored in the form of hydrogen during periods of low demand. Park et al. [13] proposed a nuclear integrated liquid air energy storage system (LAES), and carried out the thermodynamic and economic analysis. In the nuclear integrated LAES, according to grid conditions, there are three operating modes: charging mode, idling mode and discharging mode. Renewable energy sources such as solar energy and wind energy have low energy density and poor stability. The coordinated distribution of nuclear energy and renewable energy supply, the full utilization of multiple energy sources, and energy storage issues need to be focused on.

3 Scene Construction

Based on the above-mentioned research and analysis of key technologies, a representative scenario of comprehensive utilization of nuclear energy is constructed, as shown in Fig. 2. Taking a small reactor in a project as an example, in addition to generating power from the unit, it can be considered to use the extraction steam to supply steam to users in nearby industrial parks through steam conversion devices, such as steel, paper, chemical, textile and other enterprise users. These enterprises usually require different steam parameters, and the steam conversion device and steam extraction position need to be optimized and adjusted according to the steam demand grade. If the project site has industrial or residential heating needs, combined with heat pumps and large temperature difference heat exchangers, it can be considered to use extraction steam to first conduct heat exchange in the plant, and then heat the high-temperature water to the outside through a multi-circuit design. If there is cooling demand near the project site, the comprehensive nuclear energy utilization plan can use the steam or hot water output by the nuclear power plant, use lithium bromide units or heat pump technology, build refrigeration stations in areas with concentrated air conditioning loads, or rent large cold storages. If there is a demand for fresh water near the project site, the improved low-temperature multiple-effect distillation (MED) technology can be used to prepare fresh water for external supply. If the project site is rich in renewable energy such as wind and solar, distributed photovoltaic and distributed wind power can also be built to couple with nuclear power. When the seasonal load fluctuates and the nuclear power cannot be fully generated, it can be considered to abandon electricity to produce hydrogen. Product sales are also a measure of energy storage (Fig. 2).

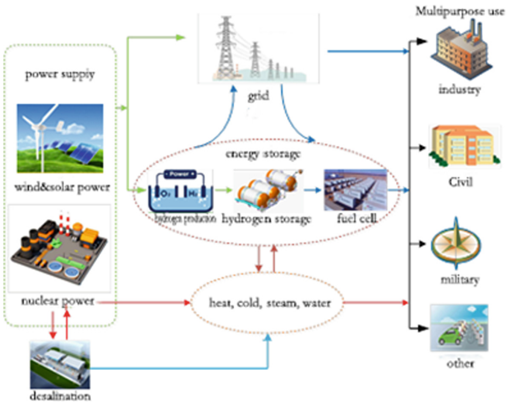

Fig. 2. Representative scenarios of comprehensive utilization of nuclear energy

4 Suggestions on the Development of Comprehensive Utilization of Nuclear Energy

4.1 Strengthen the Top-Level Design and Coordinate the Promotion of Comprehensive Nuclear Energy Utilization Planning

In the era of realizing the "3060" goal and addressing climate change, in the process of energy clean and low-carbon transformation, nuclear energy has the advantages of non-intermittency and higher energy density compared with other renewable energy such as solar energy and wind energy. And after the long-term development of nuclear energy, nuclear energy has outstanding advantages in terms of maturity, economy and sustainability. In China, nuclear power generation accounts for 5% of the total power generation, which is lower than the world average (10%). We should actively develop nuclear power in a safe and orderly way, and increase the installed capacity of nuclear power and the proportion of power generation. Based on this, the nuclear energy heating, nuclear energy steam supply, nuclear energy seawater desalination, nuclear energy hydrogen production and nuclear energy-storage-renewable energy coupled use planning and layout shall be comprehensively promoted, the formulation of specific guidelines for the comprehensive utilization of nuclear energy shall be accelerated, and the direction of work shall be clarified. Combined with local needs and industries, comprehensive utilization of nuclear energy will be implemented in different regions and scenarios.

4.2 Improve Scientific and Technological Research and Development Capabilities and Make Breakthroughs in Key Technology Application Innovations

Nuclear energy heating and nuclear energy seawater desalination require physical isolation, which involves multi-loop design and steam conversion, with the increase of heat loss. Thermochemical cycle hydrogen production involves many reaction stages, the entire process is complex, and strong corrosive and even toxic substances will be produced. The integrated energy system composed of nuclear energy-storage-renewable energy coupling face various difficulties in terms of the control and management of equipment, the optimal scheduling with the grid side and the user side, as well as the development of data and analysis systems.. To deal with the difficulties, we should integrate the strengths of universities, research institutes and enterprises, build joint laboratories, mobilize the strengths of all parties in the way of "revealing the list", carry out forward-looking, systematic and strategic research and development of key nuclear energy technologies, and increase scientific and technological research and development. Make breakthroughs in the researching, developing and manufacturing of key materials, equipment, and control systems, and implement design optimization of reactor technology and demonstration applications for intelligent integrated nuclear energy construction.

4.3 Promote the Reform of the System and Mechanism, and Improve the Construction of the Standard System for Comprehensive Utilization of Nuclear Energy

Research on the nuclear energy industry management system, thermal management system, and energy management system shall be carried out to promote the diversification of investment and financing for the comprehensive utilization of nuclear energy, further allowing energy-intensive enterprises such as petrochemicals and steel and thermal enterprises participating in the operation, improving the development of the comprehensive nuclear energy utilization industry, and opening up the investment and financing system construction. In accordance with the needs of nuclear energy development and safety operation, the industrial technical standards and management systems for the comprehensive application of nuclear energy shall be established and improved. Additionally, the role of a standardized information platform shall be played to promote the top-level design of the standard system for the comprehensive utilization of nuclear energy.

4.4 Strengthen Industry Supervision and Continuously Improve the Safety Performance of Nuclear Energy

Safety is the lifeblood of nuclear power. The development of nuclear power should adhere to the principle of safety, activeness, and order. Based on fully learning of the lessons of nuclear power plant accidents, we could research and develop more advanced and safer nuclear power technologies, continuously improve engineering standards, and improve the safety performance of nuclear power. The safety supervision of the construction, operation, and maintenance of the nuclear power plants should be strengthened properly to minimize the potential safety hazards of nuclear power plants. Further, we should strengthen the scientific and technological innovation in uranium resource development and nuclear waste treatment, and continuously improve the standards for development, utilization and treatment. In addition, we should increase the popularization of nuclear energy technology safety, eliminate the public's fear of nuclear power, and increase the public's acceptance of nuclear energy.

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