Technology and Innovation

Focusing on self-reliance in state-of-the-art technologies, we embrace innovation as the key driving force for development, promote the construction of incubators for home-grown technologies, and strengthen independent research and commercialization of core technologies to support high-quality development.

Technological Innovation System

At CNPC, aiming at technological self-reliance and self-strengthening at higher levels and emphasizing the ability of independent innovation, we continue to deepen the reform of the framework for innovation governance and strengthen top-level design and overall planning to improve our technological innovation management system. Technology platform programs make further headway. The CNPC-led national key laboratory on green development of continental shale oil was approved for construction. The national key laboratory on deep oil and gas resources in partnership with China University of Petroleum (East China) was also approved. As of the end of 2023, the Company has more than 60,000 R&D personnel and 16 national innovation bases, including national key laboratories on enhanced oil recovery, oil and gas drilling, production, and transportation equipment, as well as multi-resource collaborative green development of continental shale oil.

Reform of Innovation Governance Framework

- Improve the top-level design for innovation governance
- Improve the three-tiered system for technological innovation management
- Maximize the role of Science and Technology Committee
- Build world-class research institutes and innovation-oriented enterprises
- Issue the *Management Measures for Innovation-oriented Enterprises* and introduce a mechanism of regular evaluation and dynamic management

Research personnel at work

Major R&D Achievements

At CNPC, we actively implement an innovation-driven strategy, focusing on major bottlenecks in key areas. Debottlenecking in core technologies and forward-looking, basic and strategic research are strengthened and commercialization of new technologies for productivity gains is accelerated, which achieved fruitful results in E&P, refining, petrochemicals and new materials, as well as low-carbon and new energies, as represented by the Top 10 Technological Achievements.

Top 10 Technological Achievements in 2023

Clay shale oil enrichment theory and key technical breakthroughs for the development of Gulong Shale Oil Demonstration Zone

The Gulong shale is a typical mudstone shale characterized by the highest clay content, lowest hardness and smallest porosity in the world, with no successful exploration and development examples reported at home and abroad. Daqing Oilfield's original in-situ self-sealing and enrichment theory of shale oil has revealed the cross-scale exploitation mechanism of nanoscale reservoirs. Its novel double-sweet-spot identification technique for high clay shale oil has turned the traditional "out-of-bounds area" into a new frontier of production replacement, increasing single-well production and EUR by three times and proving 204 million tons of shale reserves. As a national demonstration zone, it is expected to become the largest continental shale production base in China.

Deep coal-bed methane enrichment theory and key technological innovation for industrial development

It reveals the unique occurrence characteristics and production mechanism of deep coal-bed methane with "high gas content, high saturation and rich free gas" and forms an accumulation and enrichment model featuring "extensive development, rich hydrocarbon generation, self-sealing, strong preservation and micro-adjustment". The Company developed "five-in-one" differentiated well pattern design, targeted large-scale volume fracturing technology to form extensive fracture networks, and full life cycle drainage techniques, which tackled the world class challenge of commercial development of deep coal-bed methane, and increased single-well production significantly. It has supported CNPC to add a proven reserve of over 200 billion cubic meters in the eastern margin of Ordos Basin and build an annual capacity of 1.5 billion cubic meters. As of now, the project has been approved as a national demonstration base for its pioneering role.

Amine deep regeneration technology for high-efficiency treatment of sulfurous natural gas

Compared to similar technologies overseas, CNPC's innovative deep-regeneration technology for amine solution can remove 8 times as many types of metamorphic byproducts and reduce the loss rate of active agent from 98% to less than 2%. Challenges in ensuring the stable operation of natural gas purification plants, such as the deterioration of desulfurization performance due to metamorphic amine and the foaming related production disruption, are solved for the first time in the world. Such a breakthrough brought the amine deep-regeneration technology to the next level globally. This technology has supported the safe and efficient treatment of 27.9 billion cubic meters of sulfurous natural gas since it was applied at Southwest Oil and Gas Field and Tarim Oilfield.

A technology package for solution-based production of high-performance ethylene-octene copolymerized elastomer (POE)

POE is essential for green energy and high-end manufacturing. Focusing on the core needs of the industry and leveraging its R&D, design, engineering and production resources, CNPC has solved many common technical challenges, such as high-temperature, high-activity metallocene catalyst, mass and heat transfer and devolatilization in high-viscosity systems, as well as oligomer clogging in 1-octene production, which created a complete production process from monomer 1-octene to POE products, breaking foreign technical barriers.

China's first technology package for PETG copolyester

PETG copolyester is an advanced chemical material of national priority. CNPC has developed 5 series of 48 key technologies, a full set of 10 PETG products and the complete technology package for PETG production. We built China's first 100,000 t/a PETG production plant, and became the third company in the world and the first in China to produce a full range of PETG products, disrupting the dominance of American and Korean manufacturers. Leading the high-quality development of China's polyester industry, this technology was included in the technological innovation achievements of China's central SOEs and CNPC's key proprietary innovations in 2022.

A novel technology for high-performance SSBR for tires

CNPC's proprietary technology for the production of high-performance polymerized, end-functionalized, high-styrene

and high-Mooney-viscosity SSBRs has received 21 invention patents. The technology is used to produce 4 SSBR products and adopted by a number of well-known tire enterprises to enable performance improvement in rolling resistance, wet skid resistance and wear resistance that meet the requirements of A/B under the EU labeling scheme. Such a breakthrough ensures technological self-reliance in key basic materials for tires and supports the industrial upgrading and high-quality development of domestic tire enterprises.

Intelligent seismic operation system for high-efficiency seismic acquisition

CNPC has launched GISeis, the industry's first intelligent seismic operation system, with features such as intelligent navigation of vibroseis operation, digitalized active safety, two-tier ad hoc network for real-time data interaction and AI-driven management based on total-element big data analysis. This system reshapes geophysical exploration and boosts efficiency by more than 15%. The technology heralds an era of intelligent seismic acquisition and improves the core competitiveness of CNPC in the field of petroleum geophysical exploration.

Domestic substitution of through-bit imaging and logging equipment and processing software for horizontal wells

CNPC has developed its own through-bit imaging and logging equipment set and processing software for horizontal wells, tackling challenges in relation to high-reliability and temperature and pressure resistance in narrow space, intelligent and controllable pumping and recovery, and 3D phase-controlled heterogeneous reservoir modeling etc. This achievement improves data acquisition in horizontal well logging and integrated geological evaluation for unconventional oil and gas resources. As an import substitution of foreign equipment and software, it saves more than RMB 200 million. Two sets of such equipment have been sold to Halliburton. The temperature and pressure parameters of the equipment reach 175 ºC and 140 mpa respectively, and the continuous working time is not less than 20 hours. The equipment and software have been used 1,100 well-times in logging operation, with time efficiency rising by 53% and sweet spot identification accuracy increased to 90%. They play an important role in supporting the large-scale and cost-effective development of five national shale oil demonstration zones in Longdong, Changqing Oilfield and Gulong, Daqing Oilfield etc.

A major breakthrough in passive magnetic ranging technology

Passive magnetic ranging is essential for drilling emergency rescue wells and plugging underground gas storage. China has long been dependent on imported tools in this area. Through years of continuous efforts, CNPC has innovated a high-precision magnetic positioning technique to locate the borehole of target wells, and developed an engineering software integrating magnetic signal acquisition, positioning calculation, as well as trajectory measurement and control. The Company has also launched four series magnetic ranging tools with temperature and pressure parameters increased to 175 ºC and 140 mpa respectively. Such a breakthrough marks the shift from active magnetic ranging to passive magnetic ranging, and reduces the total error in directional trajectory measurement from meter-level to centimeter-level.

A technology package for 1,000-cubic meter flexible-load, low-energy-consumption hydrogen production based on alkaline water electrolysis

CNPC's technology package for 1,000-cubic meter flexible-load, low-energy-consumption hydrogen production based on alkaline water electrolysis has been applied successfully in one of its petrochemical parks in China, marking a breakthrough in electrolytic hydrogen production. As the first of its kind to be designed in accordance with petrochemical standards, the system uses electrodes with a 3D multi-element alloy skeleton to enable operating reliability over a wide operating window from 20%–120% of nominal capacity. We also achieved the breakthrough in lye flow field structure and the optimization of flow channel, which enables low-energy-consumption operation at 4.37 KWH/standard cubic meter. An intelligent control system was developed to realize unmanned and intelligent production process. These technologies form a complete proprietary process package with DC power consumption and load adjustment capacity indicators reaching advanced levels internationally.

E&P

Innovative geological theories of multistage hydrocarbon generation and accumulation in superimposed basins provided a theoretical basis for exploring 10,000-meter-deep oil and gas resources and supported the deployment of 10,000-meter-deep wells in Tarim Basin and Sichuan Basin. Based on the theories of reservoir/reserve controlling in Cratonic strike-slip faults, the "faults + facies + fissures" three-element reservoir formation and the "source rocks-faults-reservoirs-preservation" four-element coupled theoretical model for reservoir controlling were established to support the E&P breakthroughs in Fuman and central Sichuan. The proprietary clay shale oil enrichment theory and high-efficiency E&P techniques supported the development of shale oil demonstration zones. The deep coal-bed methane enrichment theory and exploitation techniques helped achieve a major breakthrough in deep coal-bed methane E&P in the eastern margin of Ordos Basin. EOR techniques such as finely-controlled water flooding, chemical compound flooding ensured the stable production and high-efficiency development in Daqing and other mature oilfields. The research and testing of the intelligent layered injection-production engineering technology led to an integrated technological system for intelligent injection-production in oil reservoir engineering. The amine deep-regeneration technology supported the high-efficiency treatment of sulfurous natural gas.

Refining, Chemicals & New Materials

CNPC's proprietary technology package for PETG copolyester was applied to build a 100,000 t/a production plant, which supports the high-quality development of the polyester industry. A complex raw material to catalytic pyrolysis (CTP) catalyst was developed to support the Company's efforts in reducing refined products production and increasing new chemicals production. The technology package for high-performance ethylene-octene copolymerized elastomer (POE) by a solution process was put into use to support the transformation and upgrading of the industry. The 1-octene / 1-hexene process package completed commercial tests with performance indicators of its products comparable to imported ones. R&D on the new process for high-carbon α-olefin copolymerized polyethylene made steady headway to provide a solid foundation for the development and commercialization of high-end polyethylene products. A novel technology for producing high-performance SSBR for tires was developed and put into use to ensure technological self-reliance in key materials for tires. CNPC's carboxyl nitrile butadiene rubber technology has already begun commercial production.

Oilfield Services

A 12,000-meter automated drilling rig was developed to support deep-Earth scientific exploration. A rotary steerable drilling system for up to 175℃ completed maximum temperature test with results comparable to its foreign peers. The CG STEER-150 rotary steerable drilling system made a new breakthrough in commercialization. A major breakthrough was also made in passive magnetic ranging and CNPC's high-sensitivity transducer for acoustic logging showed performance comparable to foreign products. GISeis, the industry-first intelligent seismic operation management system for high-efficiency seismic acquisition, was developed, heralding a new era of intelligent seismic acquisition. Our proprietary through-drill pipe imaging and logging equipment (FITS) and processing software (CIFLog-HW) for horizontal wells was independently developed, putting an end to the long-term dependence on imported tools.

Low-carbon & New Energies

The large-scale demonstration projects based on full-industry chain CCUS key technologies made great progress. The CO_2 injection capacity reached 1.59 Mt/a in 2023, supporting the all-round quality and efficiency improvement of the Company's CCUS demonstration projects. A proprietary 1,000m^3 system for hydrogen production using alkaline water electrolysis was launched in a commercial demonstration project. The demonstration and application of core technologies for the exploration and comprehensive utilization of geothermal resources made significant progress to support the business expansion in the geothermal heating market.

"China's first 10,000-meter borehole for deep-Earth exploration starts drilling" selected among 2023 Top Ten Scientific and Technological Developments news stories in China

On May 30, 2023, CNPC's Shendi Take 1 ultra-deep well began drilling in Tarim Basin. It aims to study the geological and engineering theories at 10,000-meter ultradeep levels, marking a major breakthrough in China's deep-Earth exploration technologies and heralding the "10,000-meter era" of our drilling capability.

CNPC developed a series of key equipment, including automated 10,000-meter drill-rod handler and 12,000-meter automated drilling rig, to provide equipment and technical support for the 10,000-meter deep-Earth scientific exploration.

Shendi Take 1 Well

Digital Transformation and Intelligent Operation

At CNPC, digital transformation is a strategic measure to promote the modernization of corporate governance system and governance capabilities. The Digital Intelligence Research Institute was set up. *The Guidelines for Digital Transformation* have been released, leveraging digital technologies such as cloud computing, Internet of Things, 5G, big data and artificial intelligence to support a digital, network-based and intelligent approach to business development. We promote in-depth integration of digital technologies into our products, services and processes along the oil and gas value chains, to facilitate a shift from the capacity-driven model to the innovation-driven model and create a new momentum and a strong growth engine for high-quality development.

Goals and Progress in Digital Transformation and Intelligent Operation

Mainline	Annual Progress
Business Development	• The construction of production and operation platform is advancing robustly; production sites are undergoing a digital transition; production and operation processes are becoming more visible, controllable and manageable to enable total-element, total-process real-time perception, dynamic analysis, intelligent control and adaptive optimization. • The optimization of oil and gas value chains delivered remarkable results in coordinated management of market forecast, plan optimization, profit estimation, and comprehensive analysis to support the Company's production and operation decision-making. • *The Guidelines for Digital Transformation* was released, covering standards for business scenario design, data, cloud computing resource requirements, production private network, network security, and Internet of Things, as well as setting forth the path and schedule for digital transformation. • Intelligent Oil and Gas Fields: A unified template for digital transformation in eight business areas, e.g., exploration, production and oilfield services, was formulated. Tarim Oilfield completed a pilot project to achieve downsizing and efficiency improvement at production sites, coordinated operation management from various points, as well as knowledge sharing and joint studies; Southwest Oil and Gas Field created three integrated collaborative operation environments and introduced new business management models in areas like well engineering and gas production. • Intelligent Refining & Chemicals: The *Technical Guidelines for Digital Transformation and Intelligent Operation of Refining and Chemicals Business* was formulated. We adopted the Intelligent Refining & Chemicals program that enhanced risk mitigation, accuracy in operation management, and dynamic optimization of production process. The Changqing ethane-to-ethylene project launched an integrated plant using 3D digital twins from design to handover, reducing the energy consumption per unit of output value (RMB 10,000) by 5%. Dushanzi Petrochemical and Guangdong Petrochemical were recognized by the Ministry of Industry and Information Technology as Intelligent Manufacturing Demonstration Factories of 2023. • Intelligent Sales & Marketing: We completed all scenario construction and continued to optimize functions for provincial and regional smart logistics scheduling, membership services, intelligent marketing, and cross-sector cooperation. • Intelligent Natural Gas Sales: We improved capabilities in relation to sales forecast, household safety check, station management etc.
Management Reform	• An integrated office automation platform is under construction. Based on the model of "platform + applications + services", we are carrying out an all-round upgrade on the comprehensive office management platform, to build six major capabilities on multi-terminal business integration, creations of visualization applications, systematic service management, intelligent utilization of data, sharing and collaboration ecosystem, as well as integrated operation and maintenance, so as to enable one-click login and integrated to-do list of 14 different office systems. • A global shared service system supporting financial shared services and HR shared services was generally set up. The financial shared services system supports unified management of accounting, statement preparation and fund settlement within China, and the HR shared services system covers six operations under three categories. • The Integrated ERP program was launched to support the optimization of the Company's resource planning system, integration of operations and finance, and coordination of business management and production, as well as to facilitate the integration of logistics flow, capital flow, information flow and value flow. Such an endeavor aims to improve the Company's ability to standardize business processes, consolidate resources and create more value.
Technology Empowerment	• Based on its four data centers, the Company continued to promote cloud-based applications and improve its cloud resources for computing capabilities and storage capabilities. • A special data governance program was implemented for data lifecycle management, as well as the co-construction, co-governance, and sharing of data. It will fully tap the value of data, improve data governance and propel the construction of data lake systems.

Kunlun Dream Cloud 4.0 was launched

In April 2023, Kunlun Digital Technology Company launched Dream Cloud 4.0, marking a key step in building an Industrial Internet platform for the oil and gas industry.

Since its R&D started in 2016, Dream Cloud has gone through four iterative upgrades and evolved into an 8-tier distributed architecture to support eight business areas including E&P and collaborative research, so as to empower the digital transformation and intelligent operation of the oil and gas industry.

Technological Exchange and Cooperation

Pursuing mutually beneficial and win-win cooperation, the Company works closely with energy companies, associations and research institutes at home and abroad to carry out S&T exchange and R&D cooperation, in a bid to promote technological progress and innovation across the industry.

Domestically

Cooperation on basic research together with Peking University, China University of Petroleum (Beijing), China University of Petroleum (East China), Southwest Petroleum University further deepened to achieve new breakthroughs and new progress in a number of areas, including deep and ultra-deep hydrocarbon generation, accumulation, reservoir formation mechanism and characterization technology, shale oil enrichment theory and evaluation technology, multivariate automatic vertical drilling equipment and technology for deeper structures, key technologies for efficient drilling in weakly consolidated hydrate reservoirs, EOR techniques for tight oil and shale oil, key supporting technology for multi-component thermal fluid process for heavy crude production, as well as catalysts for green production of specialty chemicals and R&D of relevant process etc.

Internationally

As a member of the IEA Enhanced Oil Recovery technical collaboration program (IEA EOR TCP), CNPC showcased a leading position in the field of EOR technology on behalf of Chinese companies. As a senior associate member of International Gas Union (IGU), the Company actively pushes for the development and technological progress of the gas industry. CNPC also works with TotalEnergies on the Albion project, achieving headways in multi-scale, multi-disciplinary and multi-physical field reservoir characterization techniques based on carbonate rock outcrops.

Leveraging its overall strengths in upstream technologies, the Company carries out exchanges and cooperation with academic organizations such as the Society of Petroleum Engineers (SPE) and recommends a number of its industry experts to serve as technical committee members as well as speakers and presenters at major industry and academic conferences.

S&T Awards and Intellectual Properties

The Company continued to strengthen its standardization system. CNPC's proposal on behalf of China to set up a green and low-carbon working group under the ISO Technical Committee on oil and gas industries (ISO/TC67) was approved. The Company's new Energy Standard Committee and Natural Gas Marketing Standard Committee were set up to support the green and low-carbon development and business transformation and upgrading. The Company also worked harder on the revision and research of key international standards. In 2023, CNPC led the efforts to enact 3 new international standards, 2 advanced standards from overseas, and 6 relevant amendments.

Throughout the year,

the Company filed **10,071** patent applications,

including **263** PCT applications,

and was granted **2,933** patents.

The Company received **one silver prize** and **7** excellence prizes from the 24th China Patent Award.

In 2023, the Company made it to the list of Boston Consulting Group's **50 Most Innovative Companies** for the first time.