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Case Study Analysis on the Impact of CNPC Environmental Research Reports Utilizing the 3D-IDPT Model of Information Retrieval Management (IRM)

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Abstract: This case study applies the 3D-IDPT model from Information Resource Management (IRM) to analyze the impact of China National Petroleum Corporation's (CNPC) environmental reports and strategic responses. Focusing on two critical issues—air pollution (notably VOCs) and carbon emissions—the study explores CNPC's environmental governance through the three-dimensional framework of space, time, and construction. It reveals how CNPC's environmental behaviors are shaped by individual and collective actors, instant and synchronic timelines, and the evolving construction of environmental information under technological, value-driven, and societal demand pressures. Drawing from regulatory cases, media reports, and internal sustainability strategies, the research shows that CNPC is transitioning from reactive governance to a more proactive environmental planning model. While facing persistent challenges such as opacity and high governance costs, CNPC demonstrates growing capabilities in green transformation via carbon capture (CCUS), ecological compensation, and clean energy development. This study contributes to the understanding of how state-owned enterprises engage in sustainable transformation through dynamic information practices.

Keywords: CNPC; Environmental Pollution; Carbon Emissions; Information Resource Management; 3D-IDPT Model; Sustainability; Corporate Social Responsibility; Environmental Information Behavior

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1.Introduction

This study investigates China National Petroleum Corporation (CNPC). As a pivotal state-owned enterprise under the jurisdiction of the State-owned Assets Supervision and Administration Commission of the State Council (SASAC), CNPC operates across six core business domains: oil and gas exploration and production, engineering and technical services, petroleum engineering construction, petroleum equipment manufacturing, financial services, and renewable energy development. With investments spanning 32 countries and regions, including China, CNPC ranks among the world's foremost integrated energy producers and suppliers. The corporation has garnered significant global recognition, including 5th place in the Fortune Global 500 [1]; 17th position in the S&P Global Platts Top 250 Energy Companies [2]; and 21st ranking in the Forbes Global 2000 [3]. CNPC's subsidiary, PetroChina, is publicly listed on the Hong Kong Stock Exchange (Stock Code: HK00857) and the Shanghai Stock Exchange (Stock Code: SH601857).

CNPC's corporate vision is to "construct a world-class, sustainable, and integrated international energy enterprise." Its core values prioritize "green development, empowering societal progress through stable energy provision, and fostering public well-being." Strategic guidelines are anchored in four pillars: high-quality development, deepened reform and openness, rule-of-law governance, and comprehensive strict Party discipline. Operational management adheres to the principles of "specialized development, market-oriented mechanisms, lean management, and systematic coordination." The corporation's strategic roadmap emphasizes five critical areas: innovation-driven growth, resource optimization, market expansion, global operations, and low-carbon transition [4].

2.Environmental Issue: Air Pollution -- VOCs

Notwithstanding its notable achievements and developmental aspirations, China National Petroleum Corporation (CNPC), like any global economic entity, faces inherent challenges and limitations. As the world enters the critical decade of the 2020s-2030s, the United Nations' 2030 Agenda for Sustainable Development—with its 17 global goals encompassing poverty eradication, hunger elimination, health equity, quality education, gender equality, clean water, affordable energy, decent work, industrial innovation, inequality reduction, sustainable cities, responsible consumption, climate action, aquatic conservation, terrestrial ecosystem protection, peacebuilding, and global partnerships—has become an international consensus [5]. Within this framework, environmental sustainability has emerged as a paramount concern. Concurrently, accelerated media scrutiny has brought CNPC's environmental challenges into sharp public focus.

Air pollutants derive from diverse sources, including volatile organic compounds (VOCs), sulfur oxides (SOx), nitrogen oxides (NOx), and particulate matter (PM). While SOx, NOx, and PM originate broadly from industrial and residential activities, VOCs are predominantly emitted across the entire lifecycle of petroleum products—spanning production, consumption, recycling, and reuse.

These VOCs react with atmospheric constituents to generate photochemical smog, ozone, and other hazardous substances, causing respiratory irritation, headaches, and nausea. Key VOC components include:

Aromatic hydrocarbons: Benzene, toluene, and xylene, primarily released during fossil fuel processing and industrial applications (e.g., paints, furniture, electronics);

Aliphatic hydrocarbons: Hexane, octane, and decane, emitted during petroleum refining and utilization;

Halogenated hydrocarbons: Chloroform, carbon tetrachloride, and Freon, commonly used in refrigerants, foaming agents, and fire suppressants;

Oxygenated compounds: Ethanol and acetone, byproducts of petrochemical manufacturing;

Other compounds: Ammonia, hydrogen sulfide, and hydrogen cyanide, generated through industrial processes and petroleum combustion.

Research on CNPC's Yulin Oilfield reveals that photochemical pollution—marked by elevated ozone levels—has become a global environmental challenge for industrial zones and urban clusters. Emissions from hydrocarbon exploration exhibit multi-scale impacts on air quality across temporal and spatial dimensions [6]. As energy demand escalates, global hydrocarbon extraction activities continue to expand. China, as a leading hydrocarbon producer, faces intensifying scrutiny over emissions—particularly ozone precursors—from its extraction operations, which threaten long-term air quality.

Pollutant exceedances at CNPC facilities remain problematic: refinery complexes primarily emit aromatic hydrocarbons, followed by halogenated hydrocarbons and sulfides. Xylene, chloroform, and hydrogen sulfide dominate these categories. Although volatile sulfides constitute the smallest proportion, their low odor thresholds and acute irritancy have triggered frequent public complaints [7].

Such environmental issues have precipitated legal consequences. CNPC faced public interest litigation from the China Environmental Protection Foundation—a 5A-rated public charity under the Ministry of Ecology and Environment and Ministry of Civil Affairs—resulting in a ¥9.9292 million penalty and mandated environmental remediation [8]. Subsidiary gas stations have also incurred administrative penalties for non-compliant vapor recovery systems [9].

Across CNPC's operational chain, air pollution arises from three critical phases:

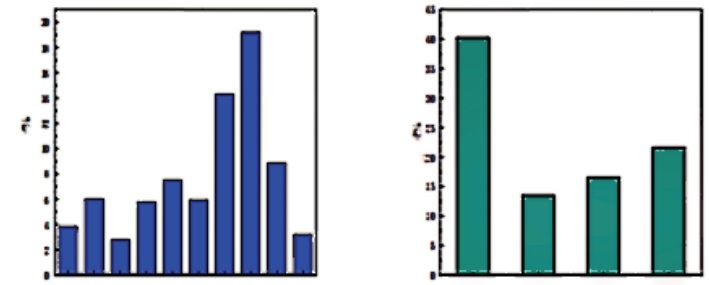
Hydrocarbon Exploration: Methane, hydrogen sulfide, and VOC emissions during extraction jeopardize air quality and

occupational/public health;

Refining Processes: Core facilities emit SOx, NOx, PM, and VOCs during refining and catalytic cracking;

Storage/Transportation: Leakage and volatilization during oil product logistics—including tanker spills, truck seepage, and storage tank emissions—contribute significantly to atmospheric contamination.

Figure1: substance with high pollutant concentration



CH2Cl2/CHCl3/2-C2H4Cl2/3-C3H4Cl2/ C4Cl6/C7H8/C8H10/PX/1,2-C8H10/C8H8

H2S/CS2/C4H6O/ C2H6S2

3.Solutions for Air Pollution

CNPC has implemented systematic measures to address environmental challenges, achieving notable progress. These initiatives integrate environmental considerations into corporate operations, mitigate ecological and climatic impacts, enhance resource efficiency, strengthen pollution prevention, advance energy conservation, promote green-intensive production, and align energy development with ecological preservation.

3.1 Environmental Management System Optimization

CNPC has established a risk-centric environmental management framework, incorporating environmental performance into executive evaluations. The corporation has refined its three-tier prevention and control infrastructure, conducted environmental risk assessments, and prioritized mitigation of six major environmental risks. A dynamic monitoring network tracks pollution sources in real time via online systems for wastewater and emissions, while flare gas recovery technologies reduce venting and combustion, achieving dual pollution-carbon reduction benefits.

3.2 Precision Pollution Control

CNPC enforces stringent source control, upgrades existing treatment facilities, and ensures compliance with emission standards for wastewater and air pollutants. Key emission metrics are integrated into annual executive performance contracts, backed by rigorous accountability mechanisms.

2022 data indicate:

Nitrogen oxide (NOx) emissions in refining decreased by 7.1% year-on-year;

Volatile organic compound (VOCs) emissions fell by 3.5%;

Methane emission intensity declined by 9.76%;

Chemical oxygen demand (COD) dropped by 7.0% [10].

3.3 Atmospheric Governance Breakthroughs

Aligned with China's Blue Sky Protection Campaign, CNPC has intensified seasonal air pollution control in critical regions and launched the CNPC Ozone Pollution Prevention and Control Action Plan (2022–2025). Targeted measures include optimizing processes to reduce benzene derivatives, halogenated hydrocarbons, and sulfide emissions, thereby mitigating odor-related public grievances.

3.4 Decarbonization Roadmap

CNPC's methane reduction strategy involves establishing a monitoring, reporting, and verification (MRV) system, implementing routine flare elimination, and upgrading closed-loop operational processes.

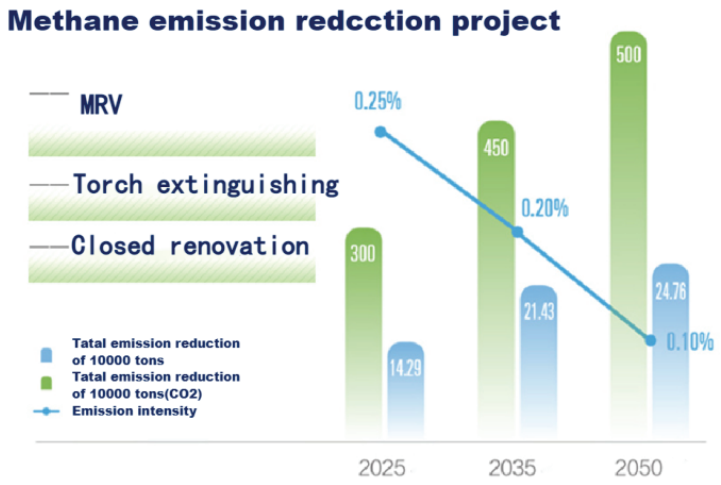
Phase-specific targets include:

Cumulative methane reductions of 3 million tons by 2025;

4.5 million tons by 2035;

Over 5 million tons by 2050 [11].

Figure2: Prediction of methane emission reduction by 2050



This trajectory aligns with global climate imperatives and underscores CNPC's strategic commitment to clean energy transition.

4.Environmental Issue: Carbon Dioxide Emissions

Petroleum, natural gas, and coal—collectively categorized as organic energy sources—differ fundamentally from renewable alternatives such as wind, nuclear, solar, and hydrogen energy. Originating from ancient carbon-based organisms, these resources formed over millions of years through photosynthesis, biochemical reactions, and prolonged geological processes that transformed solar energy and inorganic matter into organic compounds under extreme heat and pressure. Characterized by high energy density and logistical convenience, fossil fuels remain indispensable to modern industry and transportation, serving as primary energy sources and chemical feedstocks. However, their extraction and utilization generate not only air pollution but also a critical environmental challenge: carbon emissions.

4.1 Carbon Governance Challenges in Petrochemical Giants

As China's two largest state-owned petrochemical conglomerates, China National Petroleum Corporation (CNPC) and China Petrochemical Corporation (Sinopec) have long faced public scrutiny over their carbon footprints. Since 2013, People's Daily, China's official newspaper, has consistently highlighted their emission governance deficiencies. The 2012 Key Pollutant Reduction Assessment Report, jointly issued by the Ministry of Ecology and Environment, National Bureau of Statistics, and National Development and Reform Commission, revealed that both corporations failed to meet emission reduction targets due to delayed mitigation projects, obsolete technologies, operational inefficiencies, and recurrent environmental violations at subsidiary facilities. People's Daily critiqued this starkly: "CNPC and Sinopec must not remain 'dwarfs in emission reduction'" [12].

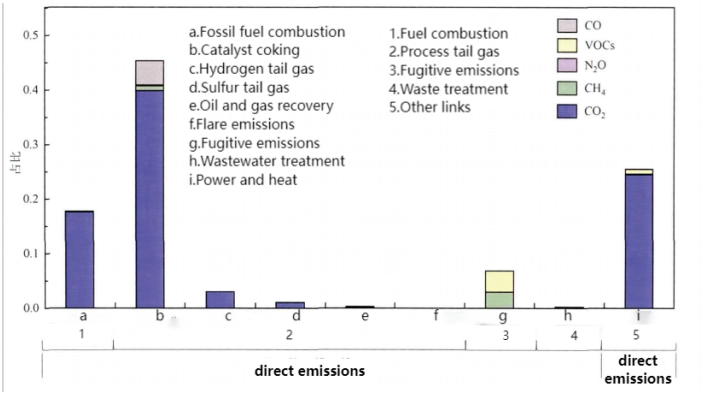
4.2 Deficiencies in Low-Carbon Accountability Disclosure

Scholarly research identifies systemic weaknesses in CNPC's low-carbon responsibility disclosure practices. Analysis of its annual reports (2007–2011) demonstrates persistent structural deficiencies, including poor information accessibility and inadequate responsiveness to stakeholder concerns [13]. As China's largest petroleum enterprise, CNPC's operational scale entails massive resource consumption—predominantly high-carbon energy. Under China's Environmental Protection Tax Law, the environmental cost of CO_2 emissions imposes significant financial burdens [14], exacerbating corporate sustainability pressures.

4.3 Carbon Emission Profiles in the Petrochemical Sector

Sector-wide studies reveal that CO_2 accounts for 86.24% of greenhouse gas emissions in petrochemical operations, primarily from direct emission processes such as catalyst calcination, electricity/heat consumption, and fossil fuel combustion [15]. This statistic underscores the structural conflict between the industry's fossil-dependent production model and decarbonization imperatives.

Figure3: Proportion of carbon emissions by category



5.Solutions for Carbon Dioxide Emissions

Acknowledging the inherent carbon constraints of fossil-based organic energy, China National Petroleum Corporation (CNPC), as a traditional petrochemical enterprise, has proactively initiated transformative measures to address emissions through process optimization, renewable energy transition, and carbon sink initiatives.

5.1 Medium to long-term planning goals

To this end, CNPC formulated a series of "medium-to-long-term planning goals" around 2020.

2025 Targets:

Launch the "Planting Trees for Carbon Neutrality" campaign to raise ≥¥200 million for corporate-affiliated voluntary tree-planting, large-scale carbon sink forests, and carbon-neutral forest projects. Establish 4000 mu (≈267 hectares) of carbon sink forests, positioning CNPC as a state-owned enterprise exemplar in carbon sequestration forestry.

2030 Targets:

Elevate the share of clean energy (e.g., natural gas) and renewables in domestic primary energy production. Ensure natural gas accounts for 55% of domestic primary energy output while controlling greenhouse gas (GHG) emissions to achieve an early peak.

2050 Targets:

Further increase the proportion of natural gas, renewables, and new energy sources in domestic primary energy production. Attain international leadership in low-carbon development, supporting China's climate commitments [16][17][18][19].

5.2 Implementation Pathways

The company actively explores and improves the technological and benefit paths of Carbon Capture, Utilization, and Storage (CCUS), continuously increasing the research and development and promotion efforts for key technologies across the entire CCUS industry chain. This has effectively enhanced the level of carbon capture and utilization, promoting the construction of CCUS demonstration projects and their commercial applications. A series of achievements have been made: the formation of technical equipment for efficient capture, transportation, injection, and storage of carbon dioxide at all stages; the layout of next-generation organic amine adsorbents, solid adsorbents, and other capture technologies; the development of long-distance, large-diameter carbon dioxide transportation, storage, and data simulation, as well as integrated monitoring from space to ground, achieving the capture, utilization, and storage of low-concentration carbon dioxide; participation in global research collaborations on Direct Air Carbon Capture and Storage (DACCS), Bioenergy with Carbon Capture and Storage (BECCS), and marine carbon sinks; and the promotion of establishing and improving the CCUS standard and regulatory system. After years of development, in 2022, the annual injection of carbon dioxide exceeded 1.1 million tons.

5.3 New Energy Business Expansion

The company regards new energy business as a new driving force for promoting green and low-carbon transformation and development, and has established a New Energy and New Materials Development Leading Group headed by the chairman. It strengthens the strategic planning and management system construction of new energy business, and accelerates the expansion of new energy businesses such as geothermal, wind and solar power generation, hydrogen energy, and charging (exchange) stations. While accelerating the construction and operation of the Shanghai New Materials Research Institute and

the Shenzhen New Energy Research Institute, the Japan Intellectual Property Research Institute was established in 2022 to further provide technical support for the development of new energy, new materials, and new businesses. In 2022, China's new energy development and utilization capacity reached 8 million tons of standard coal per year.

5.4 Progress in Carbon Sink Forest Construction

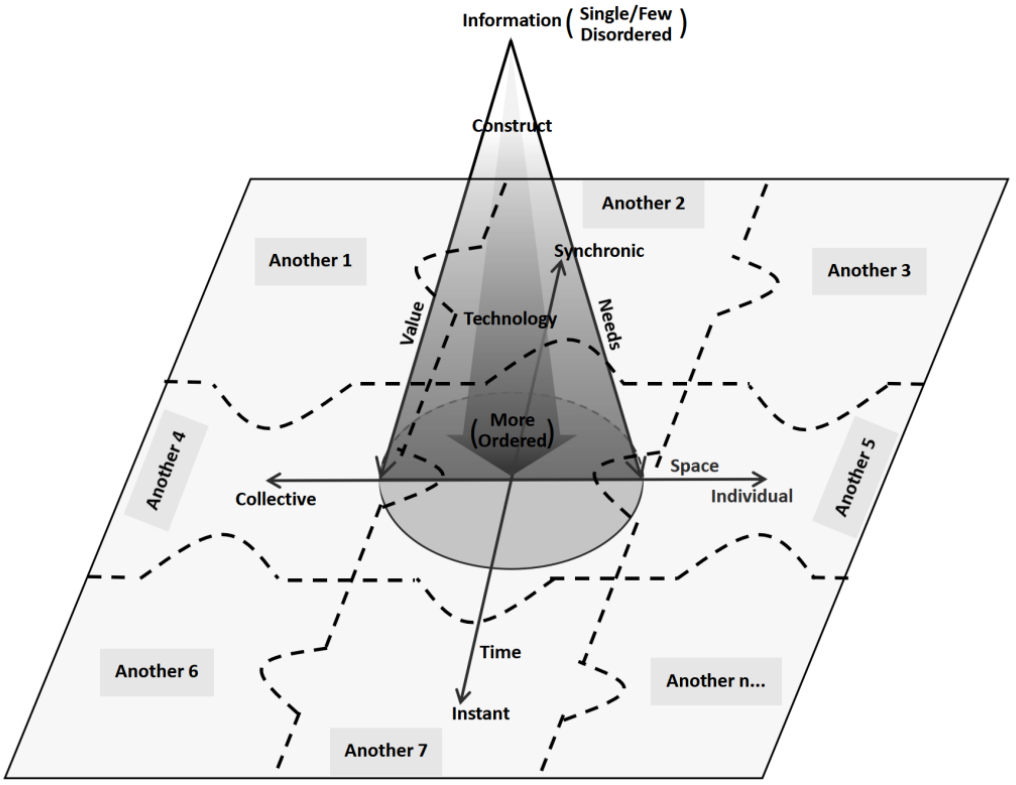
In 2022, a total of 14.925 million person-times from the entire group participated in voluntary tree planting in various forms, planting 42.25 million trees (including equivalents), and adding 13.7 million square meters of green space. During the year, three group documents were compiled and issued around the direction of "Greening Environmental Protection and Carbon Sink Forest Construction," actively promoting the layout of carbon sink forests and carbon-neutral forests. By the end of 2022, the cumulative green space area in four regions including Daqing Oilfield, Changqing Oilfield, Xinjiang Oilfield, and Yumen Oilfield reached 314 million square meters, with cumulative donations exceeding 17.889 million yuan [10].

6.Utilizing the 3D-IDPT model of IRM for behavior analysis of CNPC

6.1 The 3D-IDPT model of IRM

The Three-Dimensional Integrated Discipline Puzzle Theory (3D-IDPT) is a theoretical model extended from the Information Resource Four-Way Diagram in information resource construction [20], emphasizing the following points:

Figure4: 3D-IDPT (Integrate Discipline Puzzle Theory) model



Information, positioned as the origin, is divided into four quadrants by two axes: the time axis (Instant & Synchronic) and the space axis (Individual & Collective). Additionally, the process of information construction forms a third dimension—represented by the vertical axis—which converts this model into a three-dimensional spatial concept.

The horizontal axis (space) represents "Individual & Collective," highlighting the diversity of information users and the demand for co-construction and sharing.

The vertical axis (time) signifies "Instant & Synchronic," emphasizing the timeliness, life-cycle nature, and dynamic processes in information resource construction and usage.

The Z-axis (construction process) represents the progression of information construction as a resource, indicating a deepening process of recognition, processing, and management influenced by advancements in technology and guided by value and needs.

Through this integrated intersection of space, time, and construction, information resource construction is clearly divided into

multiple parts:

1.Individual-Instant Quadrant: Focused on immediate information needs of an individual at a particular moment.

2.Individual-Synchronic Quadrant: Examining how individuals sustainably utilize and re-utilize information over different periods.

3.Collective-Instant Quadrant: Concentrating on the immediate information needs of multiple user groups at a specific point in time.·

4.Collective-Synchronic Quadrant: Focusing on long-term, stable demand, and continuous sharing of information resources among multiple user groups.·

5.The process of information construction acknowledges potential difficulties arising from various conditions but emphasizes that, through continuous matching of information's value with needs, construction will eventually become more comprehensive, deepening the understanding and application of information.

6.2 Using 3D-IDPT for object segmentation of CNPC environmental issues

Figure5: Axis Object Subject Interpretation Table

Axis	Object	Subject	Interpretation
Horizontal: Space	Individual	CNPC	A market-operating entity
	Collective	Society and Government	Public concerns prompting governmental attention
Vertical: Time	Instant	Moment of event response	Sudden incidents, routine operational events
	Synchronic	Influenced by the past	Response, inheritance, and modification based on historical context
		Impacting the future	Long-term observation and implications
Z-axis: Construction	Value	Economic value	Ongoing development requiring petrochemical production and reinvestment
	Needs	Social benefits	Sustainable Development Goals (United Nations, 2015)
	Technology	Information circulation and environmental governance technology	Information via social media, news media, and government advisory channels; advancements in environmental management technology

6.3 Behavior Analysis of CNPC Environmental Issues Based on 3D-IDPT

While CNPC faces two main environmental issues—air pollution and excessive carbon dioxide emissions—analyzing specific examples reveals common behavioral logic,

As a market-operating entity, CNPC:

1.Individual-Instant Quadrant:Historically prioritized immediate economic benefits [12], neglecting other types of crucial information.

2.Individual-Synchronic Quadrant:Each corporate decision reflects influences from past behaviors and affects future actions. Prolonged attention solely to economic gains led to the neglect of social-environmental responsibilities, making CNPC one of the "emission reduction dwarfs"[12].

3.Collective-Synchronic Quadrant:Residents living near CNPC's industrial zones have long suffered environmental pollution, prompting local governments to criticize and penalize CNPC [8]. Additionally, to achieve global environmental governance, the Chinese government has set a nationwide 3060 carbon emission goal [21].

4.Collective-Instant Quadrant:The environmental issues caused by sudden production leaks have attracted significant attention from social groups. The Dalian Municipal Government has established an investigation team to address sudden environmental issues and to hold those responsible accountable [22].

5.Construction Axis (Z-axis):Over the past decade, from traditional print media to short-video platforms, the rapid flow of information has continuously drawn public attention to social issues. For over 20 years, governmental governance has improved through the "12345 Government Service Hotline" platform [23]. Technological advancements and deepening research have made environmental governance more scientifically effective [6].

7.Summary and Prospect

China National Petroleum Corporation (CNPC) has rigorously implemented ecological civilization principles, prioritizing pollution prevention and control while aligning environmental protection with operational efficiency. Guided by its carbon peaking and carbon neutrality objectives, the corporation has adopted a three-phase strategy—clean energy substitution, strategic transition, and green transformation—to advance its "Blue Sky, Clear Water, and Pure Land" initiatives.

7.1 Renewable Energy Transition Framework

CNPC has established six flagship renewable energy bases to drive low-carbon innovation:

Yumen Oilfield Clean Transition Demonstration Base

Daqing Oilfield Green Low-Carbon Sustainable Development Base

Jilin Oilfield Wind-Solar Power Integration Project

Beijing-Tianjin-Hebei Geothermal Heating Demonstration Zone

Qinghai Oilfield Clean Electricity Hub

Xinjiang Green Energy Industrialization Base

Supported by five core engineering initiatives, these bases accelerate the deployment of renewable energy projects, reinforcing CNPC's green industrial ecosystem.

7.2 Traditional Hydrocarbon Operations

CNPC maintains technological leadership in oil and gas exploration and processing, integrating cutting-edge extraction technologies with stringent environmental and safety protocols. The corporation continuously enhances operational efficiency and emission control through advanced management systems and international best practices.

7.3 Diversified Business Expansion

Beyond energy production, CNPC has diversified into:

Chemicals Manufacturing: Producing high-quality petrochemical products via state-of-the-art production lines;

Urban Gas Supply: Delivering secure and reliable gas services to residential and commercial users;

Global Energy Collaboration: Expanding international partnerships to foster energy security and technological exchange.

7.4 Conclusion

Through its dual focus on traditional energy modernization and renewable innovation, coupled with cross-sectoral diversification, CNPC exemplifies a holistic approach to sustainable development. The corporation remains committed to high-quality growth, positioning itself as a global leader in the energy transition while contributing to the realization of an eco-centric societal vision.

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no

Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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