

POLICY PRACTICES AND IMPLEMENTATION PATHWAYS OF UNCONVENTIONAL WATER SOURCE UTILIZATION IN CHINA — CONTRIBUTIONS TO SUSTAINABLE DEVELOPMENT GOAL 6

PRATIQUES POLITIQUES ET VOIES DE MISE EN ŒUVRE DE L'UTILISATION DES RESSOURCES EN EAU NON CONVENTIONNELLES EN CHINE — CONTRIBUTIONS AU DEVELOPPEMENT DURABLE OBJECTIF 6

Zheru Wu¹

ABSTRACT

This paper systematically reviews China's policy practices and achievements in the utilization of unconventional water resources during the 14th Five-Year Plan period, analyzes the main existing challenges, and proposes future-oriented engineering pathways and policy recommendations, aiming to provide Chinese experience and reference for the achievement of United Nations Sustainable Development Goal 6 (SDG 6).

Keywords : Policy practices; Unconventional water resources; Sustainable development goal.

RÉSUMÉ

Cet article passe systématiquement en revue les pratiques politiques et les réalisations de la Chine en matière d'utilisation des ressources en eau non conventionnelles au cours de la période du 14^e plan quinquennal, analyse les principaux défis actuels et propose des pistes d'ingénierie tournées vers l'avenir ainsi que des recommandations politiques, dans le but de partager l'expérience chinoise et de fournir des références pour la réalisation de l'Objectif de développement durable n° 6 (ODD 6) des Nations unies.

Mots-clés : Pratiques politiques; Ressources en eau non conventionnelles; Objectif de développement durable.

1. INTRODUCTION

The growing imbalance between global water supply and demand has made the development and utilization of unconventional water resources an important strategic choice for alleviating water stress and ensuring water security. SDG 6 explicitly aims to 'ensure availability and sustainable management of water and sanitation for all,' in which the use of unconventional water resources is recognized as one of the key pathways toward this goal. Against this backdrop, China has actively pursued the large-scale utilization of unconventional water resources, gradually establishing a policy system and practical approach with distinctive national characteristics. During the 14th Five-Year Plan period, China has made substantial progress in the field of unconventional water resource utilization.

¹ International Economic and Technical Cooperation and Exchange Center, Ministry of Water Resources N0.38, Yuyuantan South Street, Haidian District, Beijing, China Email : wuduizi@163.com

2. ACHIEVEMENTS DURING CHINA'S 14TH FIVE-YEAR PLAN PERIOD

2.1 Policy System and Target Management

The national government, through joint departmental initiatives, has issued guidelines on strengthening the allocation and utilization of unconventional water, guidelines on enhancing the protection and utilization of pit water, and pilot implementation plans for reclaimed water allocation in typical regions. Unconventional water has been incorporated into the dual-control target management of total water use and water intensity.

2.2 Project Construction and Pilot Promotion

A three-year rolling project reserve mechanism for unconventional water was established, with RMB 1 billion of central water development funds allocated to support 34 key projects. Pilot projects for reclaimed water allocation were completed in 76 typical cities. In collaboration with relevant departments, a three-year action plan for reclaimed water utilization in 50 key cities was implemented, alongside 38 regional pilot projects for reclaimed water recycling and industrial wastewater recycling pilots.

2.3 Technical Standards and Utilization Achievements

The technical standard system for unconventional water has been strengthened, with separate statistics by water source and end-use. The annual utilization volume is estimated to exceed 26 billion m³. The reclaimed water utilization rate in water-deficient prefecture-level cities exceeds 25%, and the pit water utilization rate in the Yellow River Basin exceeds 68%. Inner Mongolia and Shaanxi have accelerated comprehensive utilization of pit water, Chongqing and Guizhou have achieved positive results in reclaimed water allocation pilots, and Xinjiang has promoted technological innovation and application of high-salinity pit water for afforestation.

2. CURRENT STATUS AND EXISTING PROBLEMS OF UNCONVENTIONAL WATER UTILIZATION IN CHINA

3.1 Utilization Status

Through these efforts, the utilization capacity of unconventional water such as reclaimed water has been rapidly enhanced, and the scale of utilization has expanded quickly. In 2024, total unconventional water utilization reached 25.16 billion m³, an increase of 191% compared to 2020, accounting for 4.2% of total water supply. Reclaimed water accounted for 21.22 billion m³ (84.3%), harvested rainwater 1.30 billion m³ (5.2%), desalinated seawater 0.40 billion m³ (1.6%), pit water 0.70 billion m³ (2.8%), and saline water 1.54 billion m³ (6.1%). Figure 1 shows the percentage distribution of different types of unconventional water utilization in China in 2024.

By provincial administrative division, Guangdong, Shandong, Hebei, Jiangsu, Henan, and Beijing each exceeded 1 billion m³ of reclaimed water utilization annually. The reclaimed water utilization rates in Beijing, Tianjin, and Inner Mongolia reached 55%, 44%, and 51%, respectively. In Beijing, Tianjin, Inner Mongolia, Shaanxi, and Ningxia, new industrial water demand is mainly met by reclaimed water, making unconventional water a stable and reliable strategic secondary water source for many cities. By end-use sector, in 2024, unconventional water was used for agriculture (3.16 billion m³, 12.5%), industry (5.27 billion m³, 21.0%), domestic purposes (0.46 billion m³, 1.8%), and ecological use (16.27 billion m³, 64.7%) (Figure 2).

3.2 Typical Case Studies of reclaimed Water Allocation

(1) Zhengzhou: reclaimed Water as a “Super Air Conditioner”: On Longhu Financial Island in Zhengdong New District, Zhengzhou City, Henan Province, numerous office buildings and commercial facilities require cooling in summer and heating in winter, making them major energy consumers.

However, no traditional cooling towers or boilers are visible. The solution lies in three quietly operating energy stations that use reclaimed water as a “super air conditioner,” providing heating and cooling to 2.79 million m² of building space on the island. Investigation by Zhongyuan Environmental Protection Co., Ltd. and Zhengzhou Urban Management Bureau revealed that Zhengzhou produces large quantities of reclaimed water. For example, the Matougang Wastewater Treatment Plant treats domestic sewage from 1.8 million people across 209 km². After physical sedimentation, microbial decomposition, and activated carbon adsorption, the effluent reaches Class III surface water quality standards. This reclaimed water has a stable temperature – approximately 15°C in winter and 25°C in summer – with continuous and reliable flow.

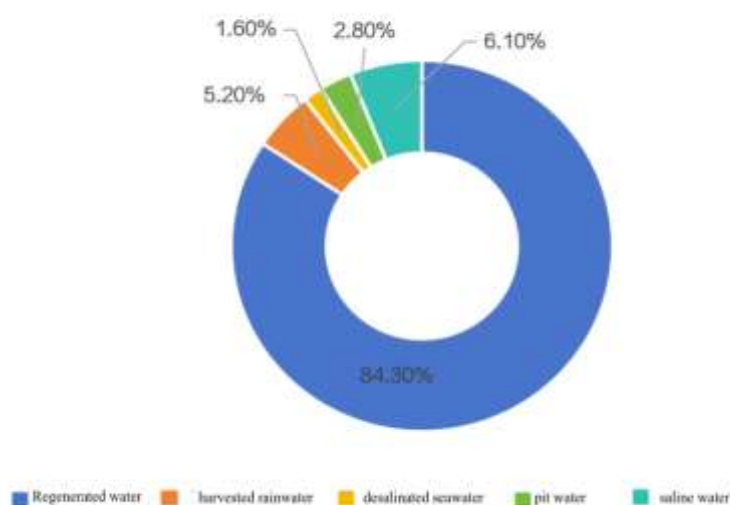


Figure 1. Percentage distribution of different types of unconventional water utilization

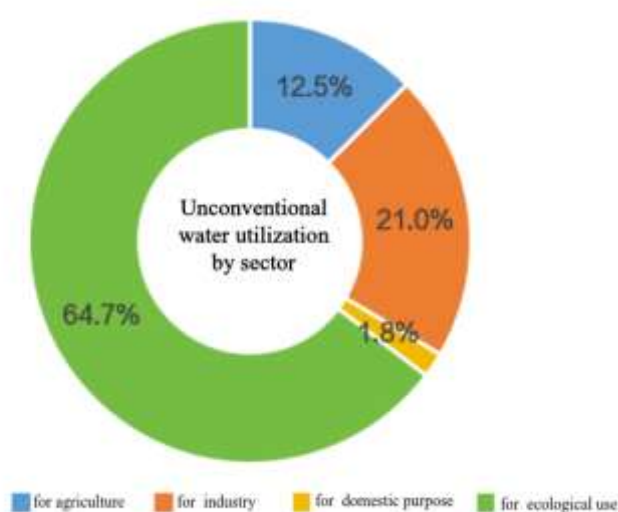


Figure 2. Percentage distribution of unconventional water utilization by sector

Using water-source heat pump technology, heat is extracted from reclaimed water in winter and transferred indoors, while indoor heat is transferred to reclaimed water and carried away in summer. The process consumes only a small amount of electricity, with no combustion or exhaust emissions. Since 2019, Zhengzhou has planned and constructed three energy stations in the underground space of Longhu Financial Island, with a total heating capacity of over 200,000 kW and cooling capacity of nearly 58,000 refrigeration tons. Connected to the Matougang Treatment Plant via a ring pipeline network, reclaimed water is continuously delivered to the island.

Data from Operator Jin Guofeng at Energy Station No. 1 shows that compared with traditional distributed energy supply, this model saves 70% of air-conditioning power capacity and 80% of plant room area. For island users, summer electricity bills are reduced by about 30%. The system's energy efficiency is more than 30% higher than conventional air conditioners, significantly reducing carbon emissions annually. Such green energy projects are no longer limited to Financial Island – across key areas such as metro stations, Zhengzhou has developed 3.75 million m² of reclaimed water-based heating and cooling, saving 32,000 tonnes of standard coal and reducing CO₂ emissions by 81,000 tonnes annually. After heat exchange, the water continues to flow into the rivers and canals as a stable source of ecological water replenishment. Zhengzhou has thus pioneered a cascade utilization model of "first energy extraction, then use, finally landscape." In 2025, reclaimed water supply stations in Zhengzhou's central urban area supplied over 60 million tonnes of reclaimed water, achieving a "dual cycle" of water resources between production/living and natural ecosystems.

(2) Karamay: reclaimed Water Driving Integrated Industrial and Ecological Development: Based on its petroleum-dominated industrial characteristics, has systematically promoted reclaimed water utilization with regional leading industry water demand as the core driver. By integrating water sources, users, and topographic features, the natural gradient of elevation is utilized to significantly save energy and construction costs.

During water resources assessment, high water-consumption projects are strictly controlled, and thermal power plants are prioritized to use reclaimed water. An inter-plant reclaimed water distribution network has been established to achieve mutual complementarity between plants, delivering treated reclaimed water precisely for oilfield injection, fracturing water supply, and other processes, creating a model of "substituting reclaimed water for fresh water." At the same time, reclaimed water utilization is deeply integrated with urban ecological construction to achieve "storage in winter, use in summer." In the initial phase, water was provided free of charge as a trial; after market maturity, a quality-based negotiated pricing mechanism was adopted.

Through optimized layout, Karamay's reclaimed water utilization reached 41.44 million m³ in 2025, with a utilization rate of 54%. The industrial sector achieved annual reclaimed water use of over 1.43 million m³, providing an innovative pathway for the transformation of industrial water use in energy-based cities. Large-scale storage of reclaimed water in the urban area has added 9.9 km² of ecological landscape, achieving multiple benefits in production, environmental protection, and water conservation.

3.3 Existing Problems

Although China has achieved remarkable progress in reclaimed water utilization – surpassing the scale of the United States, the European Union, Japan, and other developed economies – significant social demand and development potential remain. Current main constraints include:

(1) Insufficient investment in infrastructure. The number of high-standard unconventional water plants nationwide is limited. Some urban wastewater treatment plants were not planned with supporting unconventional water plants, resulting in 'inability to produce' unconventional water, and a shortage of storage facilities. In most cities, the construction of reclaimed water transmission and distribution pipelines lags behind, with few water intake points, so users 'cannot access' the water. According to relevant departmental statistics, in 2024, there were 15,259 wastewater treatment plants under emission source statistical survey, with 1.27 million km of drainage pipelines, but only 2,431 reclaimed water

plants and only 27,000 km of municipal reclaimed water pipelines. National investment support for unconventional water is mainly pilot-based and has not been fully rolled out.

(2) Urgent need for breakthroughs in key technologies and equipment. Advanced treatment processes for reclaimed water include membrane separation, coagulation-sedimentation, denitrification filters, constructed wetlands, and advanced oxidation. Among these, membrane separation is the mainstream process, but it is constrained by high pre-treatment requirements, reliance on imported reverse osmosis membranes, and membrane fouling, resulting in treatment costs (including depreciation) typically as high as RMB 1.5–4.0 per m³. To promote large-scale use of reclaimed water, there are still many deficiencies in technological innovation, safety utilization standards, and cost reduction/efficiency improvement.

(3) Efficiency gap in allocation and utilization. On one hand, unconventional water utilization is insufficient; in some regions and for some users, reclaimed water is available but not used, causing resource waste. On the other hand, the allocation structure of reclaimed water is suboptimal. In China, reclaimed water is mainly allocated to ecological sectors such as river and lake replenishment (about 75%), while the share used in sectors with higher economic benefits – industry, agriculture, and domestic use – is relatively small. Although developed countries utilize smaller absolute volumes of unconventional water, their economic benefits are greater. For example, Singapore uses about 95% of its reclaimed water for industrial production, Japan about 40% for urban domestic use, and California about 46% for agricultural irrigation.

(4) Inadequate legal management. As a strategic secondary water source alongside surface water and groundwater and unconventional water currently suffers from low legal management standards, incomplete institutional systems, and overlapping departmental responsibilities. The existing legal framework has significant limitations in promoting unconventional water use; relevant provisions are mostly principle-based, lacking mandatory clauses and effective incentives or constraints. The lag in legislation has created a disconnect with the rapidly developing practice. There is an urgent need to formulate a special regulation on the development and utilization of unconventional water and to improve the legal system for unconventional water management.

(5) Inadequate inter-departmental coordination mechanism. The production, transmission, allocation, and utilization of unconventional water involve water resource allocation, water supply and drainage, ecological environment, land and spatial planning and different sectors. However, in practice, policies, plans, standards, and supervision/management are fragmented across different departments, lacking coordination, and have not yet formed a coherent force for overall progress.

4. MEASURES AND ENGINEERING PATHWAYS FOR UNCONVENTIONAL WATER DEVELOPMENT AND UTILIZATION

4.1 Main Measures

(1) Establish a new pattern of unconventional water allocation and utilization. With the strategic positioning of unconventional water as a “strategic secondary water source,” actively allocate reclaimed water, harvested rainwater, seawater and desalinated seawater, pit water, and saline water. Promote large-scale utilization in agriculture, industry, domestic use, and ecological sectors to build a diversified water supply pattern. Implement special actions for unconventional water allocation in key regions: build a reclaimed water allocation system in the Beijing-Tianjin-Hebei region; implement seawater desalination substitution for industrial parks in coastal areas; fully tap the potential of pit water utilization in the Yellow River Basin; and advance wastewater regeneration and reuse in the Hanjiang River Basin. In severely water-scarce areas and areas with over-extraction of water resources, treat reclaimed water as a strategic water source and carry out systematic planning, construction, and high-level allocation. In the Shanxi-Shaanxi-Inner Mongolia-Xinjiang region, aligned with the westward shift of coal mining, promote large-scale collection, treatment, and distribution pipeline networks for pit water. In areas with annual precipitation of 400 mm or more, scientifically harvest rainwater and increase its use for municipal miscellaneous purposes, forest and grassland greening, and agricultural irrigation. In the arid areas of

Northwest China, North China, and coastal areas, steadily promote mixed irrigation with fresh and saline water, rotational irrigation, saline water aquaculture, and comprehensive utilization of saline water resources. In coastal and island areas, prioritize unconventional water for industrial use and, where suitable, use desalinated seawater as new municipal supply and emergency backup water sources.

(2) Improve infrastructure for unconventional water development and utilization. Focus on water-scarce areas, water-environment-sensitive areas, water-ecologically-fragile areas, and island areas. Prioritize reclaimed water development and utilization, and promote the development and utilization of pit water, desalinated seawater, harvested rainwater, and saline water according to local conditions. Construct engineering facilities from source to user for production, transmission, storage, and withdrawal, including source and water quality improvement works, transmission pipelines (channels), storage works, water intake facilities, metering and monitoring facilities, and smart systems. Accelerate the enhancement of unconventional water utilization capacity to support alleviation of water supply-demand imbalance and improvement of water security. Strengthen pre-feasibility studies for unconventional water development projects, align project planning and reserve with national, provincial, and municipal water-related plans and implementation schemes, and optimize the spatial layout of unconventional water utilization. Explore a diversified, market-oriented project financing mechanism to form an investment and financing model guided by the government, driven by the market, and participated in by society. Innovate facility operation models, and promote the introduction of professional institutions through contract water-saving management or similar mechanisms to undertake daily operation and management tasks.

(3) Improve policies and institutional frameworks for unconventional water management. Strengthen the legal and planning basis. Advance dedicated legislation for unconventional water. Coordinate and align the unconventional water plan with regional water network construction plans. Strengthen inter-departmental coordination to build a clear, divided-responsibility working mechanism with strong overall coordination. Considering the distribution characteristics, utilization conditions, and market demand for unconventional water, incorporate unconventional water into unified water resource allocation, and implement minimum utilization target management. Improve incentive policies for large-scale use of unconventional water and optimize market-based allocation mechanisms. Focus on management, engineering, water quality, and safety aspects for various water sources; improve the technical standard system for unconventional water; promote mandatory labelling management to effectively support standardized management and safe utilization. Accelerate the construction of a metering and monitoring system for unconventional water, implement online monitoring of reclaimed water, and publish annual unconventional water utilization statistics by source and by end-use.

4.2 Engineering Pathways Focusing on Five Major Directions

(1) reclaimed water utilization projects. Aiming for systematic completeness, rational structure, safety and reliability, and green intelligence, promote the construction of an internationally exemplary Beijing-Tianjin-Hebei reclaimed water allocation system, targeting an additional reclaimed water utilization of over 1 billion m³, a regional reclaimed water utilization rate close to 70%, and overall effluent quality of reclaimed water plants reaching quasi-Class IV surface water standards. In severely water-scarce areas and areas with over-extraction of water resources, encourage and support key projects to raise the reclaimed water utilization rate to over 30%.

(2) Seawater desalination projects. Strengthen inter-departmental coordination, stimulate market vitality, and promote the construction of a number of key seawater desalination and comprehensive utilization projects in coastal water-deficient areas. Focus on typical coastal cities. Prioritize new or expanded industrial parks, while also considering existing industrial parks in over-extraction areas, to promote seawater desalination substitution actions.

(3) Pit water utilization projects. In energy bases of the Yellow River Basin such as Longdong, Ningdong, Western Inner Mongolia, Northern Shaanxi, and Western Shanxi, increase large-scale comprehensive utilization of pit water. In areas with large and stable pit water inflow, build centralized

treatment plants and distribution pipelines, promote graded treatment and quality-based use, and further raise the pit water utilization rate to over 70%.

(4) Saline water utilization projects. In arid areas of Northwest and North China, as well as coastal areas with abundant saline water resources, encourage the construction of saline water irrigation and aquaculture facilities, promote salt-tolerant crop varieties, and advance the research, demonstration, and application of integrated saline water utilization technologies.

(5) Rainwater harvesting projects. In conjunction with Phase VI of the “Three Norths” Shelterbelt Program, promote the use of harvested rainwater for forest and grassland greening in key areas such as the Loess Plateau. Promote rain-fed agricultural irrigation where feasible, and encourage the construction of ditches, ponds, and reservoirs for rainwater harvesting and utilization in the hilly areas of southern China.

4. CONCLUSIONS AND IMPLICATIONS

China’s practice demonstrates that effective utilization of unconventional water is not simply a matter of ‘relaxing’ control over water resources, but rather achieving more refined and sustainable management through systematic substitution. China has developed a comprehensive governance model of ‘strategic guidance – target management – category-based measures – engineering support – market incentives.’ This not only provides a clear pathway for China’s own implementation of SDG 6, but also offers a replicable systemic approach that can contribute to global sustainable water management.

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