

From Coal to Roses: Innovative explorations for sustainable development in the abandoned mining area of Zichuan District, Shandong Province

Abstract: Zichuan District is a resource-depleted industrial city with a century-old coal mining history. Taking the Dakuishan mine as a demonstration site, Zichuan District is pioneering an integrated “energy + industry” transition model that leverages decommissioned shafts and abandoned mines to develop a multifaceted complex comprising **agrivoltaic power stations, distributed pumped storage power stations in abandoned shafts, mine-water waste heat recovery systems, and a high-end rose industry chain**. Upon full completion, the project is expected to cut CO₂ emissions by 9,400 tons annually, restore 600 mu (approximately 40 hectares) of degraded mining land, generate over CNY 60 million in annual profit, and create 200 jobs. The initiative will promote integrated development of industries and form a virtuous cycle of emissions reduction, resource utilization, and efficiency improvement. Amid the global trend of moving away from fossil fuels, the Zichuan model can serve as a replicable model for the green transition of other abandoned mining areas.

Keywords: Abandoned mines and decommissioned shafts; renewable energy; rose industry value chain; ecological restoration; job creation

I. Background

Zichuan District of Zibo City, Shandong Province, is among the third batch of officially designated resource-depleted cities in China. The district is burdened with 195 decommissioned coal shafts and 64 abandoned mines, covering more than 34,000 mu (approximately 2,267 hectares) of industrial and mining area and unused land. These sites are largely unsuitable for direct use and entail high ecological restoration costs. Long-term heavy industrial development has led to extensive environmental degradation. Mineral extraction has destroyed vegetation across 9,200 hectares, and the average groundwater level has dropped from 30 metres to below 200 metres. Additionally, widespread water rebound from abandoned mines has caused cross-layer contamination of underground high-quality aquifers. Centring on the coal-based economy, the district has fostered an energy-intensive and high-polluting industrial structure dominated by building materials and chemicals, with energy output efficiency reaching only about 70% of the provincial average. This highlights the urgent need for a green transition.



Figure 1 Overall project rendering

Credit: Ecology Institute of Shandong Academy of Sciences.

II. Key Measures

(1) Building a Diversified and Synergistic Energy Network Using Mining Resources

The project leverages abandoned mines and decommissioned shafts to develop **agrivoltaic power stations, distributed pumped storage power stations in mine shafts, mine-water waste heat pump systems,** and associated infrastructure. Phase I has been completed and is now operational. It includes the installation of a 2.6 MW photovoltaic system across more than 60 mu (approximately 4 hectares) of abandoned mining slopes, making efficient use of land resources to supply clean electricity to the park. A 100 kW experimental pumped storage station has been constructed, utilizing

the 165-metre vertical drop of a disused shaft channel, marking China's first pumped storage facility built in an abandoned mine. In addition, a 1.5 MW heat pump heating and cooling system has been installed to harness the stable 15°C temperature of mine water for cooling greenhouse facilities in summer and heating them in winter. Phase II is currently under construction and, upon completion, it will provide an 11.3 MW solar power station, a 12 MW × 4-hour pumped storage power station, and 12 MW of integrated heating and cooling capacity.



Figure 2 On-site view of the agrivoltaic power station in the park
Credit: Ecology Institute of Shandong Academy of Sciences.



Figure 3 On-site view of the distributed pumped storage power station in an abandoned mine shaft

Credit: Ecology Institute of Shandong Academy of Sciences.

(2) Driving Regional Economic Development via the Rose Industry Chain

Capitalizing on the park's abundant land, clean electricity, waste heat, and mine water resources, the project has introduced a high-end fresh-cut rose industry through greenhouse cultivation. By supplying greenhouses with clean electricity generated on site, production costs can be reduced by 50%. Phase I, which has been completed, involved the construction of 13,000 m² of flower greenhouses. Phase II will expand this to 113,000 m² of greenhouse space and 200 mu (approximately 13.33 hectares) of outdoor flower cultivation, with an expected annual output of 36 million fresh-cut roses. Upon full completion, the project is expected to generate over CNY 60 million (about USD 8.35 million) in annual profit. With the rose industry as its foundation, the project is building a new economic ecosystem that integrates the secondary sector represented by floral deep processing with the tertiary sector, including e-commerce, logistics, livestreaming, and cultural tourism.

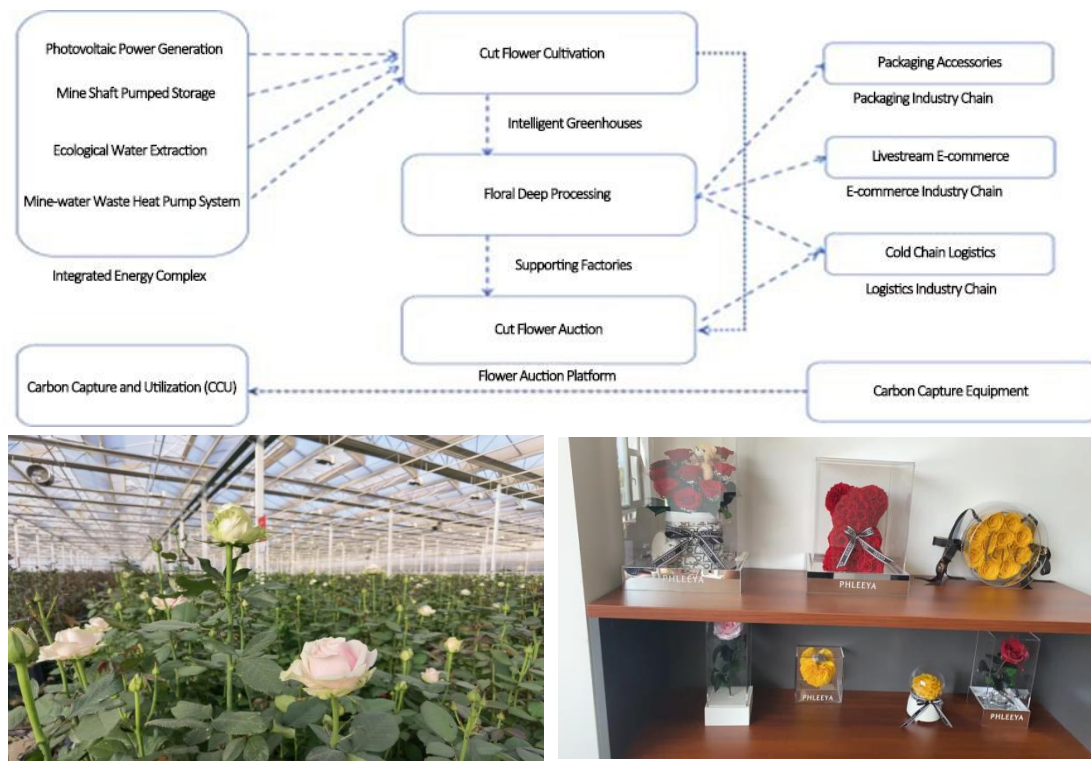


Figure 4 High-end rose industry chain

Credit: Ecology Institute of Shandong Academy of Sciences.

(3) Advancing Ecological Restoration of Abandoned Mining Areas via Project Construction

The project integrates agrivoltaic systems and flower cultivation to promote the ecological restoration of former mines. With a total planned investment of CNY 12 million, the project aims to rehabilitate 200 mu (approximately 13.33 hectares) of abandoned land and 400 mu (approximately 26.67 hectares) of land with agricultural facilities. In Phase I, 20% of the targeted restoration has been completed. In the meantime, an integrated water-fertilizer drip-irrigation system has been deployed to supply water for flower

cultivation while preventing long-term accumulation of mine water, thereby reducing the risk of infiltration and contamination of underground aquifers.



Figure 5 On-site view of mine ecological restoration and mine water treatment

Credit: Ecology Institute of Shandong Academy of Sciences.

(4) Promoting Re-employment of Local Residents via Project Development

The project has created employment opportunities for local residents, particularly laid-off coal miners—many of whom are middle-aged. The project operator has signed labour agreements with nearby communities to provide flower cultivation training and secure job placements for residents. Statistics show that Phase I can address the re-employment of 30 individuals. Upon the full completion of Phase II, the project is expected to provide 200 re-employment opportunities annually. These jobs have low entry barriers in terms of education and age, and most can be undertaken after basic training.



Figure 6 On-site view of flower workers cutting roses

Credit: Ecology Institute of Shandong Academy of Sciences.

III. Lessons and Insights

(1) Integrated Planning and Systematic Governance

The project was successfully implemented through coordinated government leadership and a systematic approach. First, a dedicated task force comprising departments of development and reform, energy, and natural resources was established to accelerate project approval and implementation. Second, scientific planning and design were unified under research institutions to avoid fragmented construction and ensure consistent execution guided by a single master blueprint. Third, government funding played a catalytic role in leveraging public credibility to mobilize private capital, ultimately achieving the goals of restoring a mine, building up an industrial park, and driving an industry.

(2) Localized Strategies and Technological Innovation

Abandoned mining areas should not be viewed as problem zones but rather as innovation zones. By harnessing local resource endowments as the foundation, driving transition through technological innovation, promoting industrial integration as the development pathway, and securing institutional innovation as a safeguard, these abandoned mining areas can be transformed from ecological scars into green assets.

(3) Multistakeholder Collaboration for Win-Win Development

The project has established a collaborative model involving government, enterprises, research institutions, and philanthropic organizations to ensure coordinated and sustainable progress. The government agencies of Zichuan District provided efficient and compliant approval processes for the project, offering policy and institutional support for its successful implementation. As a philanthropic organization, Energy Foundation China supported the project's early-stage research and development on the transition of depleted mining areas, helping to initiate and guide the regional transition pathway. The foundation also proactively promoted the transition outcomes to facilitate experience sharing and replication both domestically and internationally. The Shandong Academy of

Sciences, as the scientific partner, provided a rational and science-based top-level design plan along with guidance for construction and operations. In parallel, financing institutions supplied stable funding, while developers and operators leveraged their technical expertise to ensure safe and steady project progress.

(4) Replication and Promotion to Sustain Broader Impact

The successful model of the Dakuishan project will be replicated in similar areas across Zichuan. Zichuan Urban Investment Group plans to invest CNY 500 million (about USD 59.6 million) and intends to apply for funding from central government budget allocations, ultra-long-term treasury bonds, and potentially multilateral development banks. The goal is to implement similar projects in Lingzi and Xihe Towns, with 800,000 m² of flower greenhouse cultivation and an 80 MW “PV+” energy system built on a virtual power plant platform, coupled with heat pumps for waste heat and electrochemical energy storage. As China is expected to decommission up to 15,000 coal mines by 2030, the Zichuan model will offer considerable potential for nationwide reference, replication, and promotion.