

Green and Low-Carbon Development and Utilization Technology of Coal in China and its Prospects

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CONTENTS

- 1** Preface
- 2** Green Development Technologies and Practices in Coal
- 3** Clean and Low-Carbon Utilization Technologies and Practices in Coal
- 4** Prospects of Green and Low-Carbon Technologies in Coal
- 5** Prospects for Cooperation in Green and Low-Carbon Technologies between China and Japan



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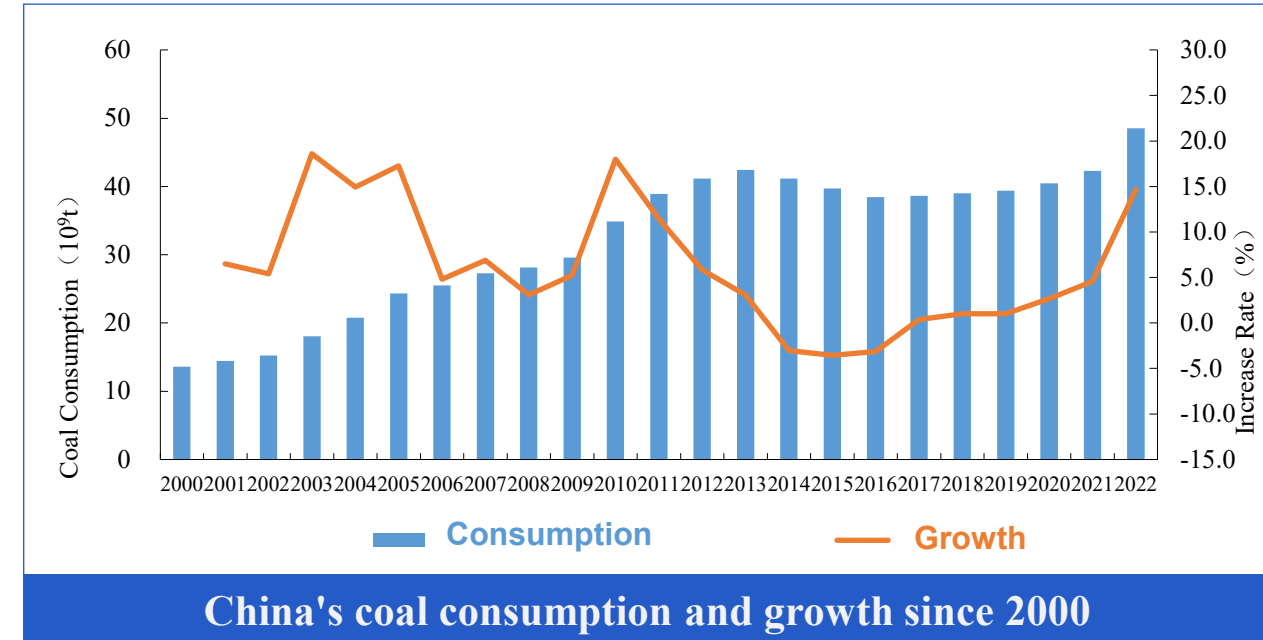
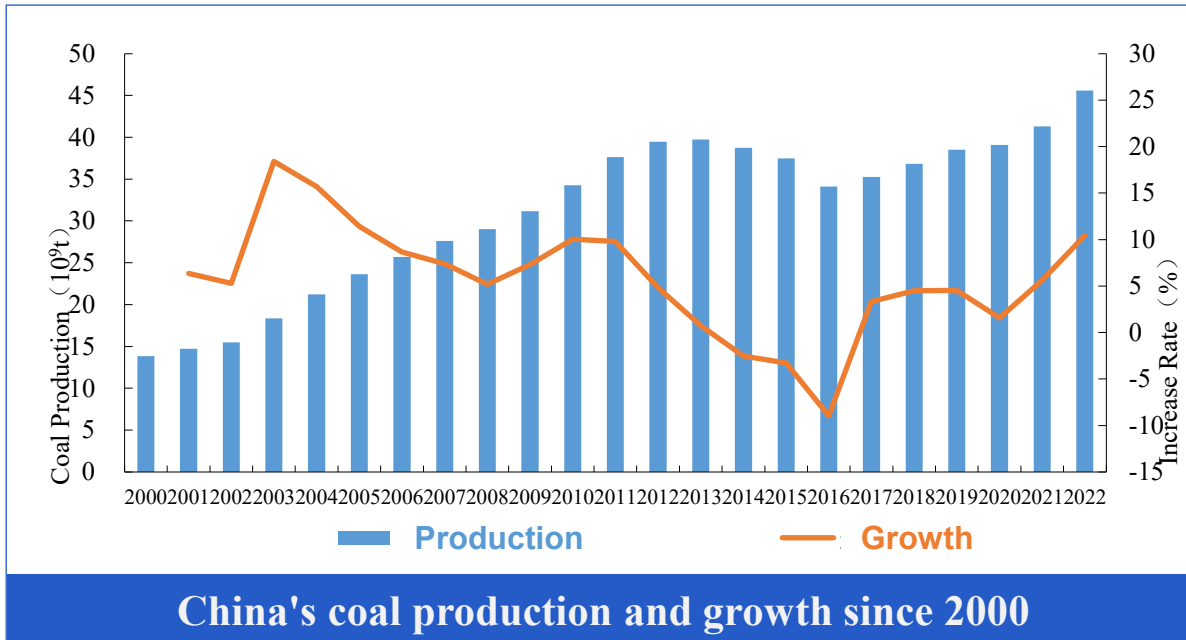
Preface

1. Preface



» Coal is a crucial global energy and main energy in China

- ❑ The global proven reserves of coal are **1.07 T.tn.**, making coal one of the most abundant, widespread, and economical energy resources in the world.
- ❑ Coal has long accounted for **>50%** of China's energy production and consumption. In 2022, China produced **4.56 B.tn.** of coal and consumed **4.85 B.tn.**, accounting for approximately **54.8%** of the world's coal production and **60.6%** of consumption.



1. Preface



➤ China Continues to Promote Safe and Efficient Coal Production

- ❑ Coal mining has gradually shifted from comprehensive mechanization to intelligentization.
- ❑ **4,400** coal mines, including > 360 open-pit mines; **85%** large mines with annual outputs > 1.2 M.tn; **79** mines with a production capacity of **10 M.tn.**, contributing 1.28 B.tn.
- ❑ Coal production has shifted towards the Western Region, with the raw coal of Shanxi, Shaanxi, Inner Mongolia and Xinjiang being **3.3 B.tn**, accounting for **79.9%**. The top eight companies produced **2.026 B.tn**, accounting for **49.1%**.



China's Haluusu Open Pit Mine, 35.0M.tn./a



World's first 8.8 meter ultra-high mining face
(Shangwan Coal Mine, China)

1. Preface



»» Coal Mine Intelligent Construction Accelerate

- ❑ Deep Integration of Modern Information Technologies (IoT, 5G, Big Data, Cloud Computing, AI, etc.) with Coal Mining
- ❑ Multi-level Linkage, Data Integration, and Intelligent Control of Equipment Clusters
- ❑ More than **1000** intelligent mining faces have been established



Unmanned Driving



Robot Inspection



黄陵矿业持续推进两化融合进程，积极探索实践煤炭开采关键技术

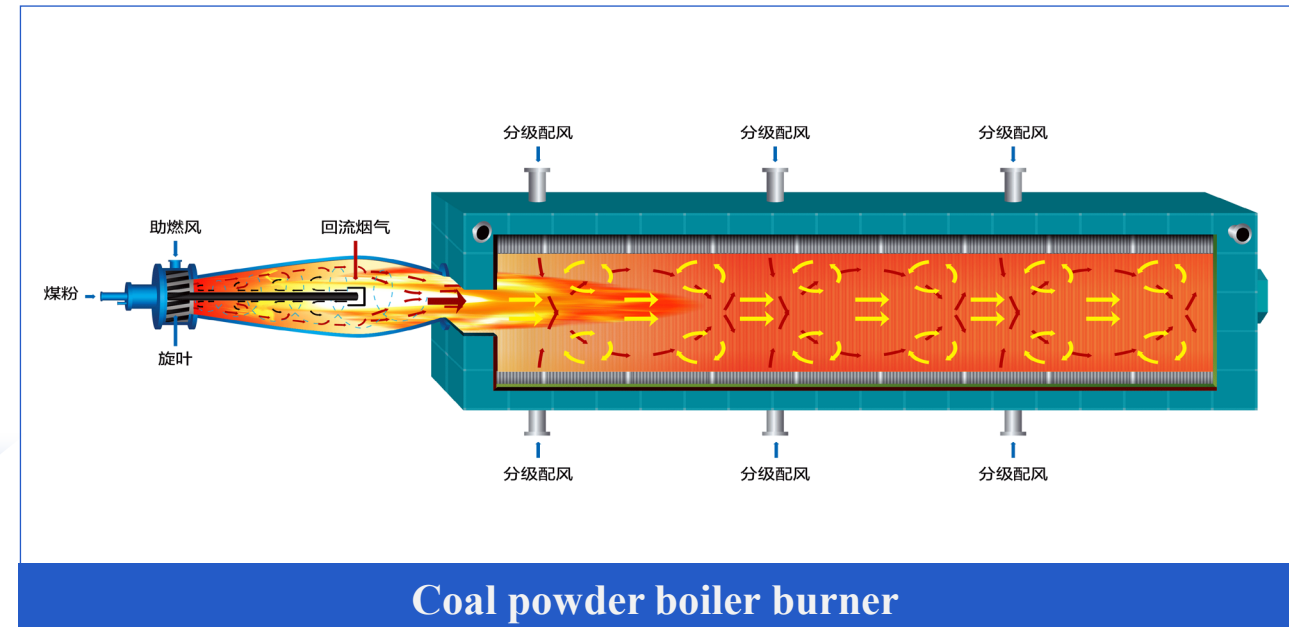
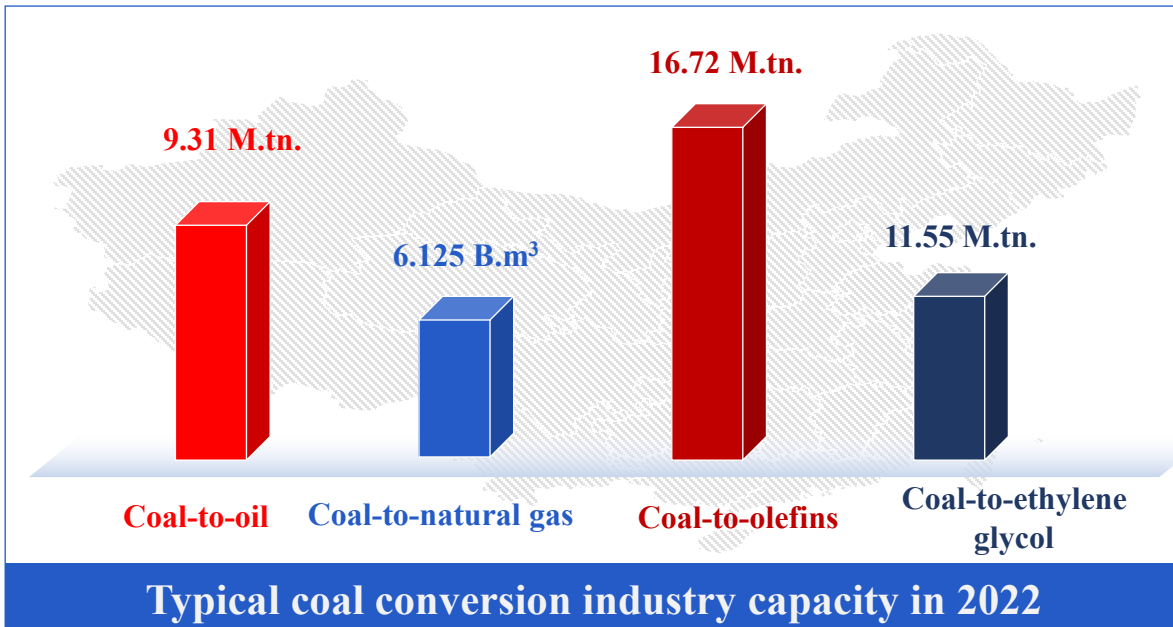
Remote Operation

1. Preface



➤ China Rapidly Promotes Clean and Efficient Coal Utilization

- ❑ Coal utilization has shifted → Large-Scale Centralized Utilization.
- ❑ Ultra-low emission coal-fired power generation, high-efficiency coal powder boilers, and modern coal chemical technologies have reached international leading levels, and large-scale coal gasification technology has been domestically produced.



1. Preface



» Establishing the World's Largest Clean Coal Power Supply System

- ❑ Completion of ultra-low emission retrofitting of 1 billion kilowatts of coal-fired power units, exceeding conventional pollutant emission standards of gas-fired units, and leading internationally.
- ❑ Heat-to-power conversion efficiency of supercritical CO₂ cycle power generation experimental unit has increased by 3-5 percentage points compared to steam units.



Datang Dongying Power Generation Co., Ltd
Million-kilowatt ultra-supercritical coal-fired power unit



China's first large-scale 5-megawatt supercritical CO₂ cycle
power generation experimental unit

1. Preface



» Establishing Ultra-Low Emission Projects for Coal-Fired Industrial Boilers

- ❑ Highly efficient coal powder combustion technology and the coal powder industrial boiler system have improved thermal efficiency of industrial boilers to over 90%.
- ❑ Pollutant emissions of coal-fired industrial boilers have reached ultra-low emission standards.



Gansu Qingyang 4×70MW Heating Project



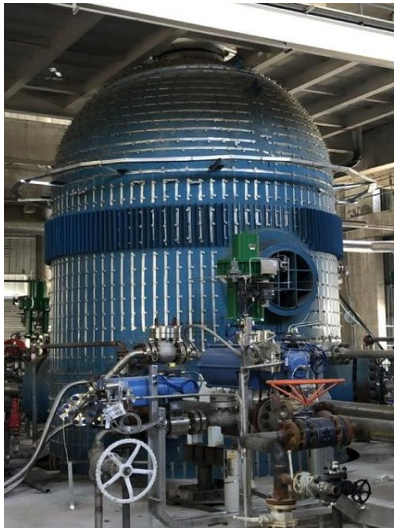
Interior view of efficient coal powder industrial boiler

1. Preface



➤ Establishing most comprehensive modern coal chemical technology system globally

- ❑ **Coal Gasification:** 4000 tn./d slurry coal gasification and 3500 tn./d dry powder fluidized bed gasification.
- ❑ **Coal-to-Oil:** 1.08 M.tn./a for direct coal liquefaction and 4 M.tn./a for indirect coal liquefaction.
- ❑ **Coal Chemicals:** Industrial production of coal-to-olefins and ethylene glycol, with methanol-to-olefins technology leading internationally.



Multi-nozzle opposed jet slurry coal gasification unit
Largest single furnace scale water coal gasification unit globally



Direct Liquefaction Demonstration (1.08 M.tn/a)
World's only M.tn level coal direct liquefaction project

1. Preface



- ✓ In the context of peak carbon emissions and carbon neutrality, coal carries critical mission of ensuring **China's energy security and supporting the development of new energy sources.**
- ✓ It is urgently necessary to undertake breakthroughs in green coal mining and low-carbon clean utilization technologies.





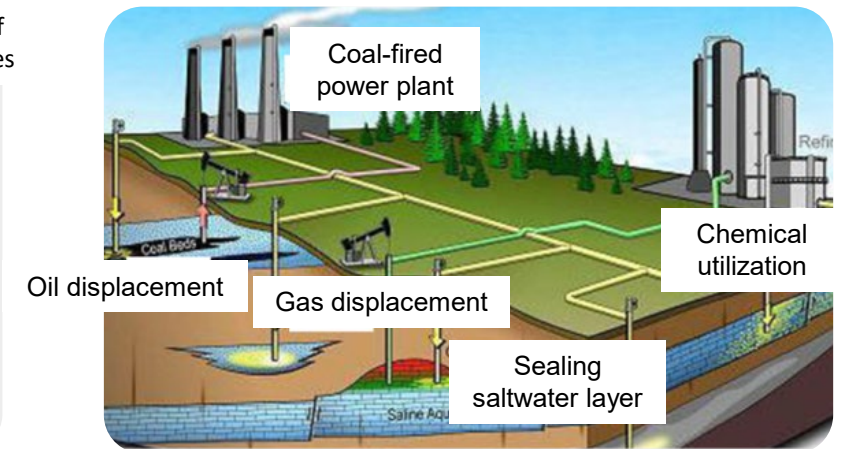
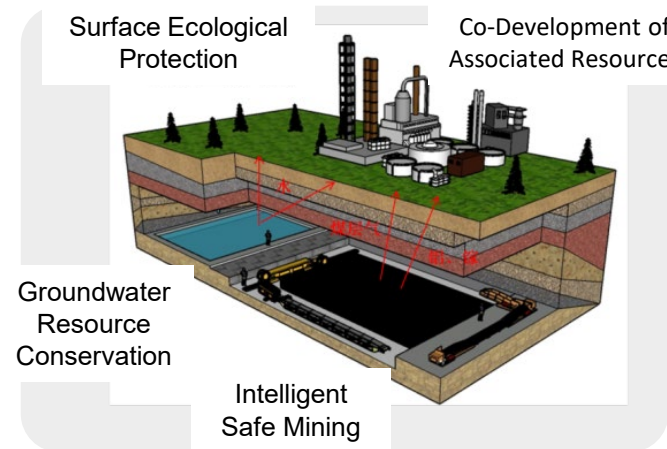
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Green Development Technologies and Practices in Coal

2. Green Development Technologies and Practices in Coal

□ Coal mining industry towards Greener practices

- ✓ Extraction methods are becoming **more eco-friendly**, causing **less harm and producing fewer carbon emissions**, with aim of minimizing disturbance to ecological environment and achieving harmless mining;
- ✓ Reduce **discharge of mine water and solid waste**, while aiming to recycle and utilize water, solid waste, and subsidence land resources.

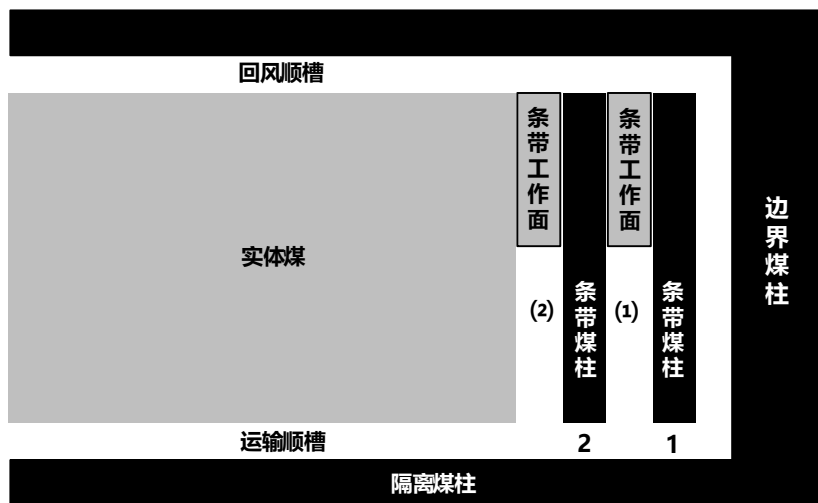


2. Green Development Technologies and Practices in Coal

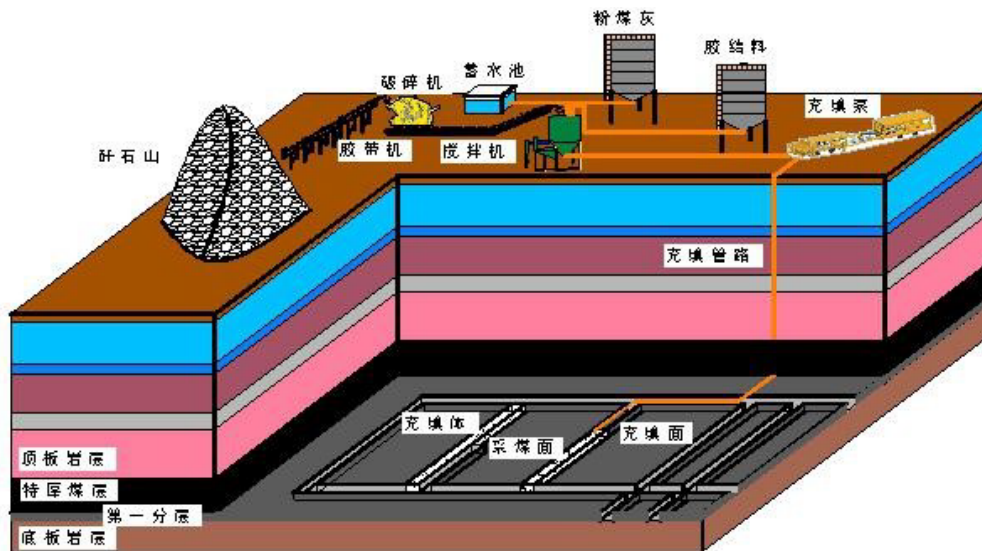


Green Mining - Reducing Surface Subsidence and Ecological Damage

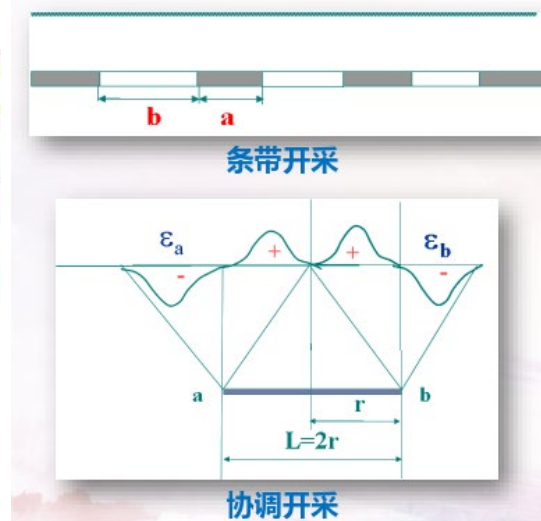
- ✓ Established rock layer control and subsidence reduction techniques: strip mining, thickness-limited mining, coordinated mining, backfill mining, and layered intermittent mining technology, and overburden strata grouting technology.
- ✓ Ensured safety of buildings and structures over coal mining areas: high-voltage power lines, highways, oil and gas pipelines, and high-rise buildings passing, etc.



Strip Mining



Backfill Mining

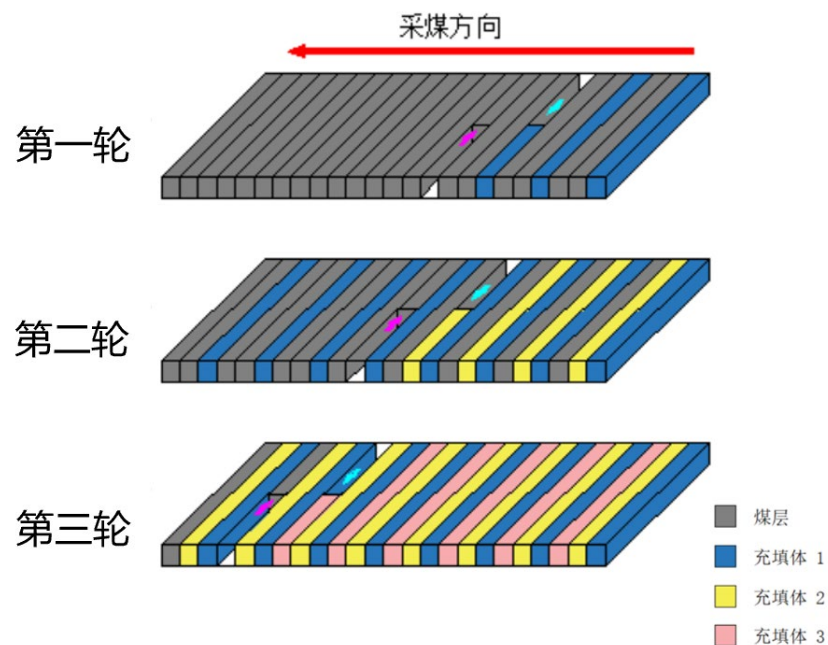


Coordinated Mining

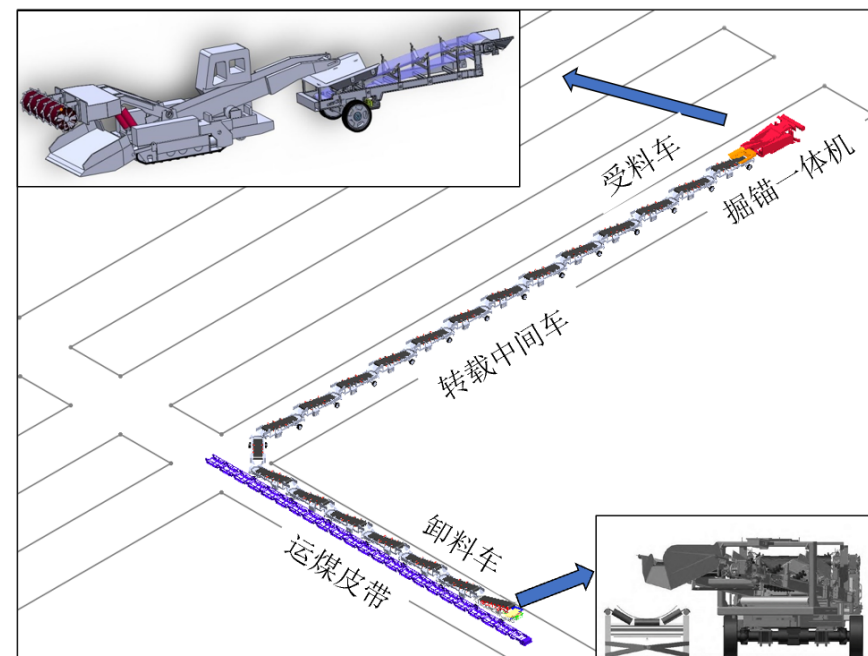
2. Green Development Technologies and Practices in Coal



- ✓ **1 M.tn/a Continuous Mining and Filling Technology & Equipment**
- **Coal mining in irregular sections and under three circumstances → Developed a “continuous mining, continuous transportation, and continuous filling process and equipment”. Built a working face for continuous mining and filling with an output of **1 M.tn./a**, and process **0.9 M.tn./a** of gangue at Guojiawan Coal Mine of National Energy Group.**



Guojiawan Continuous Mining and Filling Process



Continuous Mining and Transportation Equipment

2. Green Development Technologies and Practices in Coal



□ Green Mining—Water Conservation Mining

- ✓ Water conservation in mining is a priority. We've developed techniques to protect water bodies, conserve water resources, and address environmental challenges.
- ✓ According to different water bodies and geological mining conditions, 3 major categories of water conservation mining techniques have been developed: natural water conservation, limited mining for water conservation, and water resource reuse.



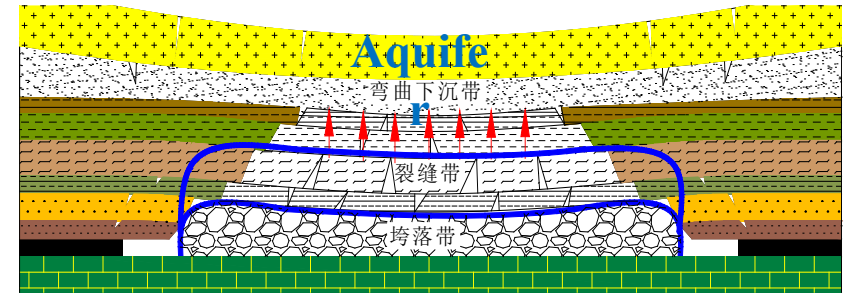
2. Green Development Technologies and Practices in Coal



Natural Water Conservation



No measures are taken against protected water body. Mining-induced damage does not change original water-resisting performance of aquiclude, realizing natural water conservation mining.



Limited Mining



Limited Thickness Mining

Strip Mining

Backfill Mining

Reconstruction of Aquiclude

Grouting reinforcement and strengthening surrounding rock structure of mined-out areas

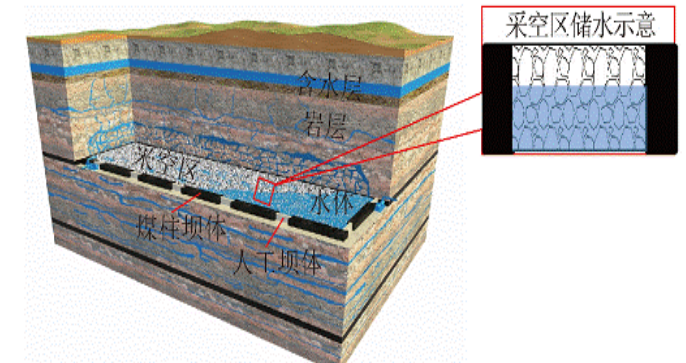


Water Resources Reuse



Underground Reservoir

Technologies for treating mine water in the underground mined-out areas
Circulation systems and water resources utilization technology

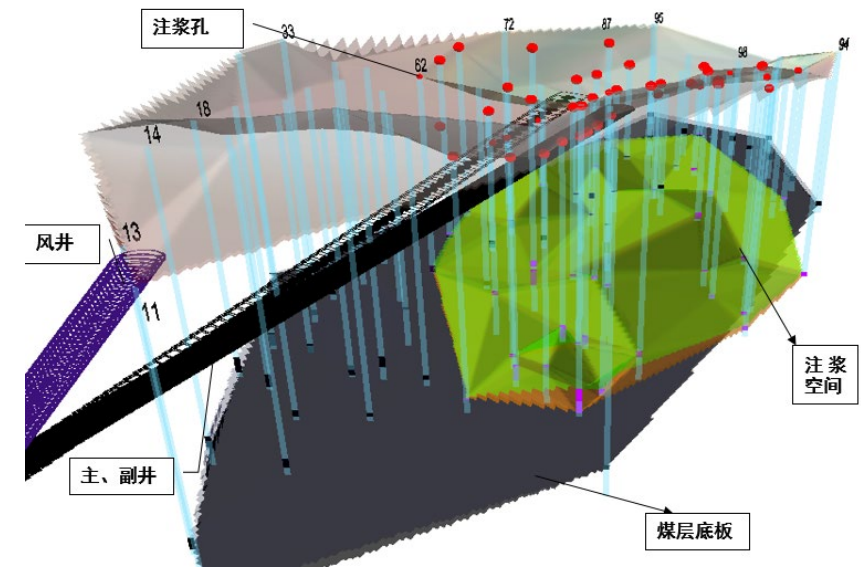
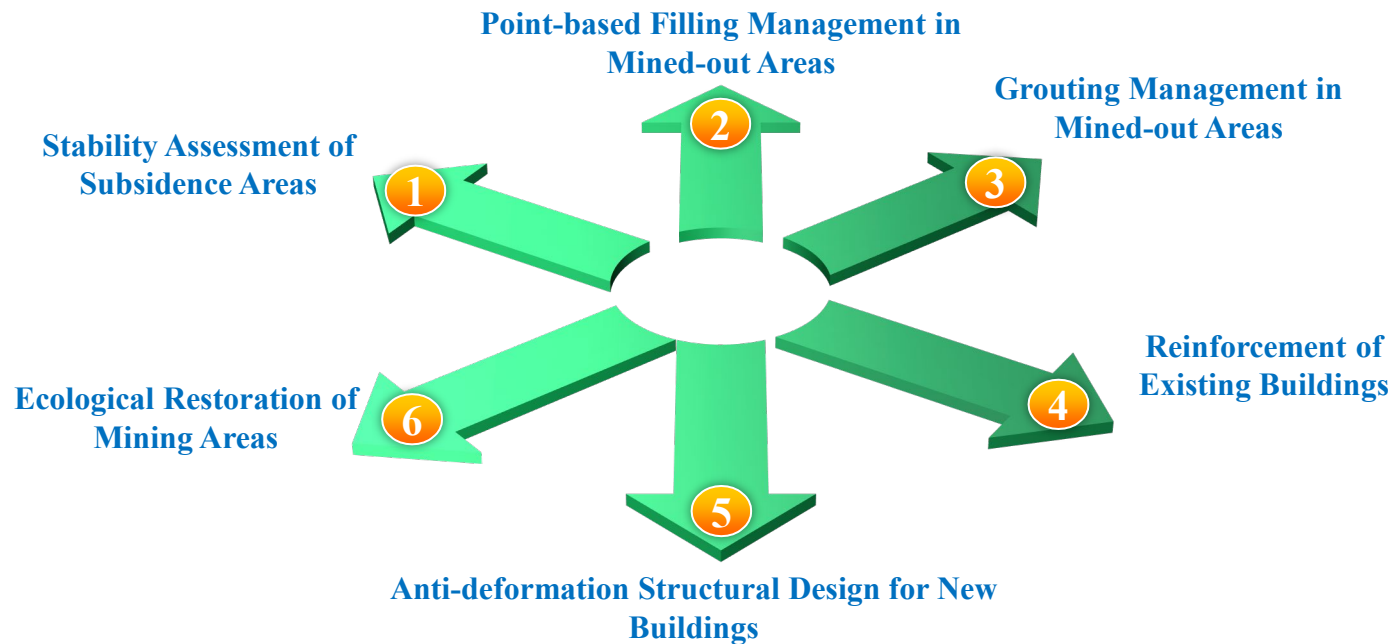


2. Green Development Technologies and Practices in Coal



□ Green Mining—Collaborative Management for Subsidence Areas

- ✓ Based on subsidence prediction theories and control technology, a complete technical system for managing mined-out areas is developed, integrating "exploration, design, evaluation, and construction," and a comprehensive technical system for managing subsidence areas with surface and subsurface methods.



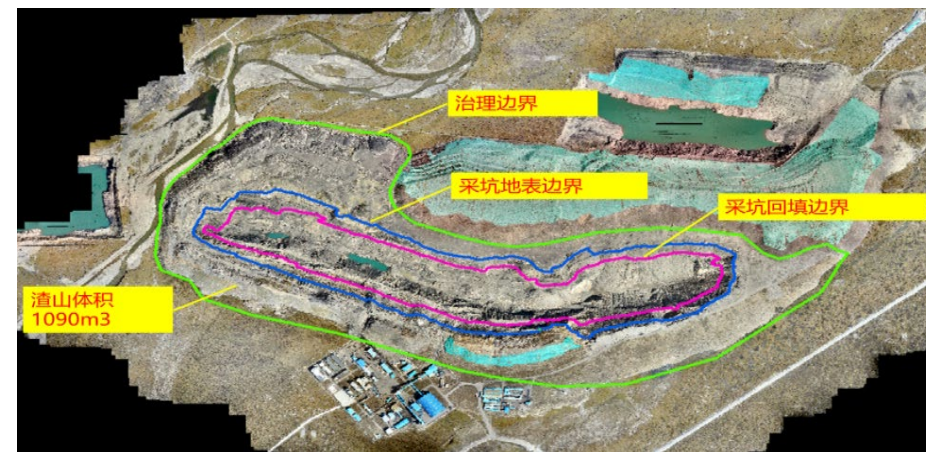
Grouting Effect

2. Green Development Technologies and Practices in Coal



□ Green Mining - Ecological Restoration for Mining Areas

- ✓ Development of ecological restoration technology for mining areas with high potential water levels, ecological restoration of open-pit coal mine geological disasters, and ecological restoration for large coal-electricity bases in the eastern grassland area.
- ✓ Comprehensive management of key technologies in Fushun West Open-pit Mine. Demonstration projects for mining pits and slag mountains in cold highland region, providing support for ecological management of open-pit mines.



Demonstration project in Jiangcang mining area of Muli coal field.



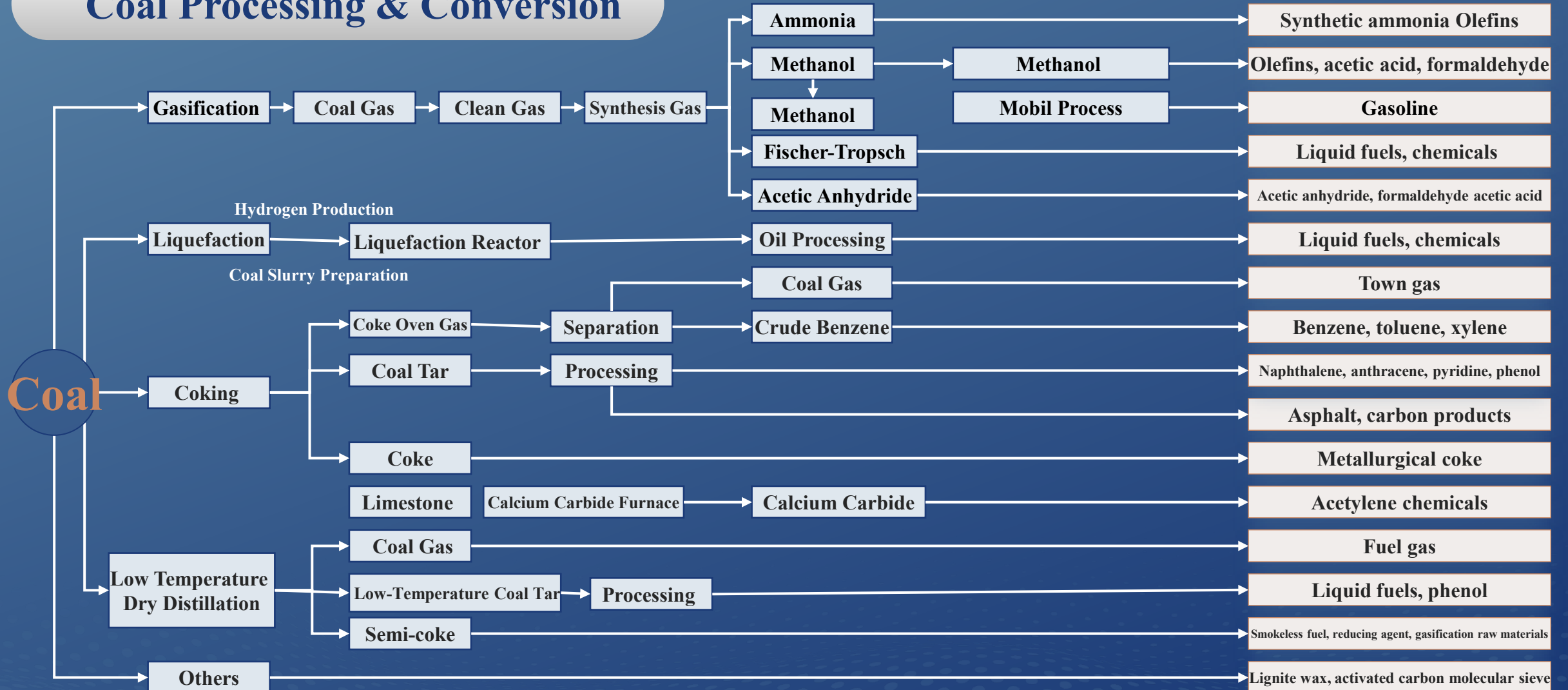
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Clean and Low-Carbon Utilization Technologies and Practices in Coal

3. Clean and Low-Carbon Utilization in Coal



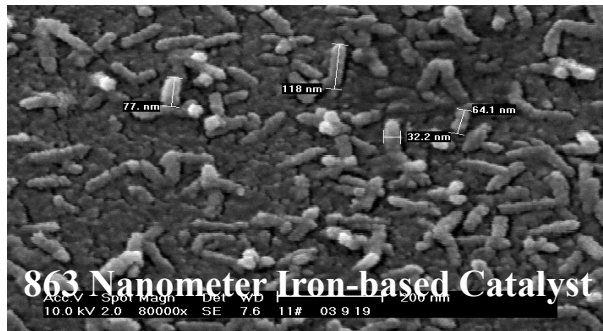
Coal Processing & Conversion



3. Clean and Low-Carbon Utilization in Coal



Direct Coal Liquefaction



- ✓ In 1979, CCRI established a team to direct coal liquefaction technology, progressing from 0 to 1.
- ✓ Developed 1st generation of nanoscale high-efficiency catalysts for direct coal liquefaction and world's first basic process for M.tn. level demonstration projects.
- ✓ Technology for refinement of coal tar phenol and techniques for coal-based high-energy fuels and fine chemicals derived from coal is ongoing.

3. Clean and Low-Carbon Utilization in Coal



□ Efficient Combustion Technology for Pulverized Coal Industrial Boilers

- ✓ Technologies are developed, including dense phase feeding of pulverized coal, central reverse jet twin cone dense phase combustion, shell-type and membrane-type water wall boilers, and pollutant control.
- ✓ Furthermore, mixed combustion technologies of pulverized coal with natural gas and biomass realized large-scale, modular, and serial production of industrial boilers. Thermal efficiency is **>90%**, achieving ultra-low pollutant emissions.



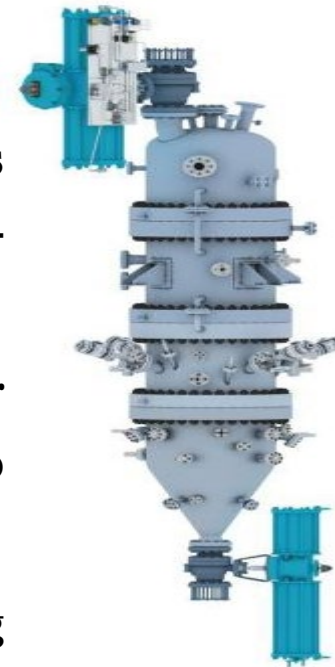
3. Clean and Low-Carbon Utilization in Coal



□ Upgrade and Renovation of Fixed Bed Gasifier

To address issues, e.g. low processing capability, high wastewater content, low effective gas output in Lurgi gasifiers, fixed bed gasifier has undergone an upgrade and renovation:

- ✓ Continuous slag removal technology was upgraded to resolve issues with lifespan of parts like nozzles and slag tanks, achieving long-cycle operation.
- ✓ Upgrades to technology for co-gasification of dust-laden tar returned to furnace allow for the conversion of dust-laden tar into raw gas inside furnace.
- ✓ Upgrades to full recycling technology of phenol-containing wastewater enable complete re-utilization of such wastewater, truly solving problems of dust-laden tar and phenol-containing wastewater in fixed bed gasifier.



3. Clean and Low-Carbon Utilization in Coal



□ Low-Concentration Coalbed Methane Concentration Utilization

- ✓ Developed industrially applicable technology and equipment for deoxygenating and concentrating low-concentration coalbed methane, and independently developed coal-based carbon molecular sieves → Concentrate low-concentration coalbed methane of about **10-30%** to over **90%**, with a CH₄ recovery rate of over **90%**. Concentrated gas can be processed into CNG or LNG. A demonstration base with an annual processing capacity of 18 million Nm³/a has been built in Yangquan.
- ✓ Chongqing Research Institute has developed cryogenic liquefaction and concentration technology and equipment for low-concentration coalbed methane, forming a process technology package. In Guizhou Panjiang, a project was established for the cryogenic liquefaction of oxygen-containing coalbed methane with a daily raw gas processing capacity of **100,000 Nm³**, producing **25,000 tons of LNG per year**.

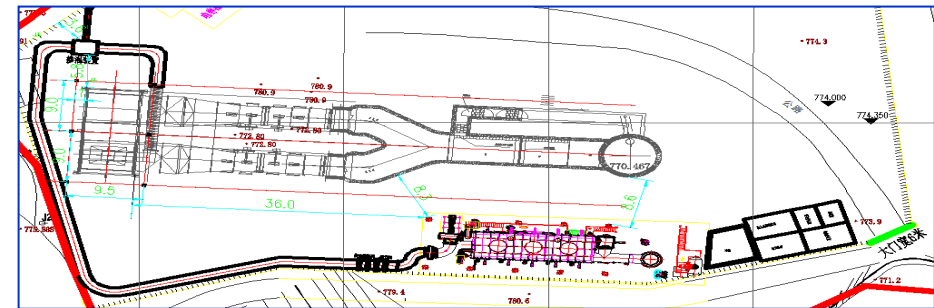
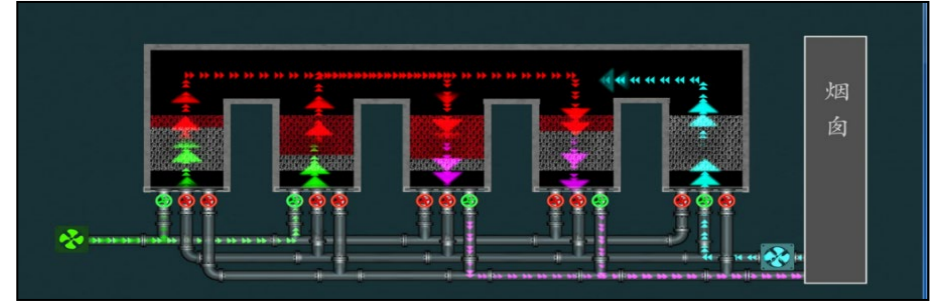


3. Clean and Low-Carbon Utilization in Coal



□ New Five-Bed Exhaust Gas Heat Storage Oxidation Device

- ✓ In response to the technical difficulties in utilizing exhaust gas oxidation, a new five-bed exhaust gas heat storage oxidation device has been developed, with a single device capable of processing up to **100,000 Nm³/h**, and methane oxidation rate reaching as high as **98%**.
- ✓ An industrial test system for **100,000 Nm³/h** exhaust gas heat storage oxidation has been built, which can produce 9 tons of superheated steam per hour using residual heat. This provides advanced and reliable technology and equipment for the utilization of exhaust gas.





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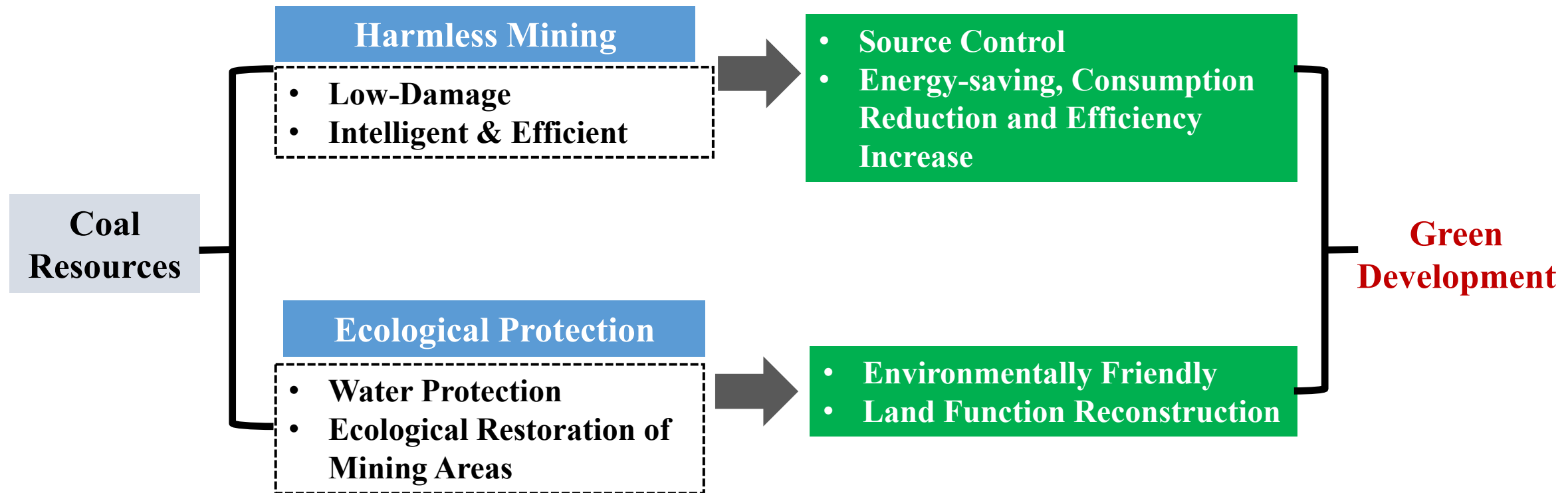
Prospects of Green & Low-Carbon Technologies in Coal

4. Prospect of Green & Low-Carbon Technologies



□ Green Coal Mining Technology

- ✓ Green development of coal: Achieving ultra-low damage, Environmentally friendly, and Ecological protection.

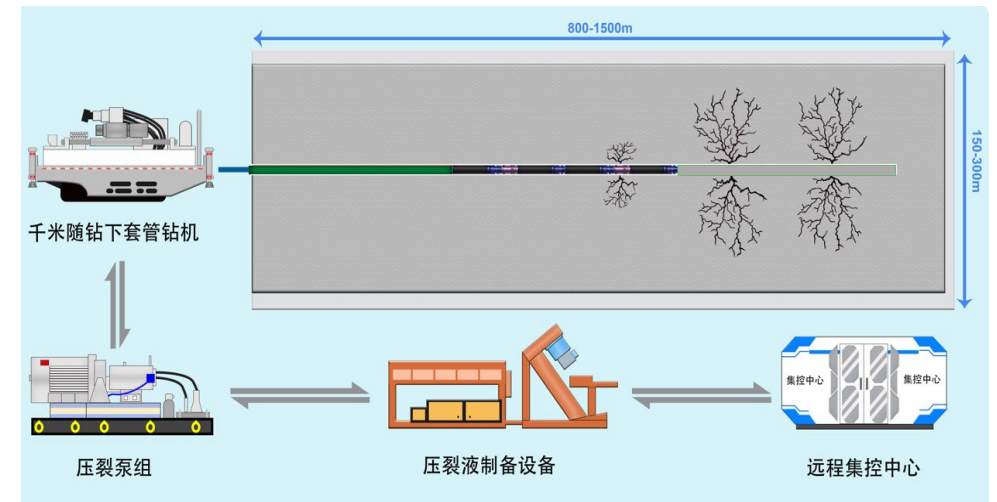
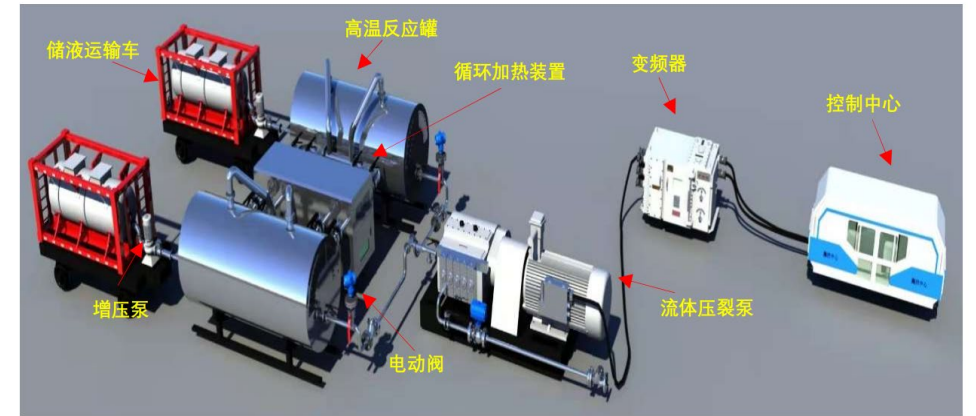


4. Prospect of Green & Low-Carbon Technologies



✓ Technologies and Equipment for Coal and Gas Co-Mining

- Coal Seam Gas Parameter Drilling Measurement Technology;
- Efficient Drilling Technology and Equipment for Ultra-Long Directional Holes;
- Large-Scale Pressure Relief and Permeability Enhancement Technology and Equipment for Long Drill Holes, Hydraulic Cutting, High-Power Regionalized Ultrasonic Fracturing Permeability Enhancement Technology and Equipment;
- High-Flow Dry Fracturing Technology & Equipment;
- High-Efficiency Gas Extraction Technology for Up- and Downstream Regions Under Complex Conditions.

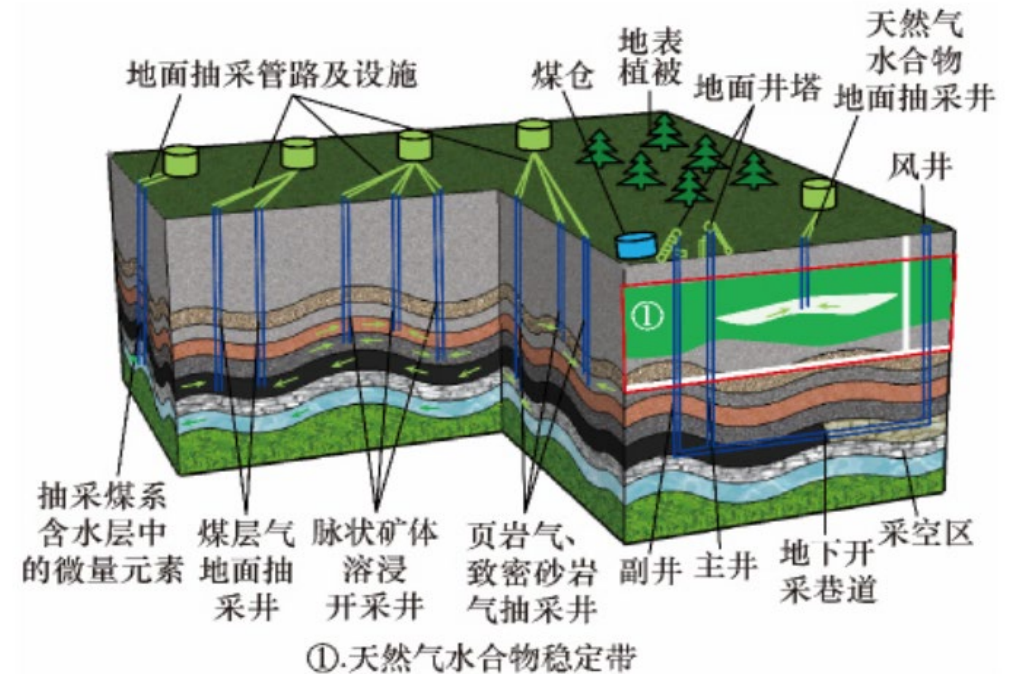


4. Prospect of Green & Low-Carbon Technologies



✓ Comprehensive Development of Coal and Associated Resources

- Coordinated development of coal-related associated resources has great potential economic benefits.
- Accurate exploration of coal, oil, unconventional natural gas, rare metals, water, and other overlapping resources in coal formations can reveal their distribution conditions. Conducting research on multi-resource, 3D, and comprehensive development patterns and technologies can lead to effective development of coal and its associated resources.



4. Prospect of Green & Low-Carbon Technologies



□ Clean and Low-Carbon Utilization of Coal

Reduce Carbon Emissions in Coal Utilization

Energy Conservation and Efficiency Improvement Reducing Total Coal Consumption

Clean, Efficient, Flexible, and Low-Carbon Coal Power Technology

High-End, Diversified, and Low-Carbon Coal Chemical Industry



Coupled Utilization of Coal and New Energy

CO₂ Capture, Storage, and Utilization (CCS, CCUS)

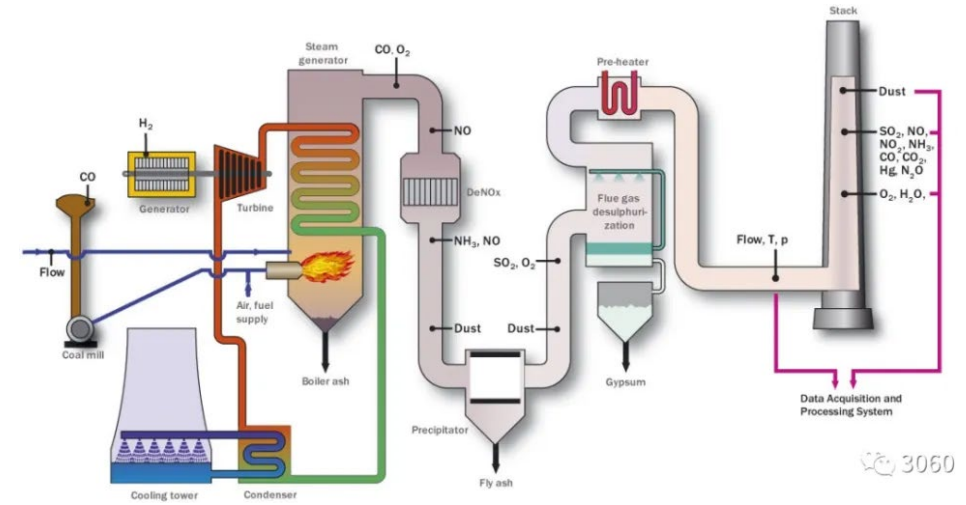
Ecological Carbon Sink in Coal Mining Areas

4. Prospect of Green & Low-Carbon Technologies



✓ CO₂ Separation, Purification, Capture and Recycling

- Coal-fired power generates **40%** of country's total carbon emissions. Separation, purification, capture, and recycling of CO₂ in coal combustion flue gas are significant to "peak carbon and carbon neutrality".
- Study characteristics of CO₂ adsorption and desorption subject to gas pressure, gas flow rate, and gas concentration, and their impact on CO₂ adsorption penetration curve. Develop CO₂ purification processes and pressure swing adsorption processes for capturing CO₂, and develop an integrated technology for efficient CO₂ separation, purification, capture, and recycling.



Adsorption Separation Device



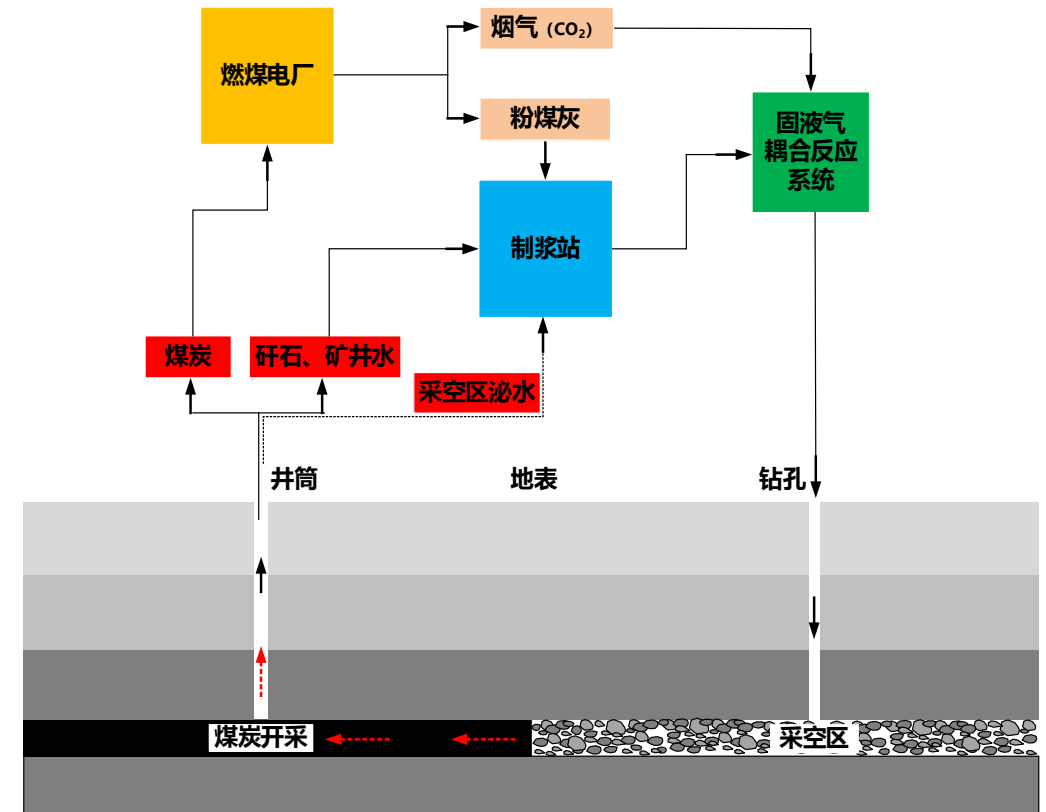
Skid-mounted Separation Device

4. Prospect of Green & Low-Carbon Technologies



✓ Exploring Use of High-Alkaline Fly Ash Slurry for CO₂ Solidification

- Underground coal mining carbon sequestration is one way to achieve carbon reduction.
- Power plant high-alkaline fly ash and mine water are made into slurry, which is then introduced into a solid-liquid-gas coupling reaction device to capture CO₂ from power plant's flue gas. Slurry is transported to empty mining areas via pipelines, and water from slurry is transported back to surface to serve as water source for making more slurry. This process achieves multiple goals: solidifying CO₂ with fly ash, using fly ash grout to prevent fire, and filling mined-out areas to reduce subsidence.



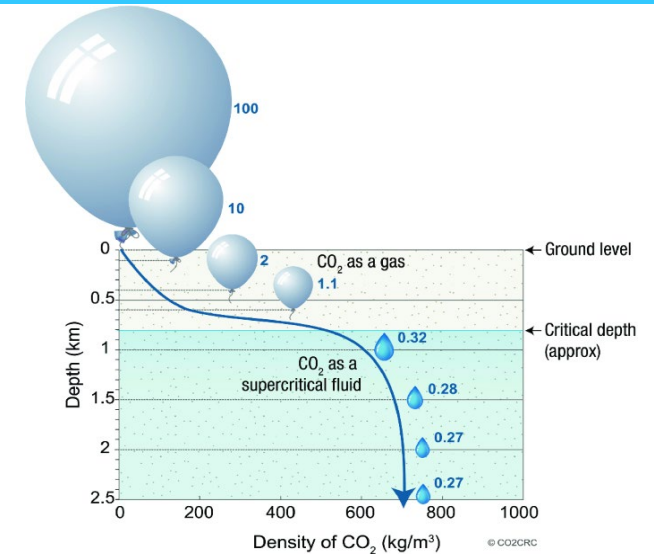
Underground Coal Ash Slurry Injection System

4. Prospect of Green & Low-Carbon Technologies

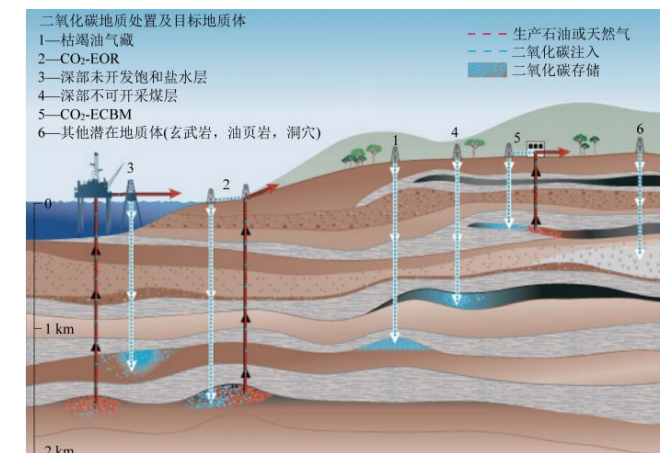


✓ Deep CO₂ Sequestration Technology

- Deep geological bodies (>1km), such as coal seams, basalt, and saltwater layers, serve as storage layers, and injection of CO₂ easily achieves a supercritical state. Supercritical CO₂ has a small volume and a large diffusion coefficient. Deep burial of CO₂ is realized through mechanisms such as adsorption sequestration, geological structure sequestration, trapped gas sequestration, dissolution sequestration, and mineralization sequestration.
- Utilizing geological strata of mining area → Explore technologies such as deep stratum CO₂ geological sequestration, CO₂ displacement for coal seam CH₄, solidification of CO₂ for underground backfilling, to create a coal mine "Carbon Capture, Utilization, and Storage" (CCUS) technical pattern.



Variations in CO₂ Volume and Density with Geological Depth



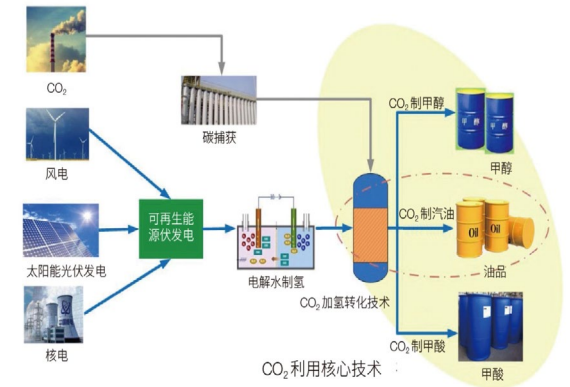
CO₂ Geological Sequestration Mode

4. Prospect of Green & Low-Carbon Technologies

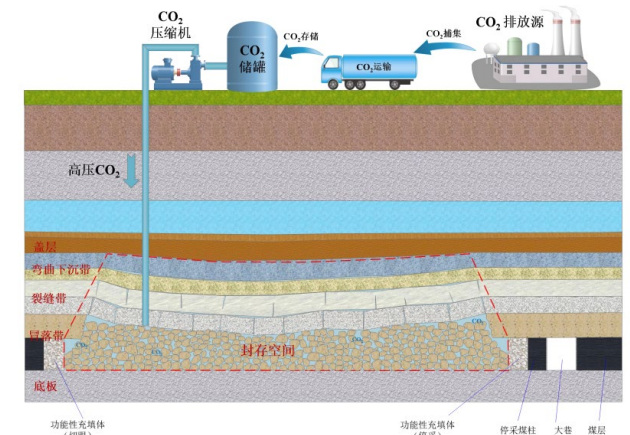


✓ Carbon Neutral Mine Construction for Coal Development and Utilization

- Integration technology of gas extraction and utilization during coal mining, energy storage and multi-energy complementarity technology in coal mine areas, and smart mine and mine IoT technology → Establish models for low-carbon development in coal mine, "**Coal Development + Coal-Fired Power Generation + CCUS**".
- Construct a technological pathway for carbon-neutral coal development & utilization, and reasonably layout direction of key technical breakthroughs for coal carbon neutrality.
- Build demonstration area for carbon-neutral coal mines.



Zero-carbon energy coupling with CO₂ transformation and utilization



Technical roadmap of CO₂ sequestration in mined-out areas.



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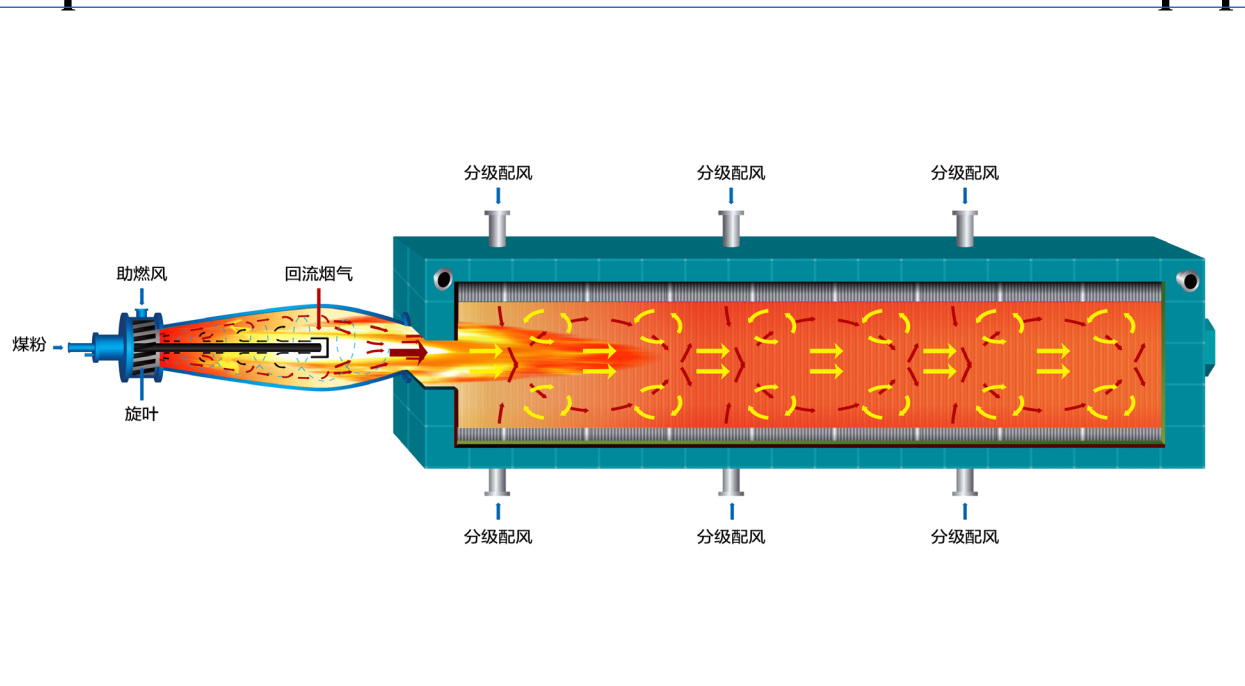
Prospects for Cooperation in Green and Low-Carbon Technologies between China and Japan

5. Cooperation between China and Japan



▶▶ Cooperation for the Clean Transformation of Coal-fired Industrial Boilers and Coke Ovens

- China's technological edge in coal-fired industrial boilers and coking processes enables it to offer clean transformation services to Japanese fuel, power, steel, and metallurgical enterprises, enhancing pollution control standards for coal utilization equipment.



Coal Powder Boiler Burner



Coal Powder Silo for High-Efficiency Coal Powder Boiler

5. Cooperation between China and Japan



» Collaboration in the Development of Clean and Low-Carbon Coal Utilization Technologies

- Analyzing clean coal conversion technical directions and needs for markets in China, Japan, and international chemical products and carbon-based materials.

Coal-to-Synthetic Ammonia and Urea

High-Pressure Fluidized Bed Gasification

Deep Processing of Coal-Derived Oil Products

Coal-to-Olefins and Other High-Value Chemicals

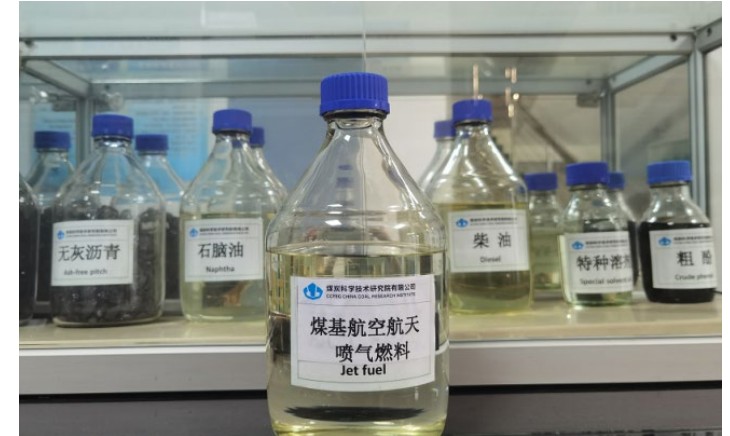
- Through profound integration of coal with renewable sources, we elevate energy utilization quality, paving the way for a new era of low-carbon coal development.

Accelerate the Reduction of Carbon Contribution Ratio

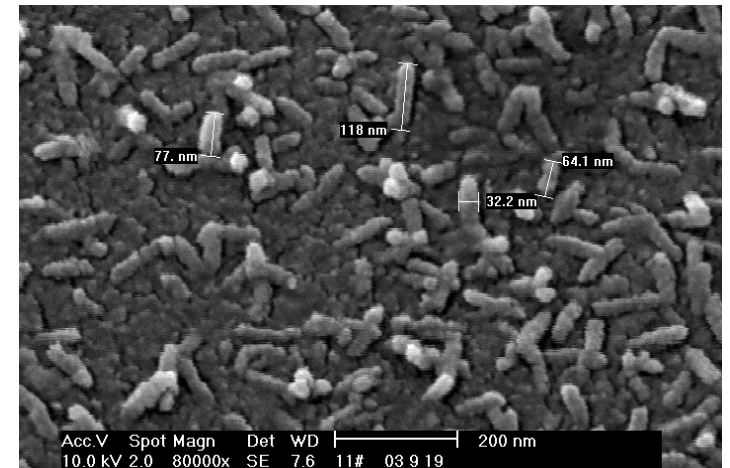
Synergize with Solar Power Generation, Wind, and Hydropower Development"

Integrated Hydrogen Production and Conversion

Providing a Foundation for Smoothing Renewable Energy Fluctuations



Coal Liquefaction Products



863 Nanometer Iron-based Catalyst

5. Cooperation between China and Japan



- **Our collaborative efforts with Japan symbolize our dedication to a sustainable future.**
- **Together, we're pioneering new technologies, setting industry standards, and championing green and low-carbon energy.**
- **I believe that through international collaboration and a shared vision, we can achieve a cleaner, greener, and more sustainable future for all.**



Thank you for your attention!