Industrialization Application Plan for Producing High-End Nanomaterials from Coal Gangue via Intelligent Three-Ring Kiln Activated Roasting

1. Project Overview

1.1 Project Background and Strategic Significance

As a crucial energy base in China, Inner Mongolia has accumulated vast amounts of coal gangue solid waste from coal mining, which not only occupies land but also brings severe environmental challenges. Against the backdrop of the national "dual carbon" strategy and the comprehensive utilization of bulk solid waste, this project adopts the core technology of "Intelligent Three-Ring Kiln Activated Roasting" with independent intellectual property rights. It specifically processes the high-alumina, high-silica coal gangue characteristic of the Inner Mongolia region to produce high-value-added nano α-alumina and nano-grade silica sol. It also achieves the resource utilization of all waste residues to prepare low-carbon cement, transforming coal gangue from a traditional low-value building material raw material into an "urban mine" for high-end new materials. This achieves a "clean sweep" style of full-component, high-value utilization and holds significant strategic demonstration significance for promoting regional industrial upgrading, building a new materials industry chain, and solving environmental problems.

1.2 Basic Project Information

Project Name: Industrialization Demonstration Project for Processing 1 Million Tons of Coal Gangue Annually to Produce Nano-Grade α-Alumina and Nano-Grade Silica Sol

Construction Site: Inner Mongolia

Construction Scale: Planned annual processing of 1 million tons of coal gangue

Raw Material Source: Coal gangue from the Inner Mongolia region

Main Chemical Composition:

Alumina (Al_2O_3): 40-45%

Silicon Dioxide (SiO_2): 52-57%

Loss on Ignition (LOI): Approx. 20%

Technical Route: Intelligent Three-Ring Kiln Activated Calcination + Hydrochloric Acid Gradient Leaching + Fractional Purification

Core Advantage: Producing high-end nanomaterials with high technical barriers and strong market demand at an extremely low raw material cost (as solid waste, coal gangue can receive processing subsidies), breaking foreign technology monopolies, with significant cost and market advantages.

2. Product Plan and Market Analysis

2.1 Raw Material Balance and Product Output Plan

This plan is based on the annual processing of 1 million tons of coal gangue and adopts a 90% extraction rate for material balance calculations.

Calcined Clinker Amount:

Annual processing of coal gangue: 1,000,000 tons

Loss on Ignition (LOI): 20%

Annual output of calcined activated clinker: 1,000,000 tons × (1 - 20%) = 800,000 tons

Core Component Content (calculated using intermediate values):

Al_2O_3 content in clinker: 800,000 tons × 42.5% = 340,000 tons

SiO_2 content in clinker: 800,000 tons × 54.5% = 436,000 tons

Product Extraction and Output (calculated at a 90% extraction rate):

Nano α-Alumina:

Extraction rate: 90%

Annual output: 340,000 tons × 90% = **306,000 tons**

Nano-Grade Silica Sol (based on solid content):

Extraction rate: 90%

Annual output: 436,000 tons × 90% = **392,400 tons**

Low-Carbon Cement:

Annual output: 800,000 - 306,000 - 392,400 = **101,600 tons**

Final Product Configuration Plan:

Product Name	**Annual Output (10,000 tons)**	**Product Specification & Positioning**
Nano α-Alumina	30.60	α-phase ≥95%, purity >99.5%, primary crystal size ≤1μm. For advanced ceramics, lithium battery separators, high-end refractories, etc.
Nano-Grade Silica Sol	39.24	Solid content 30-40%, particle size 10-50nm, high purity and stability. Positioned for precision

		casting, special coatings, electronic polishing fluids, and catalyst carriers.
Low-Carbon Cement (Clinker)	10.16	Meets green building material standards, prepared from alkali leaching residue, with carbon emissions reduced by over 30%.
Total	**80.00**	-

2.2 Market Prospect Analysis

Nano α-Alumina: As a key inorganic non-metallic material, it is widely used in electronic ceramics, structural ceramics, and advanced refractories. With the rapid development of 5G communications, new energy vehicles, and the semiconductor industry, the demand for high-performance α-alumina continues to rise. The high-end market, especially for microcrystalline, low-sodium products that meet the requirements of the special ceramics and semiconductor industries, still partially relies on imports. This project's products directly target the high-end market and have strong import substitution capabilities due to cost advantages and stable quality.

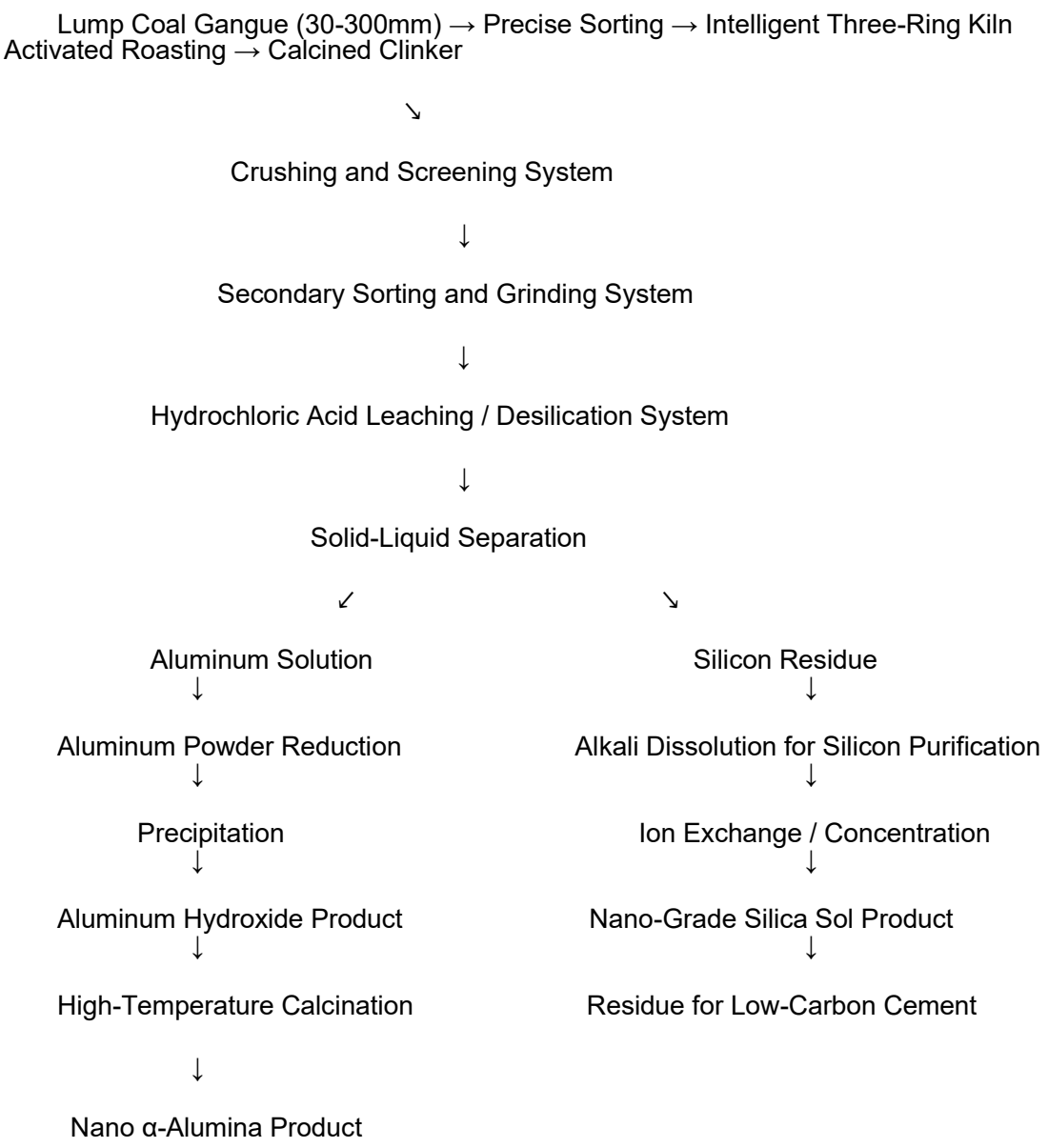
Nano-Grade Silica Sol: This is a technology-intensive product, and the self-sufficiency rate for high-end domestic brands is insufficient. It is widely used in precision casting, coatings, textiles, and electronics (CMP polishing fluid). The price of high-quality products is stable, and market demand is growing annually. This project's products have significant cost advantages and strong competitiveness.

Low-Carbon Cement: Under the "dual carbon" policy, green building materials are the inevitable direction for the transformation and upgrading of the construction industry. As a green building material, it aligns with dual-carbon policy guidance, and its annual growth rate is expected to exceed 15% in the next five years.

3. Process Technology Plan

The core of this project's technical route is the organic combination of "Intelligent Three-Ring Kiln Activation" and "Acid-Base Stepwise Gradient Purification," ensuring the efficient separation and high-value utilization of silicon and aluminum resources in coal gangue.

Process Flow Diagram:



Detailed Technical Path:

Pre-treatment and Activation: Large blocks of coal gangue (30-300mm) are screened and then fed into the Intelligent Three-Ring Kiln. This kiln performs low-

temperature activation roasting, breaking the original crystal lattice structure to maximize the activity of alumina and silica. This process fully utilizes waste heat and has low energy consumption.

Acid Leaching for Aluminum Removal: After grinding, the activated clinker enters a hydrochloric acid gradient leaching system, which efficiently dissolves the active alumina to form an aluminum chloride solution (aluminum solution), while the silicon dioxide remains as a solid (silicon residue), achieving the initial separation of silicon and aluminum.

Nano α-Alumina Preparation: The aluminum solution is purified and precipitated to obtain high-purity aluminum hydroxide. This high-purity aluminum hydroxide is then sent to a dedicated high-temperature rotary kiln for calcination, with precise temperature control to completely transform it into the α-crystal phase, finally obtaining nano-grade α-alumina powder.

Nano-Grade Silica Sol Preparation: The high-silicon residue from acid leaching enters an alkali dissolution system to produce a sodium silicate solution. After multi-stage deep purification, this solution undergoes an ion exchange process to remove impurity ions. Under specific conditions, it stably forms an aqueous dispersion of nano-grade silicon dioxide, which is then concentrated to obtain a high-quality nano-grade silica sol product.

Waste Residue for Low-Carbon Cement: All final insoluble residues produced during the purification process, whose main components are stable silicates, can be directly used as high-quality raw materials for low-carbon cement after proportioning, achieving "zero waste residue" discharge for the project.

4. Main Equipment Configuration

The equipment configuration for this project must balance advanced technology, reliability, and investment economy. The core equipment uses an intelligent control system to ensure process stability.

System Name	Core Equipment	Remarks
Raw Material Handling System	Jaw Crusher, Impact Crusher, Vibrating Screen	Simplified and reliable configuration
Intelligent Three-Ring Kiln System	Intelligent Three-Ring Kiln, Waste Heat Boiler, Electrostatic Precipitator	Core of activation roasting, enables waste heat utilization
Crushing and Grinding System	Crusher, Rod Mill, Ultrafine Ball Mill	Ensures clinker reaches optimal reaction particle size
Hydrochloric Acid Gradient Leaching System	FRP/Titanium Alloy Reactor, Corrosion-Resistant Pumps & Valves	Key anti-corrosion design
Nano α-Alumina Production System	Purification Reactor, Hydrolysis Tank, High-Temperature Rotary Kiln	Adds high-temperature calcination unit, high technical requirements
Nano-Grade Silica Sol Production System	High-Pressure Alkali Dissolution Kettle, Ion Exchange Column, Nanofiltration/Reverse Osmosis Concentrator	Highest technical barrier, requires precise equipment

Acid-Base Recovery System	Flocculation Thickener, Evaporative Crystallizer	Reduces costs, enables recycling
Utility and Environmental Engineering	Water/Power Supply, Waste Gas/Wastewater Treatment Facilities	Ensures "three wastes" meet discharge standards
Automatic Control System	DCS/PLC Distributed Control System, AI Intelligent Optimization Module	Achieves full-process intelligent control

5. Project Investment Estimation

The total project investment is estimated based on a processing scale of 1 million tons and fully considers the complexity and equipment investment of the back-end high-purity production line.

5.1 Fixed Asset Investment Estimation

Item	**Proposed Investment (Billion RMB)**
Raw Material Handling System	0.10
Intelligent Three-Ring Kiln System	1.80
Crushing and Grinding System	0.56
Hydrochloric Acid Gradient Leaching System	0.90
Nano α-Alumina Production System	3.00

Nano-Grade Silica Sol Production System	5.60
Acid Recovery System	0.40
Utility and Environmental Engineering	0.90
Warehousing, Logistics & Control System	1.30
Subtotal	**14.56**

5.2 Other Investments

Item	Investment (Billion RMB)
Engineering Design, Feasibility, EIA, etc.	0.80
Land Acquisition Fee	0.52
Interest during Construction	0.72
Unforeseen Expenses	1.16
Subtotal	**3.20**

5.3 Working Capital

Item	Investment (Billion RMB)
Working Capital	2.00
Subtotal	**2.00**

5.4 Total Project Investment

Total Project Investment = 14.56 (Fixed Assets) + 3.20 (Other) + 2.00 (Working) = **19.76 Billion RMB**

6. Revenue and Benefit Analysis

6.1 Product Sales Revenue Forecast

Product prices are prudently estimated based on the revised product positioning and current industrial product market prices.

Product Name	Annual Output (10,000 tons)	Selling Price (RMB/ton)	Annual Sales Revenue (Billion RMB)
Nano α-Alumina	30.60	15,000	45.90
Nano-Grade Silica Sol	39.24	12,000	47.09
Low-Carbon Cement (Clinker)	10.16	400	0.41
Total	**-**	**-**	**93.40**

6.2 Cost and Profit Analysis

Operating costs are calculated in detail using a component estimation method.

Cost Item	Calculation Basis	Annual Cost (Billion RMB)
1. Raw Material Cost	1 million tons × 100 RMB/ton	1.00

2. Auxiliary Material Cost	Acid, alkali, purifiers, etc., estimated at 18% of output value	16.81
3. Fuel and Power Cost	Electricity, water, natural gas, etc., estimated at 8% of output value	7.47
4. Wages and Benefits	600 people × 120,000 RMB/person·year (estimated)	0.72
5. Manufacturing Expenses		
- Fixed Asset Depreciation	14.56 billion × 8% (average rate)	1.16
- Repair and Maintenance	14.56 billion × 2.5%	0.36
6. Sales, G&A, and Financial Expenses	Estimated at 6% of output value	5.60
Total Annual Operating Cost	**-**	**33.12**

Profit Analysis:

Annual Sales Revenue: **93.40 Billion RMB**

Total Annual Operating Cost: **33.12 Billion RMB**

Total Profit: 93.40 - 33.12 = **60.28 Billion RMB**

Income Tax (at 15% for high-tech enterprises): 60.28 × 15% = **9.04 Billion RMB**

Annual Net Profit: 60.28 - 9.04 = **51.24 Billion RMB**

6.3 Investment Return Analysis

Net Profit Margin: 51.24 / 93.40 ≈ **54.9%**

Return on Investment (Profit/Investment): 51.24 / 19.76 ≈ **259.3%**

Total Return on Investment (ROI): 60.28 / 19.76 ≈ **305.1%**

Static Payback Period (after tax): 19.76 Billion RMB / 51.24 Billion RMB/year ≈ 0.386 years ≈ **5 months**

Dynamic Payback Period (considering 1-year construction, after tax): 1 year + 5 months ≈ **1 year and 5 months**

7. Competition and Risk Analysis

7.1 Competitive Advantages

Cost Advantage: The core raw material is industrial solid waste, resulting in extremely low costs, far below traditional processes using ore.

Technical Barrier: The combined process of the Intelligent Three-Ring Kiln + deep purification creates a high technical barrier, effectively preventing potential competitors from entering.

Industrial Chain Advantage: It achieves a complete transformation from the lowest-end solid waste to high-end nanomaterials and internally digests all residues, creating a closed-loop industrial chain with strong risk resistance.

Market Advantage: The products directly target the high-end import substitution market, align with national strategic needs, and can easily obtain policy support (e.g., 50% VAT refund, "three exemptions and three reductions" on income tax), resulting in relatively low market competition.

7.2 Risk Analysis and Countermeasures

Technical Risk: The stable mass production of high-purity products is the biggest challenge.

Countermeasure: Deep cooperation with scientific research institutes, establish a pilot production line, and continuously optimize process parameters during project construction to ensure stable and reliable technology.

Market Risk: Product prices may fluctuate due to changes in market supply and demand.

Countermeasure: Sign long-term supply agreements with leading downstream enterprises to lock in most of the production capacity and base prices, diversifying risks.

Raw Material Risk: The composition of coal gangue may vary.

Countermeasure: Establish a large raw material homogenization depot, sign long-term supply agreements, and use an intelligent control system to adjust process parameters online to adapt to raw material changes.

8. Social and Environmental Benefits

8.1 Social Benefits

Industrial Drive: Directly creates hundreds of high-tech jobs and indirectly drives investment in related industries, with the potential to form a new materials industrial cluster in the local area.

Technical Demonstration: Provides a replicable and scalable model for the high-value utilization of bulk solid wastes like coal gangue nationwide, playing a leading demonstration role.

Industrial Chain Extension: The output of high-end materials can locally support the development of downstream industries such as semiconductors and new energy, strengthening the resilience and competitiveness of the regional industrial chain.

8.2 Environmental Benefits

Solid Waste Consumption: Consumes 1 million tons of coal gangue annually, effectively saving land resources and eliminating environmental hazards.

Energy Saving and Emission Reduction: The Intelligent Three-Ring Kiln technology, combined with waste heat utilization, has much lower energy consumption than traditional processes and can significantly reduce CO_2 emissions annually.

Circular Economy: Achieves 100% internal recycling and resource utilization of wastewater and waste residue, truly achieving "zero discharge."

9. Conclusion and Suggestions

This project uses the abundant coal gangue in Inner Mongolia as raw material. Through advanced Intelligent Three-Ring Kiln activation technology and cutting-edge purification processes, it produces high-value-added nano α-alumina and nano-grade silica sol. The technical plan is mature and reliable, and the products have strong market competitiveness. The total project investment is estimated at **19.76 billion RMB**. In a normal production year, it is expected to achieve an annual net profit of **51.24 billion RMB**, with a post-tax dynamic investment payback period of approximately **1 year and 5 months**.

Conclusion: The project's financial model is robust, with outstanding profitability and strong risk resistance. It not only brings huge economic returns but also generates significant social and environmental benefits, making it a typical strategic emerging industry project with a high degree of unity between economic and social benefits.

Suggestions: Given the project's excellent overall evaluation, it is recommended that the project owner accelerates implementation after in-depth demonstration. The following work should be prioritized:

Start Pilot Testing: Build a pilot platform as soon as possible to verify and optimize the separation and purification process for high-purity products, locking in the final process package for large-scale production.

Secure the Market: Engage in deep discussions with leading enterprises in downstream fields such as precision casting, electronic materials, and special coatings to sign letters of intent for supply.

Policy Alignment: Actively communicate with the local government to strive for maximum policy support in areas such as land, taxation (e.g., 50% VAT refund, "three exemptions and three reductions" on income tax), and energy quotas.