Comprehensive Solution for High-Value Utilization of High-Alumina Flint in Tisdale, Canada via "Saskatchewan Process"

Coupled with Intelligent Three-Ring Kiln Activation Calcination Technology

— Technical Promotion and Cooperation Plan for Canadian Partners

This proposal aims to present a disruptive technical path targeting the abundant high-alumina flint resources in the Tisdale region of Saskatchewan, Canada. The core objective is the production of electrolytic aluminum while achieving a "squeeze dry and clean" style of comprehensive resource utilization. The core of this path is the deep integration of the local Canadian "Saskatchewan Process" (acid-based aluminum extraction technology) with the internationally leading "Intelligent Three-Ring Kiln Activation Calcination System" owned by Shandong Heningshun Kiln Industry Co., Ltd. Through the Intelligent Three-Ring Kiln's disruptive "direct firing of lump materials and precise activation" technology, the front-end links of the traditional process are completely reshaped from the source. This achieves a leapfrog breakthrough: "halving front-end investment, reducing calcination energy consumption by 60%, increasing aluminum recovery rates, and increasing the value of silicon-based co-products by N times". This proposal details the new integrated technical path and flow chart, and systematically analyzes its outstanding "1+1>2" performance. It aims to demonstrate to Canadian partners a path for cooperative development that is technologically advanced, economically competitive, and environmentally exemplary, jointly opening a new era of non-bauxite aluminum extraction technology.

I. Analysis of the Saskatchewan Process and its Traditional Bottlenecks

The "Saskatchewan Process" was developed by the Saskatchewan Research Council (SRC) as an acid-based aluminum extraction process specifically for kaolin-type minerals (such as high-alumina flint). Its basic principles and process are as follows:

1. **Raw Ore Pre-treatment:** Based on the Mohs hardness of the ore, the high-alumina flint raw ore is crushed and ground to a particle size of 10-20 mesh (the Mohs hardness of the material is directly proportional to the processing mesh size).

2. **Traditional Calcination Activation:** The processed high-alumina flint powder (mainly kaolinite, $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) is heated in a traditional kiln (such as a rotary kiln) to 650-850°C to remove structural water, converting it into chemically active amorphous metakaolin ($Al_2O_3 \cdot 2SiO_2$).

3. **Hydrochloric Acid Leaching:** Concentrated hydrochloric acid (HCl) is used to leach the activated metakaolin. Active alumina (Al_2O_3) reacts with hydrochloric acid to produce soluble aluminum chloride ($AlCl_3$), while silicon dioxide (SiO_2) largely does not react and remains in solid form.

4. **Impurity Removal and Purification:** The leachate usually contains impurity ions such as iron (e.g., $FeCl_3$), which need to be separated via solvent extraction or other chemical methods to obtain a pure aluminum chloride solution.

5. **Crystallization and Decomposition:** Hydrogen chloride gas is introduced into the purified aluminum chloride solution to crystallize aluminum chloride hexahydrate ($AlCl_3 \cdot 6H_2O$). Subsequently, the crystals are thermally decomposed in a calciner at a specific temperature to finally obtain metallurgical grade alumina (Al_2O_3), while recycling the hydrogen chloride gas.

6. **Electrolytic Aluminum Production:** The metallurgical grade alumina is sent to an electrolytic cell for electrolysis using the Hall–Héroult process to produce metallic aluminum.

Analysis of Core Bottlenecks in Traditional Processes:

While the Saskatchewan Process is mature in chemical principles, its overall economics and environmental performance are constrained by the **first and second steps—raw ore pre-treatment and traditional calcination activation**. The high hardness of flint poses three fundamental challenges for pre-treatment and the use of traditional equipment like rotary kilns:

Exorbitant Pre-treatment Costs: Traditional kilns cannot handle large lump materials. The hard flint must be multi-stage crushed and finely ground into powder or small particles. This process requires huge equipment investment, consumes astonishing amounts of energy, and causes serious dust pollution.

Low and Uneven Calcination Efficiency: The thermal efficiency of traditional kilns is generally lower than 50%, with serious heat loss. More critically, their heat transfer method leads to extremely uneven heating of powder materials, easily causing the phenomenon of "outer scorched, inner raw" (the exterior is over-burnt forming an inert phase, while the interior is not thoroughly activated). The material activation degree is often less than 70%, leading to low and fluctuating product activity (Loss on Ignition is often 3-8%), which directly affects the aluminum dissolution rate and acid consumption in the subsequent acid leaching step.

Huge Environmental Pressure: The open or semi-open structure of traditional kilns leads to prominent unorganized emissions of flue gas and dust. End-of-pipe treatment costs are high, making it difficult to meet increasingly strict environmental regulations.

These three bottlenecks are precisely the entry points where the Intelligent Three-Ring Kiln technology can solve problems perfectly and achieve disruptive optimization.

II. Revolutionary Core Equipment—Intelligent Three-Ring Kiln Activation Calcination System

The Intelligent Three-Ring Kiln is a disruptive major thermal equipment for which China Shandong Heningshun Kiln Industry Co., Ltd. possesses completely independent intellectual property rights. It fundamentally reconstructs the calcination logic of lump and heterogeneous materials. Its core advantages align perfectly with the needs of this project:

1. **Disruptive "Direct Firing of Lump Materials" Process:** This is the global pioneering core technology of the Intelligent Three-Ring Kiln, capable of directly processing large lump materials ranging from 3-30 cm. Applied to the Tisdale project, this means the flint raw ore only needs simple primary crushing and screening (e.g., selecting 1-7cm lumps) to be directly fed into the kiln. This **completely eliminates the secondary crushing and fine grinding systems** of the traditional process, which are high in cost and energy consumption, greatly simplifying the front-end process and saving massive equipment investment and operating costs.

2. **"Precise Activation" Quality Assurance:** The kiln realizes extremely precise control over the material activation process through unique "three-temperature zone gradient heating" and "smoldering homogenization" technologies.

Three-Temperature Zone Step Activation: The kiln body is vertically designed with three zones: preheating, decomposition, and activation. This ensures that flint lumps undergo the transformation from kaolinite to highly active metakaolin gently, evenly, and deeply under the optimal temperature curve, with a **material average activation rate exceeding 95%**.

Smoldering Homogenization Technology: A slow-cooling homogenization section at the kiln bottom lasting 24-36 hours utilizes the material's own residual heat to complete residual reactions. This thoroughly solves the century-old problem of "undercooked" lumps, ensuring highly uniform product quality. The **Loss on Ignition (LOI) is stably below 1%**, far superior to the 3-8% level of traditional kilns. This directly translates into higher aluminum dissolution rates, shorter reaction times, and lower acid consumption in the subsequent acid leaching step.

3. **"Closed-Loop Circulation" Energy Efficiency Innovation:** The Intelligent Three-Ring Kiln utilizes a precise four-stage waste heat closed-loop circulation system to "squeeze dry" thermal energy, achieving a **comprehensive thermal efficiency as high as 85.2%**, which is more than 1.7 times that of traditional rotary kilns (<50%). This means that for calcining the same amount of flint, **energy costs can be reduced by 40-60%**. Recovered waste heat can also be used for raw material drying and steam power generation (can support a 3.2MW generator set), further reducing total plant operating costs.

4. **"Near-Zero Emissions" Environmental Friendliness:** The system embeds environmental protection within the process. Through the integration of technologies such as wet activation desulfurization, heavy metal vitrification, and nano-fiber bag filtration, emissions of pollutants like SO_2 and dust are far better than the strictest international standards. This fully complies with Canada's high standards for environmental protection, which will greatly simplify the project's EIA process and reduce environmental investment.

III. The Deeply Integrated "Saskatchewan-Heningshun" New Technical Path

With producing high-purity aluminum as the primary goal, and achieving high-value utilization of all resources, we have planned a new "comprehensive valorization" technical path composed of the following five major sections:

Section 1: Raw Material Pre-treatment and Intelligent Three-Ring Kiln Efficient Activation Section

Goal: To prepare metakaolin clinker with stable composition and high chemical activity at the lowest cost.

Process:

1. **Coarse Crushing & Screening:** Mined Tisdale high-alumina flint ore is processed into **1-7cm lumps** via a primary crusher and vibrating screen. Material larger than 7cm is returned for crushing; fines smaller than 1cm are sent directly to Section 4 as raw material for silicon-based materials.

2. **Pre-homogenization Yard:** Qualified lumps enter the pre-homogenization yard and are mixed evenly through a "flat stacking and vertical reclaiming" method to ensure stable chemical composition of the kiln feed.

3. **Intelligent Three-Ring Kiln Activation Calcination:** Homogenized flint lumps are sent into the Intelligent Three-Ring Kiln. Inside the kiln, they pass through the **Preheating Dehydration Zone (approx. 120-350°C)**, the **Core Decomposition Activation Zone (approx. 700-900°C)**, and the **Cooling Setting Zone**. The kaolinite lattice is fully and uniformly decomposed into highly active amorphous metakaolin (Active $Al_2O_3 \cdot 2SiO_2$), with an activation rate exceeding 95%. All waste heat at the kiln tail is recovered.

Section 2: Selective Acid Leaching Aluminum Extraction and Solid-Liquid Separation Section

Goal: Use hydrochloric acid to selectively dissolve active alumina, achieving efficient separation of aluminum and silicon components.

Process:

1. **Activated Material Cooling & Transport:** Highly active clinker discharged from the Intelligent Three-Ring Kiln is cooled and transported directly to the acid leaching section. **Note: Unlike alkaline processes, fine grinding is not required here**; it only needs to be crushed to a particle size suitable for reaction, or even small granular clinker can be used directly, further reducing costs.

2. **Hydrochloric Acid Leaching Reaction:** In a corrosion-resistant reactor, the active clinker is mixed with regenerated and supplementary concentrated hydrochloric acid. Due to the extremely high activity of the clinker, the reaction proceeds rapidly under milder conditions. Active Al_2O_3 quickly reacts to form soluble $AlCl_3$, while highly stable amorphous SiO_2 remains in the solid phase.

3. **Solid-Liquid Separation:** The reacted slurry passes through a filter press or settling

tank to separate the leachate rich in $AlCl_3$ (crude liquor) from the solid residue rich in SiO_2 (silicon residue).

Section 3: High Purity Alumina Product Preparation Section

Goal: Prepare metallurgical grade alumina from the crude leachate and achieve closed-loop acid circulation.

Process:

1. **Iron Removal Purification:** Advanced solvent extraction or ion exchange technology is used to efficiently remove impurity ions such as Fe^{3+} from the leachate, obtaining a high-purity $AlCl_3$ solution.

2. **Crystallization & Separation:** HCl gas from the subsequent calcination process is introduced into the pure $AlCl_3$ solution. Using the common-ion effect, "salting out" crystallization occurs, producing high-purity $AlCl_3 \cdot 6H_2O$ crystals.

3. **Crystal Calcination:** $AlCl_3 \cdot 6H_2O$ crystals are sent to a dedicated decomposition furnace and calcined at a temperature of about 1000-1100 °C to decompose into metallurgical grade alumina (Al_2O_3) powder, simultaneously releasing high-concentration HCl gas.

4. **Acid Circulation:** The HCl gas produced by calcination is cooled, absorbed, and returned to the crystallization and leaching processes, achieving a high degree of closed-loop acid circulation and greatly reducing acid consumption and production costs.

5. **Electrolytic Aluminum:** The produced metallurgical grade alumina enters the aluminum electrolysis process to produce metallic aluminum ingots.

Section 4: Full High-Value Utilization of Silicon-Based Co-Products Section

Goal: Turn the silicon residue separated in Section 2 from "waste into treasure," developing a high-end silicon-based new material industry chain and achieving "zero solid waste".

Process:

1. **Silicon Residue Washing & Purification:** Silicon residue from Section 2 undergoes multiple counter-current washings to thoroughly remove entrained chlorides, yielding high-purity wet amorphous silica.

2. **High-End Product Preparation:** Based on this high-purity, high-activity silica raw material, one or more high-value-added product lines can be developed:

Nano Silica Sol: Through specific chemical treatments, nano silica sol with controllable particle size (e.g., 28±3nm) can be prepared. This is the core polishing liquid for semiconductor chip Chemical Mechanical Polishing (CMP), possessing extremely high market value and capable of breaking existing technical monopolies.

High-End White Carbon Black: After precipitation, filtration, and drying, high-performance white carbon black with a specific surface area exceeding $200m^2/g$ can be prepared. Its reinforcing performance far exceeds traditional products, making it a key material for manufacturing green energy-saving tires.

Silicon-Carbon Anode Material: By further reducing silica and compositing it with carbon materials, silicon-carbon anode materials with a specific capacity exceeding 550mAh/g can be prepared, far surpassing traditional graphite anodes (372mAh/g). This is a key solution to solving "range anxiety" for next-generation high-energy-density power batteries.

LC3 Low-Carbon Cement Raw Material: Even as a basic application, this high-activity amorphous silica is an ideal "calcined clay" raw material for producing LC3 low-carbon cement. It can replace up to 50% of cement clinker, reducing carbon emissions in the cement production process by over 40%.

Section 5: Systemic Circulation and Near-Zero Emission Section

Goal: Integrate the energy and material flows of the entire plant to achieve ultimate resource utilization and environmental friendliness.

Process:

1. **Energy Cascade Utilization:** Waste heat recovered by the Intelligent Three-Ring Kiln is prioritized for drying flint raw materials (if needed) and silicon residue products, or driving waste heat boilers for power generation, providing cheap electricity and steam for the whole plant.

2. **Material Closed-Loop Circulation:** Hydrochloric acid achieves over 98% closed-loop circulation in Sections 2 and 3. Most process water is recycled after treatment, with minimal wastewater discharge.

3. **Standard-Compliant Waste Gas Emission:** Waste gas from the entire process, especially from the Intelligent Three-Ring Kiln and the alumina decomposition furnace,

undergoes high-efficiency treatment to ensure all emission indicators are far superior to Canadian environmental standards.

IV. Outstanding "1+1>2" Performance of the Integrated Solution

Integrating the Intelligent Three-Ring Kiln technology into the Saskatchewan Process is not a simple equipment replacement, but a systemic reconstruction and value leap for the entire industrial chain.

1. **Revolutionary Simplification of Front-End Process, Significant Reduction in CAPEX:** Relying on the "direct firing of lumps" capability, the expensive, complex, and high-energy-consuming secondary crushing and fine grinding systems are completely eliminated. It is estimated that **equipment investment in the front-end section can be reduced by more than 40%**, and the construction period significantly shortened.

2. **Disruptive Reduction in Core Energy Consumption, Huge OPEX Advantage:** The 85.2% comprehensive thermal efficiency of the Intelligent Three-Ring Kiln reduces the unit energy consumption of flint activation calcination by **40-60%**. Combined with waste heat power generation and high acid circulation, the energy and raw material costs of the entire plant become extremely competitive in the market.

3. **Significant Improvement in Main Product Yield and Quality:** The high-activity, highly uniform metakaolin clinker (activation rate >95%, LOI <1%) produced by the Intelligent Three-Ring Kiln ensures a **higher and more stable aluminum dissolution rate in the acid leaching section (expected to reach >95%, higher than traditional processes)**. This improves the total yield of final electrolytic aluminum and may reduce the difficulty of subsequent purification due to stable product quality.

4. **Exponential Growth in Co-Product Value, "Zero Waste" Becomes "Total Treasure":** Silicon residue produced by traditional processes is mostly regarded as low-value solid waste. However, this solution obtains high-purity, high-activity silica through precise activation and efficient separation, laying the foundation for developing frontier silicon-based materials needed by strategic emerging industries like semiconductors and new energy. The value of co-products leaps from a few hundred Canadian dollars/ton to thousands or even tens of thousands of Canadian dollars/ton. **The profits created may equal those of the main alumina product**, completely changing the project's profit structure.

5. **Excellent Whole-Process Green Low-Carbon Performance, Aligning with Global Sustainability Trends:** From the calcination source saving 40-60% energy to the end-product of low-carbon materials like LC3 cement, the carbon footprint of the entire process path is far lower than any traditional route. Combined with near-zero emission environmental performance, this project is not only an economic project but also a green industrial model fitting ESG (Environmental, Social, and Governance) concepts. This helps gain broad support from the government, community, and financial institutions, and prepares fully for potential future carbon taxes and carbon trading.

V. New Technical Path Flow Chart

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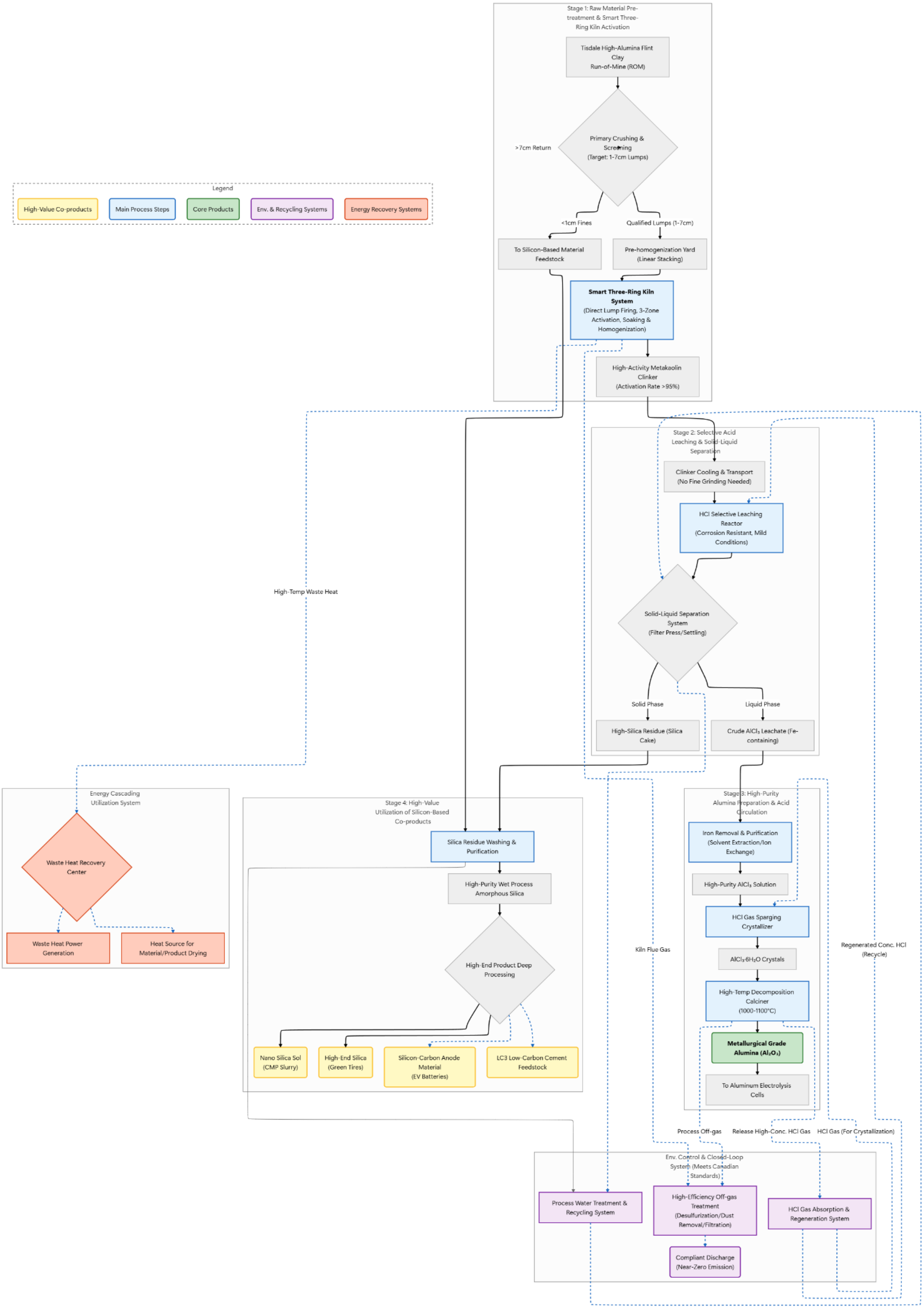
Tisdale High-Alumina Flint Clay Integrated Treatment Project 'Saskatchewan-Hening Shun' Deep Fusion Process Flow



VI. Cooperation and Outlook

The high-alumina flint in the Tisdale region of Canada is an "Urban Mine" with huge potential. The Saskatchewan Process provides the chemical principle foundation for its development, while the Intelligent Three-Ring Kiln Activation Calcination System gives it the wings to achieve commercialization, greening, and high-value utilization. The "Saskatchewan-Heningshun" deeply integrated technical path we propose is a strong alliance in the truest sense. It systematically solves all the core pain points of traditional processes, constructing a new industrial chain with lower investment, lower costs, higher value, and a better environment.

This is not just a technology export and cooperation, but the joint construction of an industrial ecosystem and a win-win situation. We believe that with your deep understanding of local resources and markets, combined with our core technical advantages in disruptive thermal equipment and process integration, deep cooperation between both parties will surely build a global technological benchmark and commercial model in the field of non-bauxite aluminum extraction in Tisdale.

China Shandong Heningshun Kiln Industry Co., Ltd. is full of anticipation for this cooperation and proposes that both parties form a joint technical team to conduct more detailed feasibility studies, material testing, and economic model calculations based on this plan. We are willing to join hands with Canadian partners with the most open attitude to turn this grand blueprint into reality.

China Heningshun Kiln Industry Co., Ltd.

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