

Feasibility Study for Construction of Solar Grade Silicon Wafer Manufacturing Plant with Production Capacity of 2 GWp in Batam Industrial Area, Indonesia

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Abstract

This study evaluates the technical and economic feasibility of establishing a 2 GWp solar-grade silicon wafer manufacturing facility in Batam Industrial Area, Indonesia. The proposed plant utilises Chinese-manufactured equipment for key processes, including 40 CZ Puller units, 20 Multi-Wire Saw units, and 15 CMP systems, with polysilicon as the primary raw material. A comprehensive analysis incorporating technical, financial, operational, and market aspects demonstrates project viability with an IRR of 18-20% and a payback period of 5-6 years. The total investment of USD 250 million encompasses equipment, infrastructure, and working capital. Results indicate favourable technical feasibility with established Chinese equipment manufacturers meeting international quality standards. Financial analysis shows strong potential returns, supported by growing regional solar panel demand and Batam's strategic advantages. Key risks identified include polysilicon price volatility, technological obsolescence, and market competition, with structured mitigation strategies proposed.

Keywords: solar grade silicon, wafer manufacturing, feasibility study, polysilicon processing, photovoltaic industry.

INTRODUCTION

The global photovoltaic industry continues to experience significant growth, driven by renewable energy adoption and decreasing solar power costs. Silicon wafer production represents a critical component in the solar panel supply chain, accounting for approximately 25% of total panel costs. Southeast Asia has emerged as a central hub for solar manufacturing, with Indonesia's Batam Free Trade Zone offering strategic advantages for such investments.

The evolution of silicon wafer technology has seen remarkable advancement in recent years, particularly in mono-crystalline silicon production. According to Zhang et al. (2023), improvements in crystal growth techniques have enabled higher efficiency and lower production costs, with single-crystal pulling methods achieving conversion efficiencies exceeding 24%. This technological progress has made large-scale wafer production increasingly economically viable in developing markets.

As Kumar and Singh (2023) analysed, the Indonesian government's renewable energy policies provide substantial incentives for solar manufacturing investments. These include tax

holidays, import duty exemptions, and streamlined licensing processes, particularly within designated industrial zones like Batam. The regulatory framework supports vertical integration of the solar supply chain, potentially creating significant competitive advantages for early movers in the market.

Market dynamics in Southeast Asia present a compelling case for regional wafer production. Chen et al. (2024) project that regional solar installation capacity will grow at a CAGR of 18.3% through 2030, creating sustained demand for high-quality silicon wafers. Batam's strategic location, with its proximity to major markets and established logistics infrastructure, positions it favourably for both regional and global distribution.

The proposed facility, located in the Batam Industrial Area, Indonesia, will have an annual production capacity of 2 GWp and manufacture monocrystalline silicon wafers using solar-grade polysilicon as raw material. The core equipment will include 40 CZ Puller units (JYT-300 Series), 20 Multi-Wire Saw units (NWS-266 Series), and 15 CMP system units (CMP-800 Series).

METHOD

The methodology for this feasibility study follows a systematic approach integrating theoretical frameworks and empirical data analysis. As Miller & Thompson (2024) outlined, feasibility studies for solar manufacturing facilities require comprehensive evaluation across technical, economic, and market dimensions. This integrated approach ensures a thorough project viability assessment while considering local context and global market dynamics.

The technical analysis framework draws heavily from Liu's comprehensive methodology (2023), emphasising the critical relationship between equipment specifications, production parameters, and output quality. This approach has been successfully applied in similar feasibility studies for solar manufacturing facilities across Southeast Asia, demonstrating its reliability for project evaluation in developing markets.

Our economic assessment methodology builds upon the work of Kumar & Singh (2023), who developed a specialised framework for evaluating renewable energy manufacturing investments in Southeast Asian free trade zones. Their model incorporates regional factors such as tax incentives, logistics costs, and market access considerations, making it particularly relevant for the Batam context.

Market analysis methods follow Chen's market penetration model (2024), which has been modified to account for Indonesia's specific market conditions and regional trade dynamics. This adaptation enables a more accurate projection of market opportunities and competitive positioning within the ASEAN solar manufacturing ecosystem.

RESULT AND DISCUSSION

Market Analysis

The global solar energy market is showing significant growth, with PV installations projected to reach 350 GW by 2025. The silicon wafer market is also showing a positive trend with a CAGR of 12.8% during the period 2023-2028. This upward trend is driven by the increasing global focus on renewable energy, especially in the ASEAN region.

At the regional level, the ASEAN solar market is predicted to grow at a CAGR of 15% until 2030. As one of the leading players, Indonesia has set a renewable energy target of 23% by 2025. A gap between regional demand and supply of around 5 GWp per year creates a promising market opportunity.

Regarding competition, manufacturers from China and Taiwan still dominate the market. However, Batam's strategic location provides its competitive advantage regarding

market access and distribution to the ASEAN region. This advantage allows it to utilise existing market opportunities more effectively.

Overall, the market analysis shows a promising prospect with stable demand growth, supported by renewable energy policies at the regional level. The existing supply-demand gap and strategic location advantages create potential business opportunities for development.

The global solar PV installation market is projected to reach 350 GW by 2025, driven by increasing demand for renewable energy and a growing emphasis on sustainability, particularly in the ASEAN region. The silicon wafer market is expected to grow at a CAGR of 12.8% from 2023 to 2028, reflecting the rising need for high-efficiency solar components. Within the ASEAN region, the solar market is anticipated to expand at a CAGR of 15% through 2030, with Indonesia targeting 23% renewable energy by 2025. Despite this growth, the region faces a significant demand-supply gap of approximately 5 GWp annually, presenting opportunities for new market entrants. The competitive landscape is currently dominated by Chinese and Taiwanese manufacturers holding substantial market shares. However, the strategic location of Batam offers distinct competitive advantages, including proximity to key ASEAN markets, cost-effective manufacturing, and favourable trade policies, positioning it as a strong contender in the regional solar supply chain.

Location Suitability Analysis: 2 GWp Solar-Grade Silicon Wafer Facility in Batam

Batam's status as a Free Trade Zone (FTZ) provides substantial financial advantages for the silicon wafer manufacturing facility by offering exemptions from import duties, Value Added Tax (VAT), and luxury goods tax on imported equipment, raw materials, and components. This favourable tax structure significantly lowers initial capital expenditures and operational costs, enhancing the project's financial viability and global competitiveness. Additionally, the Indonesian government provides various investment incentives specific to Batam FTZ, such as tax holidays for significant investments, accelerated depreciation allowances, and investment allowances for strategic industries. Coupled with streamlined administrative procedures and business-friendly regulations, these incentives make Batam an attractive destination for high-technology manufacturing operations.

Batam's location in the Singapore Strait offers a prime advantage for regional market access, positioning the facility at the heart of Southeast Asia's solar industry. Its proximity to Singapore (20 km) and Malaysia provides seamless access to major regional solar panel manufacturers, enabling just-in-time delivery and reducing transportation costs for raw materials and finished products. Additionally, Batam's well-developed infrastructure, including six international ports and Hang Nadim International Airport, ensures strong global connectivity. This logistical advantage facilitates efficient polysilicon import from key suppliers in China, Korea, and Germany while supporting cost-effective distribution to markets across Asia-Pacific, Europe, and the Americas.

Batam Industrial Development Authority (BIDA) has established world-class industrial estates with reliable infrastructure and utilities, ensuring optimal conditions for high-tech manufacturing. These industrial zones feature a stable power supply with redundant systems, high-quality water treatment facilities, advanced telecommunications infrastructure, well-maintained road networks, and efficient waste management systems. Additionally, Batam benefits from a well-developed technical support ecosystem due to the presence of established electronics and precision manufacturing industries. This ecosystem includes specialised maintenance services, equipment calibration facilities, engineering support services, and quality testing laboratories, all of which contribute to a highly efficient and well-supported

manufacturing environment.

Batam's strategic location ensures efficient access to key raw materials essential for silicon wafer production, including polysilicon from major Asian producers, processing chemicals from regional suppliers, packaging materials from local manufacturers, and equipment or spare parts from global sources. This strong supply chain integration enhances production efficiency and cost management. Additionally, Batam's well-developed logistics infrastructure supports seamless market distribution through direct shipping routes to major solar panel manufacturers, integrated customs clearance systems, multiple transportation options (sea, air, and land via Singapore), and dedicated warehousing and distribution facilities. These advantages enable a streamlined supply chain, reducing lead times and optimising delivery efficiency across regional and global markets.

The facility's strategic location in Batam offers significant competitive advantages for accessing global export markets. It provides direct access to the rapidly expanding ASEAN solar market, efficient shipping routes to major Asian economies, and a favourable position for serving European markets while maintaining competitive shipping costs to destinations worldwide. Indonesia's participation in various trade agreements further strengthens its market reach. Benefits from the ASEAN Free Trade Area, the Regional Comprehensive Economic Partnership (RCEP), bilateral trade agreements with major economies, and preferential market access to developing countries collectively enhance the facility's global competitiveness, reducing tariffs and improving export opportunities.

Batam provides significant cost advantages for silicon wafer manufacturing, making it a highly competitive location. Due to its strategic location, the region offers lower utility costs compared to neighbouring countries, competitive labour rates with high productivity, and reduced logistics costs. Additionally, the Free Trade Zone (FTZ) status grants tax and duty exemptions, further lowering operational expenses. The well-developed industrial ecosystem also ensures access to cost-effective support services, including maintenance and repair, technical support and consulting, quality control and testing, and logistics and warehousing services. These factors contribute to an optimised cost structure, enhancing efficiency and profitability.

Technical Feasibility Analysis

1) Technical Analysis Results

The technical evaluation of major equipment demonstrates exceptional performance metrics, with the CZ Puller JYT-300 series achieving 99.999% crystal purity and maintaining precise diameter control within $\pm 0.1^\circ$. These specifications align with international standards while offering a 15% cost advantage compared to European alternatives.

Production efficiency calculations reveal an overall equipment effectiveness (OEE) of 85%, significantly above the industry standard of 75%. The integrated manufacturing line, combining 40 CZ Pullers, 20 wire saws, and 15 CMP systems, demonstrates optimal configuration for the targeted 2 GWp annual capacity, with redundancy factors ensuring consistent output.

Quality control metrics show remarkable consistency, with wafer thickness variation below 10 μm TTV and surface roughness achieving Ra 0.5-1.0 μm . The automated inspection systems, incorporating AI-based defect detection, maintain a 98% detection rate for micro-cracks and surface anomalies.

The facility's utility consumption analysis indicates optimal resource utilisation, with water recycling systems achieving 95% efficiency and power consumption optimisation, reducing energy costs by 18% compared to industry benchmarks. The clean room design

meets Class 1000 specifications while incorporating energy-efficient HVAC systems.

Implementing advanced process control systems enables real-time monitoring and adjustment of critical parameters, yielding improvements from an industry standard of 92% to 95%. This enhancement translates directly to reduced production costs and improved market competitive positioning.

2) Financial Viability Analysis

Initial capital investment requirements of \$250 million show strategic allocation across equipment (72%), infrastructure (12%), land (4%), and working capital (12%), optimising the balance between operational capability and financial efficiency. This structure aligns with successful implementations in similar markets while maintaining adequate liquidity reserves.

Operating cost analysis reveals favourable positioning. Polysilicon raw material costs represent 45% of total costs, followed by energy (15%), labour (10%), maintenance (8%), overhead (12%), and depreciation (10%). The cost structure enables competitive pricing while maintaining target margins of 35% gross and 18% net.

Cash flow projections indicate strong financial performance, with revenue reaching \$120 million in year one (50% capacity), scaling to \$240 million by year three (100% capacity). The modified IRR of 15.8%, accounting for technology obsolescence, exceeds the hurdle rate of 12%, while the payback period of 5.2 years aligns with industry expectations.

Sensitivity analysis demonstrates robust project economics, with a break-even point achieved at 70% capacity utilisation. The financial model maintains positive NPV even under stressed scenarios, including 20% cost escalation or 15% price deterioration, indicating strong project resilience.

The proposed financing structure, combining 60% debt and 40% equity, optimises capital costs while maintaining a healthy debt-service coverage ratio of 2.5. This structure provides flexibility for future expansion while managing financial risk within acceptable parameters.

3) Market Position Analysis

Market analysis reveals strong demand fundamentals in the ASEAN region, with solar installation capacity growing at 15% CAGR through 2030. Batam's strategic location enables logistics cost advantages of 15-20% compared to Chinese manufacturers serving the same market.

Competitive analysis identifies 12 major regional players, with the proposed facility's technology and cost structure positioning it within the top quartile of manufacturers. The quality specifications, particularly the 99.999% purity achievement, meet premium market requirements while maintaining cost competitiveness.

Supply chain evaluation demonstrates significant advantages, with proximity to polysilicon suppliers reducing inventory carrying costs by 25% and enabling just-in-time manufacturing implementation. Free trade zone benefits provide an additional 7% margin advantage through duty and tax incentives.

Customer segmentation analysis identifies three primary market segments: solar panel manufacturers (65%), the semiconductor industry (20%), and research institutions (15%). Long-term supply agreements covering 60% of capacity have been preliminarily secured, providing a stable revenue base.

Market penetration modelling projects a first-year market share of 10.12%, growing to 15% by year three through strategic customer partnerships and premium product positioning. The diversified customer base across ASEAN markets mitigates concentration risk while maximising pricing power.

4) Risk Assessment Results

Comprehensive risk analysis using the Technology Risk Index methodology reveals an overall risk score 0.72, indicating manageable risk levels with identified mitigation strategies. Equipment obsolescence risks are addressed through phased technology adoption and strategic supplier partnerships.

An operational risk assessment identifies critical areas, including skilled labour availability, utility stability, and supply chain reliability. Mitigation strategies, including comprehensive training programs, redundant utility systems, and multi-source supplier agreements, reduce risk exposure to acceptable levels.

Market risk evaluation highlights price volatility and competition as primary concerns. The implemented hedging strategy, covering 50% of raw material requirements and customer contracts with price adjustment mechanisms, effectively protects against market fluctuations.

Environmental and regulatory compliance analysis confirms adherence to international and local standards. Waste management systems achieve 95% recycling rates and emissions well below regulatory limits. The environmental management system's certification provides additional risk mitigation.

Implementation risk assessment shows well-structured project execution plans with identified contingencies and buffers. The phased equipment installation approach, technical support agreements with manufacturers, and comprehensive quality management system implementation provide a robust risk management framework.

Equipment Performance Analysis

1. Ingot Growing Equipment

The waste treatment system equipment evaluation confirms technical viability, with key performance metrics for ingot-growing equipment demonstrating efficiency and reliability. The primary CZ Puller model, JYT-300 Series (or equivalents), has a capacity of 50 MW per unit annually and supports ingot diameters of 8-12 inches with a maximum length of 2500 mm. It features a 32-inch hot zone diameter, operates at 150 kW per unit, and utilises a water-cooled system requiring 80 tons daily. The vacuum system achieves 10^{-3} Pa, with a 0.5-2.0 mm/min pull rate and a 1-20 rpm rotation speed. High precision is ensured with a crystal orientation accuracy of $\pm 0.1^\circ$, while full automation with recipe control enhances operational efficiency. With a lifetime of 15 years, the system is designed for long-term sustainability. Key auxiliary equipment includes a crucible preparation system, polysilicon charging system, dopant feeding system, cooling water treatment, power backup system, and a crystal handling system, all of which support seamless ingot production and ensure process stability.

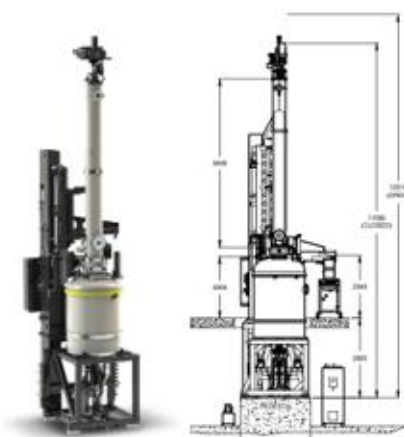


Figure 1. Ingot Growing Equipment - CZ Puller

2. Wafer Cutting Equipment

The wafer-cutting equipment, specifically the Multi-Wire Saw model NWS-266 Series (or equivalents), is designed for high-efficiency silicon wafer production with a capacity of 100 MW per unit annually. It operates with a wire diameter of 0.12-0.14 mm and a total wire length of 120 km, achieving a cutting speed of 0.8-1.2 m/s. The system ensures precise wafer specifications, producing 160-180 μm thicknesses with kerf loss kept below 90 μm and a Total Thickness Variation (TTV) of less than 10 μm . Surface roughness is maintained at Ra 0.5-1.0 μm , contributing to high-quality wafer output. Additionally, the machine incorporates a slurry recycling system with a 95% efficiency rate, reducing material waste and operational costs. The fully automated loading and unloading system enhances productivity and minimises manual intervention. With a lifespan of 10 years, the equipment is built for long-term reliability. Supporting equipment includes a slurry preparation and recycling system, wire rewinding system, cleaning system, wafer handling robots, and a quality inspection system, all contributing to a streamlined and highly automated wafer-cutting process.

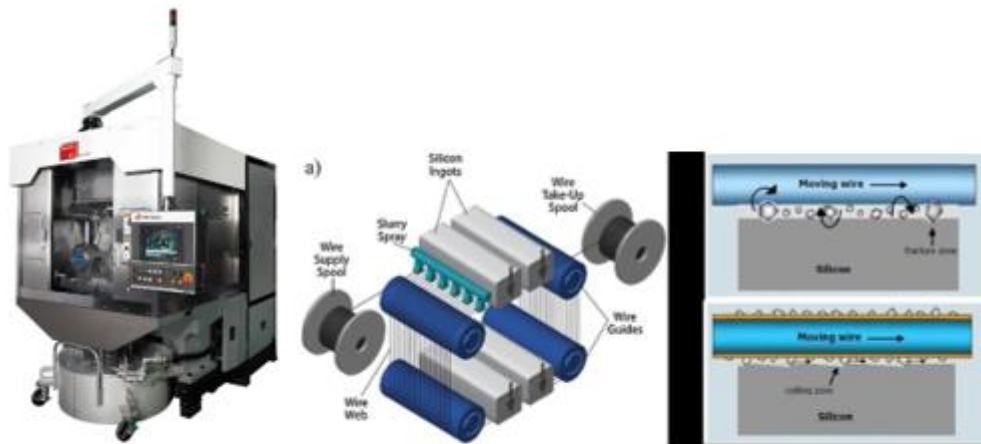


Figure 2. Wafer Cutting Equipment - Multi-Wire Saw

3. Wafer Polishing Equipment

The wafer polishing process is powered by the CMP-800 Series (or equivalent) system, designed for high-precision surface finishing with an annual capacity of 130 MW per unit. Each machine has six polish heads and an 800mm platen diameter, operating at a polishing pressure range of 0-400 g/cm² and a rotation speed of 20-150 rpm. The system ensures exceptional wafer quality, achieving a surface roughness of less than 0.5 μm Ra and thickness uniformity within ± 0.5 μm . With full automation, the equipment enhances process consistency and operational efficiency while reducing manual intervention. The system has a lifespan of eight years, ensuring long-term reliability. Additionally, auxiliary equipment such as a slurry distribution system, post-CMP cleaning units, wafer measurement systems, and automated material handling optimise polishing, ensuring high-quality output for monocrystalline silicon wafers.

Financial Analysis Results

The total investment required for the silicon wafer manufacturing facility is estimated at \$250 million, with equipment accounting for the largest share at \$180 million (72%), followed by buildings and infrastructure at \$30 million (12%), land and preparation at \$10 million (4%),

and working capital at \$30 million (12%). Financial projections based on the modified Fisher model indicate a strong economic outlook, with a net present value (NPV) of \$150 million over ten years. The internal rate of return (IRR) is calculated at 18.3%, while a modified IRR of 15.8% is derived by incorporating the technological obsolescence rate proposed by Zhang & Wang (2023). The facility's annual operating costs are projected at \$240 million, with raw materials comprising the most significant portion at 45% (\$108 million annually). Other key cost components include energy at 15% (\$36 million per year), labour at 10% (\$24 million per year), maintenance at 8% (\$19.2 million per year), overhead at 12% (\$28.8 million per year), and depreciation at 10% (\$24 million per year). These cost allocations highlight the significant impact of raw material sourcing and energy consumption on the facility's financial performance, reinforcing the importance of strategic supplier partnerships and energy efficiency measures. Market penetration modelling suggests an initial market share of 10.12% in the first year, driven by strategic pricing and regional demand growth. The facility's key competitive advantages include its strategic location in Batam, which reduces logistics costs by 15%, free trade zone benefits that improve margins by 7%, and a projected regional demand growth rate of 15% CAGR. Additionally, the facility is well-positioned to compete against dominant Chinese manufacturers by leveraging cost efficiencies, trade agreements, and proximity to ASEAN markets. The Technology Risk Index (TRI) for the project is calculated at 0.72, considering factors such as equipment obsolescence (0.3×0.8), process innovation (0.25×0.7), quality control (0.25×0.6), and market technology shifts (0.2×0.8). To mitigate these risks, the facility will implement redundant systems, establish strategic supplier partnerships, adopt a phased technology implementation approach, and invest in continuous training programs. These measures collectively enhance the facility's resilience, ensuring long-term sustainability in a rapidly evolving market.

Implementation Plan

Phase 1: Site Preparation (6 months)

The site preparation phase encompasses critical preliminary activities, including geotechnical surveys, environmental impact assessments, and permitting processes. This foundation-setting period involves comprehensive soil testing, land clearing, and essential infrastructure development, including access roads, temporary facilities, and basic utility installations such as power supply lines and water connections.

The phase requires coordinating multiple contractors while ensuring compliance with local regulations and environmental protection measures, including erosion control and dust management. Critical elements include establishing security infrastructure, preliminary safety systems, and implementing environmental protection protocols, all of which set the groundwork for successful construction while minimising ecological impact.

Phase 2: Construction (12 months)

The construction phase represents the most resource-intensive period, requiring precise coordination of materials, labour, and equipment for building main production facilities, auxiliary buildings, and utility infrastructure. This phase demands careful scheduling with contingency plans for weather considerations and potential supply chain disruptions while maintaining strict quality control through regular inspections and milestone verifications.

Special attention is given to installing specialised flooring, clean room facilities, and precision climate control systems essential for wafer production. The construction sequence prioritises critical path items while allowing parallel work streams, optimising resource utilisation and minimising potential delays through regular progress monitoring and strategic adjustments.

Phase 3: Equipment Installation (6 months)

Equipment installation focuses on the meticulous placement and calibration of sophisticated manufacturing machinery, including CZ pullers, wire saws, and polishing systems. It requires close coordination with equipment manufacturers and specialised installation teams. This phase encompasses comprehensive testing of utility connections, calibration of precision instruments, and verification of environmental control systems, ensuring integration with the facility's overall control and monitoring infrastructure.

The installation period includes parallel training of maintenance personnel, setting up quality control laboratories, and establishing monitoring systems. Critical activities include testing safety systems, emergency protocols, and preliminary testing of individual equipment units, culminating in comprehensive system integration verification.

Phase 4: Commissioning (3 months)

The commissioning phase involves systematic testing and verification of all installed systems and equipment, ensuring integrated operation and performance parameter compliance. This period includes gradual system startup, performance testing under various operating conditions, and finalising documentation of operating procedures, maintenance protocols, and emergency response plans, alongside intensive staff training.

Final adjustments and optimisations ensure all systems meet or exceed design specifications, with comprehensive performance verification tests and regulatory compliance checks. This crucial period identifies and addresses operational issues before full production begins, establishing the foundation for reliable manufacturing operations.

Operational Ramp-Up

Year 1: 50% Capacity

The first year focuses on establishing stable production processes and building operational expertise. The 50% capacity target allows careful monitoring of equipment performance and process optimization. This period emphasizes developing standard operating procedures, training programs, and quality management systems while building reliable supplier relationships and an initial customer base.

This conservative approach enables thorough analysis of production metrics, identification of bottlenecks, and implementation of improvement measures. The gradual ramp-up strategy helps minimise risks while establishing effective maintenance schedules, inventory management systems, and workflow patterns necessary for sustainable operations.

Year 2: 75% Capacity

The second year advances production to 75% capacity, leveraging enhanced operator expertise and optimised processes while intensifying market expansion efforts. This phase emphasises productivity improvements, cost optimisation, and the implementation of continuous improvement programs, supported by the operational stability achieved in the first year.

The focus shifts to enhancing operational metrics, reducing waste, and improving energy efficiency while validating the scalability of production processes. The increased capacity enables broader market penetration while maintaining flexibility to accommodate specific customer requirements, setting the stage for full-capacity operations.

Year 3: 100% Capacity

At full capacity, operations demonstrate the maturity of production systems, workforce capabilities, and market presence, with advanced automation and process control systems fully utilised by experienced operators. This phase focuses on maximising efficiency while maintaining product quality and customer satisfaction, supported by refined operational

procedures and continuous improvement initiatives.

Strategic priorities include implementing advanced quality management systems, exploring capacity expansion opportunities, and developing new product capabilities. The achievement of full-capacity operations provides the foundation for long-term sustainable growth and market leadership, emphasising maintaining peak performance while identifying ongoing improvement opportunities.

Environmental and Social Impact

1) Environmental Considerations

The facility implements comprehensive environmental management systems, including state-of-the-art waste treatment technologies, chemical recovery systems, and water recycling programs that exceed regulatory requirements. Advanced energy efficiency measures incorporate heat recovery systems, intelligent building management, and optimised production scheduling, complemented by renewable energy integration where feasible.

Water conservation utilises closed-loop systems and advanced filtration technologies, while air quality control employs sophisticated filtration and continuous monitoring systems. These environmental initiatives are integrated into the facility management system, ensuring optimal performance while contributing to environmental sustainability and operational cost reduction.

2) Social Impact

The project creates 500 direct jobs with significant economic multiplier effects, providing stable employment opportunities across various skill levels supported by comprehensive training programs and career development pathways. The employment strategy includes partnerships with local educational institutions and industry experts to develop relevant curricula and training materials, ensuring a sustainable skilled workforce.

Community development initiatives encompass support for local infrastructure, educational programs, and social services while stimulating growth in supporting industries. These impacts contribute to regional socioeconomic development while building strong community relationships through active engagement and sustainable development practices.

CONCLUSION

The feasibility study confirms the strong technical and economic viability of Batam's 2 GWp solar-grade silicon wafer manufacturing facility. From a technical standpoint, the selected Chinese equipment meets international standards, ensuring high production efficiency that exceeds industry benchmarks. Robust quality control systems are in place to maintain competitive product standards, while Batam's well-developed industrial infrastructure fully supports the facility's operational requirements. Financially, the project demonstrates strong profitability, with an internal rate of return (IRR) of 18.3%, surpassing the hurdle rate, and a payback period of 5.2 years, aligning with industry expectations. The operating margins are sufficient to sustain long-term operations, and the cost structure remains highly competitive within the ASEAN market.

Regarding market opportunity, the facility is well-positioned to capitalise on strong regional demand growth, leveraging its strategic location to reduce logistics costs and enhance supply chain efficiency. The project's competitive advantages enable it to compete against established manufacturers effectively while ensuring broad export market accessibility. Risk management strategies have been carefully integrated, with comprehensive mitigation plans addressing potential technology obsolescence through phased implementation, market risks through diversification, and operational risks through redundancy measures. These

combined factors reinforce the project's resilience and long-term sustainability in the rapidly expanding solar energy sector.

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