DIPONEGORO JOURNAL OF ACCOUNTING *Volume 15, Nomor 3, Tahun 2026, Halaman 1-15*
http://ejournal-s1.undip.ac.id/index.php/accounting *ISSN (Online): 2337-3806*

Financial Feasibility of Lithium-Ion Battery Recycling Facilities: A Comparative Study of the Netherlands, Japan, and Indonesia

Salsabila Rizqyana Herlambang[1] **, Adi Firman Ramadhan**[2]
Department of Accounting, Faculty of Econnomics and Business, Diponegoro University
Jl.Prof. Soedharto SH Tembalang, Semarang 50239, Phone: +6282135240978

ABSTRACT

The rapid growth of electric vehicle (EV) adoption has substantially increased global demand for lithium-ion batteries (LIBs), generating a growing volume of end-of-life batteries and raising concerns about sustainable critical mineral supply chains. Battery recycling has emerged as a strategically important solution for recovering lithium, nickel, cobalt, manganese, and copper while supporting circular economy objectives. However, the financial feasibility of LIB recycling facilities varies considerably across countries due to differences in industrial maturity, cost structures, financing conditions, and market dynamics. This study compares the financial feasibility of hypothetical LIB recycling facilities, each with an annual processing capacity of 5,000 tonnes, in the Netherlands, Japan, and Indonesia. Benchmark financial and operational data are drawn from Umicore (Netherlands) and DOWA Holdings (Japan), while assumptions for Indonesia are calibrated using percentage proxies derived from Huayou Cobalt. Net Present Value (NPV), Internal Rate of Return (IRR), and Weighted Average Cost of Capital (WACC) are applied across conservative, base case, and optimistic scenarios, and sensitivity analysis identifies the variables with the greatest impact on feasibility.

Keywords: Lithium-ion battery recycling, financial feasibility analysis, Net present value (NPV), Circular economy

INTRODUCTION

The global transition toward cleaner transportation has accelerated the adoption of electric vehicles (EVs), driving a sharp increase in demand for lithium-ion batteries (LIBs). Global EV sales surpassed 17 million units in 2024 (International Energy Agency, 2025), and this growth is expected to generate a rapidly rising volume of end-of-life batteries in the coming decade. Lithium-ion batteries contain valuable critical materials, including lithium, nickel, cobalt, manganese, and copper, so improper disposal not only creates environmental hazards but also represents a loss of recoverable resources. Battery recycling has therefore emerged as a key strategy for supporting the circular economy, reducing dependence on virgin mining, and lowering the environmental footprint of the EV supply chain (Harper et al., 2019).

From a business perspective, recycling facilities can generate revenue both from gate fees charged for accepting battery waste and from the sale of recovered metals. Profitability, however, depends on metal prices, operating costs, plant efficiency, and feedstock availability factors that vary substantially across countries because of differences in industrial maturity, labour and energy costs, and regulatory environments. Mature markets such as the Netherlands, supported by Umicore, and Japan, supported by DOWA Holdings, provide established benchmarks, while Indonesia with its large nickel reserves and growing ambitions in the EV battery supply chain remains comparatively under-researched in terms of financial feasibility, with most existing studies concentrating on technical or environmental dimensions rather than investment appraisal.

[1]. *Author*
[2]. *Supervisor*

Although prior studies have examined the technical processes and environmental benefits of battery recycling, limited research has compared the financial feasibility of recycling facilities across national contexts using a standardised investment evaluation framework. This creates a gap in understanding how financial viability differs between developed and emerging markets. Accordingly, this study compares the financial feasibility of a hypothetical LIB recycling facility with a processing capacity of 5,000 tonnes per year in the Netherlands, Japan, and Indonesia by (1) analysing the financial and operational characteristics of benchmark companies in each country; (2) estimating project-level revenue, OPEX, and CAPEX; (3) evaluating feasibility using NPV, IRR, and WACC; (4) comparing outcomes across conservative, base case, and optimistic scenarios; and (5) identifying the key drivers of feasibility through sensitivity analysis.

Based on these objectives, the study addresses the following research questions: (1) What are the financial and operational characteristics of battery recycling benchmark companies in the Netherlands, Japan, and Indonesia? (2) How do revenue structures, operating expenditures, and capital requirements differ among facilities in the three countries? (3) How financially feasible are the facilities based on NPV, IRR, and WACC analysis? (4) How do conservative, base case, and optimistic scenarios influence feasibility in each country? (5) Which variables exert the greatest influence on feasibility according to sensitivity analysis?

The Netherlands, Japan, and Indonesia were selected because each represents a distinct stage of industrial development within the LIB recycling ecosystem, enabling a meaningful cross-country comparison. The Netherlands reflects a mature European market with advanced circular economy regulation and industrial-scale recycling infrastructure, exemplified by Umicore. Japan represents an advanced Asian industrial economy with long-established urban mining and metal recovery expertise, exemplified by DOWA Holdings. Indonesia, while its recycling ecosystem remains comparatively immature, is strategically important because of its abundant nickel reserves and expanding investment in EV battery manufacturing; in the absence of a domestic industrial-scale benchmark, percentage-based cost proxies derived from Huayou Cobalt are used to approximate realistic Indonesian operating conditions.

LITERATURE REVIEW

1. Lithium-Ion Battery Recycling and the Circular Economy

The increasing adoption of electric vehicles has made lithium-ion batteries one of the most important technologies supporting the transition to sustainable transportation, owing to their high energy density, long lifespan, and charging efficiency relative to conventional battery types. This growth, however, also implies that substantial volumes of spent batteries will need to be managed over the coming decades; without proper end-of-life systems, these batteries pose environmental risks because of their hazardous chemical content (International Energy Agency, 2025). Battery recycling enables the recovery of critical raw materials for reuse in new battery production rather than treating spent batteries as waste, thereby reducing reliance on virgin mining and supporting supply chain resilience (Harper et al., 2019). Recovering metals from end-of-life batteries can also substantially lower greenhouse gas emissions relative to primary extraction, particularly for nickel and cobalt (Gaines, 2018). Economically, recycling facilities generate revenue through gate fees for processing battery waste and through the sale of recovered metals and black mass, so profitability is closely tied to commodity price volatility, recovery efficiency, and the volume of feedstock processed. Because this study compares feasibility across three markets with different levels of industrial maturity, differences in recycling ecosystem development are expected to influence investment performance independently of the underlying technology.

2. Recycling Technologies

Pyrometallurgical recycling a high-temperature smelting process is widely adopted because it can process mixed battery chemistries with relatively simple sorting, as practised by Umicore, but it consumes substantial energy and yields comparatively lower lithium recovery (Harper et al., 2019). Hydrometallurgical recycling uses chemical leaching to achieve higher recovery rates for lithium, cobalt, nickel, and manganese at lower energy intensity, though it requires more complex chemical handling and wastewater treatment (Gaines, 2018). Direct recycling, which preserves the chemical structure of electrode materials for reuse, offers further reductions in energy and processing cost but remains at an early stage of commercial adoption. Because these technologies imply different capital and operating cost profiles, technology choice is a central determinant of the financial feasibility examined in this study.

3. Cost Structure: OPEX and CAPEX

Operating expenditure (OPEX) covers the recurring costs of running a recycling facility, dominated by energy, labour, chemical reagents, transportation, and maintenance (Mayyas et al., 2019) because electricity and labour costs vary widely between mature and emerging economies, OPEX differs substantially across the Netherlands, Japan, and Indonesia. This study estimates OPEX per tonne by dividing total operating cost by annual processing capacity, enabling comparison across facilities of different scale.

Capital expenditure (CAPEX) represents the upfront investment in land, buildings, process lines, utilities, safety and environmental systems, engineering, and permitting required before operations begin, and constitutes one of the principal barriers to entry (Mayyas et al., 2019). Annual depreciation is estimated using the straight-line method to distribute total investment cost evenly across the assumed project lifetime.

4. Investment Appraisal Theory

Net Present Value (NPV) discounts a project's expected future operating cash flows to their present value and nets out initial investment; a positive NPV indicates that the project is expected to create value in excess of its cost of capital (Brealey et al., 2020). Formally, NPV is calculated as the present value of annual Operating Cash Flow (OCF), obtained by multiplying OCF by the Present Value Interest Factor of an Annuity (PVIFA) at the project's WACC over its assumed lifetime, less initial CAPEX. Internal Rate of Return (IRR) is the discount rate at which NPV equals zero and is compared against the Weighted Average Cost of Capital (WACC) a blended rate reflecting the cost of equity and debt weighted by their respective proportions in the capital structure, where the cost of equity is typically derived from the Capital Asset Pricing Model using the risk-free rate, beta, and market risk premium to determine whether a project clears its minimum required return (Ross et al., 2022). A project is accepted, in principle, when IRR exceeds WACC and NPV is positive, and rejected otherwise.

Operating Cash Flow (OCF) is derived by subtracting depreciation from EBITDA to obtain EBIT, applying the relevant corporate tax rate to EBIT, and then adding depreciation back to the after-tax result, since depreciation is a non-cash expense that nonetheless generates a tax shield. This OCF figure forms the basis for discounting under the NPV framework in each of the three country models. Sensitivity analysis, commonly visualised through a tornado diagram, tests the individual impact of key variables metal prices, gate fees, OPEX, CAPEX, plant utilisation, project lifetime, tax rate, and WACC on NPV outcomes by shifting each variable to plausible low and high bounds while holding all other assumptions at their base-case level, then ranking variables by the resulting magnitude of NPV change (Brealey et al., 2020). This approach, widely used in capital budgeting and techno-economic assessment (Avagyan et al., 2022; Thompson et al., 2021), allows analysts to distinguish variables that materially determine project viability from those with only marginal influence.

5. Regulatory and Market Context

Regulatory environments differ markedly across the three countries and shape the economics of recycling investment. The European Union's Regulation (EU) 2023/1542 on batteries and waste batteries imposes mandatory collection targets, minimum recycled-content requirements, and extended producer responsibility obligations, effectively guaranteeing a growing feedstock stream for facilities such as Umicore's and reinforcing the Netherlands' position as a mature circular-economy market (European Commission, 2023). Japan does not operate under an equivalent EU-style mandate but has developed strong voluntary and industry-led urban mining practices supported by decades of experience in non-ferrous metal recovery. Indonesia, by contrast, currently has limited domestic battery take-back infrastructure; its recycling potential is instead driven by upstream policy support for nickel processing and EV battery manufacturing rather than a mature end-of-life collection system, which introduces additional feedstock uncertainty for any recycling investment in that market.

6. Benchmark Companies

Umicore, a global materials technology and recycling company operating in a mature European market with strong circular economy regulation, is used as the benchmark for the Netherlands. DOWA Holdings, with extensive experience in urban mining and metal recovery within an advanced Asian industrial economy, is used as the benchmark for Japan. Because Indonesia lacks an industrial-scale domestic benchmark, selected operational percentages from Huayou Cobalt chosen for its regional relevance to battery supply chain development are applied as an adjustment reference rather than a direct benchmark. Benchmarking in this manner is necessary because detailed project-level financial data for standalone LIB recycling facilities are rarely disclosed publicly, so company-level financial statements are used to approximate revenue and cost structures on a per-tonne basis, which are then scaled to the standardised 5,000-tonne facility assumed in this study.

METHODOLOGY

1. Research Design

This study applies a comparative, quantitative financial feasibility design (Yin, 2018; Creswell & Creswell, 2023) to evaluate a standardised hypothetical LIB recycling facility with an annual processing capacity of 5,000 tonnes in each of the three countries. Standardising project size removes distortions caused by differences in company scale and isolates the effect of country-specific cost, financing, and market conditions on feasibility outcomes.

2. Data Sources and Benchmark Selection

Secondary data were collected from company annual reports (DOWA Holdings, 2024), institutional publications (International Energy Agency, 2025), and financial databases, including Damodaran's country risk and cost-of-capital datasets (Damodaran, 2025). Secondary data collection is appropriate when researchers analyse existing industrial and financial information that is publicly available and verifiable (Saunders et al., 2019), and it is particularly suitable in this context because battery recycling projects involve financial information that is reported through official corporate and institutional channels rather than requiring primary field measurement. Key financial variables total revenue, operating expenses, EBITDA, depreciation, net income, and processing capacity were extracted from benchmark company reports to derive revenue and OPEX per tonne. Market data on metal prices, gate fees, country risk premiums, and financing assumptions were obtained from commodity market references and central bank

publications, and all figures were standardised into comparable annual, per-tonne units.

To ensure data quality, the study follows established principles of data integrity accuracy, consistency, completeness, and comparability. Accuracy is addressed by drawing figures only from audited annual reports and recognised institutional sources; consistency is maintained by expressing all financial figures in euros and on an annual, per-tonne basis; completeness is achieved by combining multiple sources when a single benchmark report does not disclose all required variables; and comparability is preserved by applying a uniform six-step modelling procedure and an identical 5,000-tonne capacity assumption across all three countries. Because financial modelling of this kind relies on benchmark proxies rather than direct project data, the resulting NPV and IRR estimates should be interpreted as indicative feasibility signals rather than precise forecasts, a limitation that is revisited in Section 6.4.

3. Financial Modelling Procedure

For each country, the model proceeds through six steps: (1) revenue estimation from benchmark gate fee and metal recovery data; (2) projection of revenue, OPEX, and EBITDA per tonne under conservative, base case, and optimistic scenarios; (3) construction of the CAPEX structure across land, building, process lines, utilities, safety and environmental systems, engineering, and permitting, together with straight-line depreciation over an assumed 15-year project lifetime; (4) derivation of Operating Cash Flow from EBITDA, depreciation, and tax on EBIT; (5) calculation of country-specific WACC from the risk-free rate, market risk premium, beta, cost of debt, tax rate, and capital structure weights; and (6) discounting of OCF using the Present Value Interest Factor of an Annuity (PVIFA) to obtain NPV, alongside IRR, benchmarked against WACC to reach a Go / No-Go verdict for each scenario.

4. Scenario and Sensitivity Analysis

Three scenarios conservative, base case, and optimistic were constructed for each country to capture uncertainty in metal prices, gate fees, and operating efficiency. Sensitivity analysis was then applied to the base case by individually varying eight variables (metal price, OPEX per tonne, plant utilisation, project lifetime, gate fee, WACC, tax rate, and CAPEX) while holding all others constant, and the resulting NPV impacts were ranked and visualised using tornado diagrams to identify the variables most critical to project feasibility.

5. Reliability and Validity

Reliability in this study is supported by the consistent application of a single, standardised six-step financial modelling procedure across all three countries, so that any differences in outcomes can be attributed to underlying country-specific inputs rather than inconsistencies in method. Construct validity is addressed by grounding each financial variable (revenue per tonne, OPEX per tonne, CAPEX components, WACC parameters) in established investment appraisal theory and in figures reported by recognised benchmark companies or institutional sources, rather than arbitrary assumptions. External validity is necessarily bounded by the study's reliance on hypothetical, benchmark-derived facilities rather than operating recycling plants; the results should therefore be read as directionally robust comparative signals of relative feasibility across the Netherlands, Japan, and Indonesia, rather than as precise forecasts for any specific real-world project.

RESULTS AND DISCUSSION

1. The Netherlands (Benchmark: Umicore)

Umicore's 2024 financial data imply a revenue per tonne of €55,143 for a processing capacity of 7,000 tonnes per year. Scaled to a 5,000-tonne facility, base case and optimistic revenue per tonne rise to €66,171 and €71,686, while OPEX per tonne falls from €68,000 (conservative) to €57,800 (optimistic) as efficiency improves, yielding base case and optimistic EBITDA of €24.86 million and €69.43 million respectively, against a conservative EBITDA of -€64.29 million.

Table 1. CAPEX Structure the Netherlands (Project lifetime: 15 years; annual depreciation: €6,175,200)

CAPEX Component	Proportion	Amount (€)
Total CAPEX	100%	99,600,000
Land	7%	6,972,000
Building	18%	17,928,000
Process Lines	45%	44,820,000
Utilities	10%	9,960,000
Safety & Environment	9%	8,964,000
Engineering	8%	7,968,000
Permitting	3%	2,988,000

The Netherlands' WACC of 5.46% reflects a risk-free rate of 2.90%, a market risk premium of 4.33%, a beta of 1.20, a cost of debt of 5.00%, a 25.80% tax rate, and a capital structure weighted 40% equity / 60% debt.

Table 2. Investment Feasibility Summary

Indicator	Conservative	Base Case	Optimistic
Annual OCF	(€46.11M)	€20.04M	€53.11M
NPV	(€563.50M)	€102.00M	€434.75M
IRR	—	18.55%	53.23%
WACC	5.46%	5.46%	5.46%
Verdict	NO GO	GO	GO

Sensitivity analysis confirms that metal price is by far the most influential variable (total NPV impact of €1,459.62 million), followed by OPEX per tonne (€913.78 million) and plant utilisation (€111.34 million), while CAPEX, tax rate, and gate fee have comparatively modest effects. These results indicate that Dutch recycling economics, although financially viable under improved conditions, remain highly exposed to commodity price fluctuations, partly offset by a strong circular-economy policy environment (Gaines, 2018).

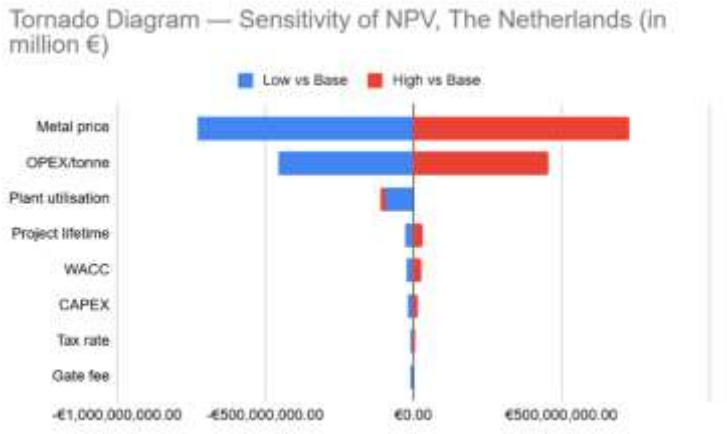


Figure 1.: Tornado Diagram of Sensitivity Analysis for the Netherlands

2. Japan (Benchmark: DOWA Holdings)

DOWA Holdings' 2024 data imply a revenue per tonne of €7,000 at a processing capacity of 14,155 tonnes per year, rising to €8,050 (base case) and €8,400 (optimistic) at the 5,000-tonne scale, while OPEX per tonne declines from €7,590 to €5,807. This yields annual EBITDA of -€2.95 million (conservative), €7.99 million (base case), and €12.97 million (optimistic).

Table 3. CAPEX and Investment Feasibility Summary

Indicator	Conservative	Base Case	Optimistic
Total CAPEX	€29,842,615	—	—
Annual OCF	(€1.88M)	€6.65M	€10.53M
NPV	(€49.75M)	€40.38M	€81.36M
IRR	—	21%	35%
WACC	4.75%	4.75%	4.75%
Verdict	NO GO	GO	GO

As in the Netherlands, metal price is the dominant driver of NPV in Japan (total impact of €180.73 million), followed by OPEX per tonne (€98.91 million) and plant utilisation (€37.58 million). Japan's comparatively low WACC driven by a low risk-free rate and low cost of debt together with its moderate CAPEX requirement of €29.8 million, positions it as a balanced middle ground between the capital-intensive Dutch market and the higher-risk Indonesian market (Brealey et al., 2020).

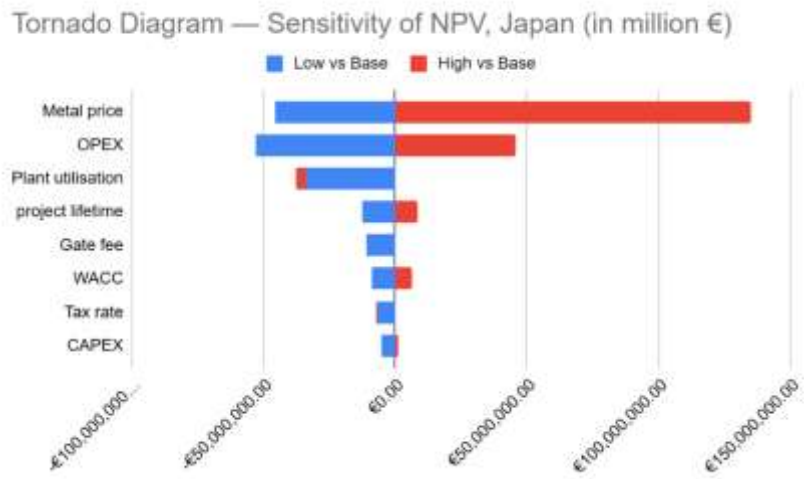


Figure 2. Tornado Diagram of Sensitivity Analysis for Japan

3. Indonesia (Benchmark: Huayou Cobalt Proxy)

Using percentage proxies derived from Huayou Cobalt, revenue per tonne rises from €4,188 (conservative) to €4,607 (base case) and €5,298 (optimistic), while OPEX per tonne falls from €4,327 to €3,310, producing annual EBITDA of –€0.70 million, €3.56 million, and €9.94 million respectively across the three scenarios.

Table 4. CAPEX and Investment Feasibility Summary

Indicator	Conservative	Base Case	Optimistic
Total CAPEX	€12,684,392	—	—
Annual OCF	(€0.37M)	€2.96M	€7.93M
NPV	(€15.72M)	€11.87M	€53.19M
IRR	—	22.14%	62.46%
WACC	8.49%	8.49%	8.49%
Verdict	NO GO	GO	GO

Indonesia offers the lowest capital entry point of the three countries and the highest percentage returns under optimistic conditions, but its WACC of 8.49% nearly 1.8 times that of the Netherlands and 1.9 times that of Japan reflects elevated emerging-market financing risk. Sensitivity analysis again ranks metal price (total impact of €80.81 million) and OPEX per tonne (€50.47 million) as the most influential variables, followed by plant utilisation, underscoring the importance of feedstock reliability in a less mature recycling ecosystem (Damodaran, 2025).

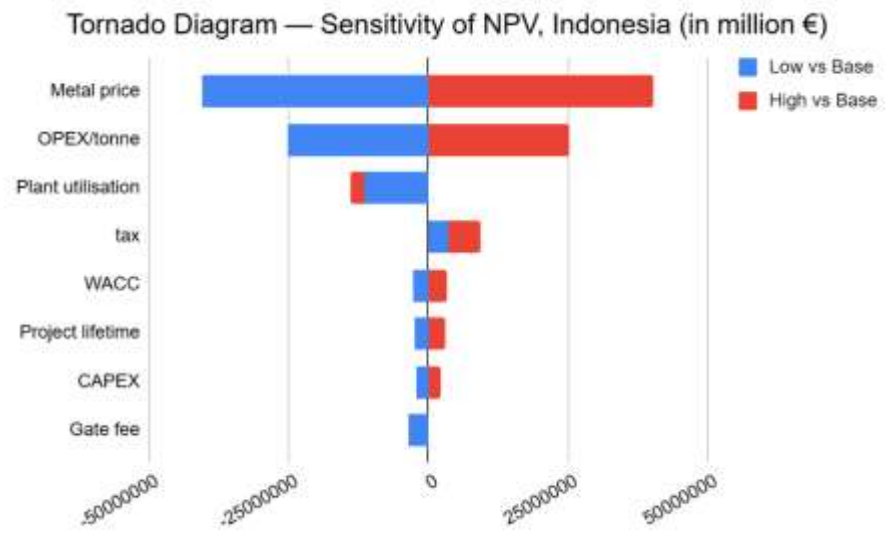


Figure 3.Tornado Diagram of Sensitivity Analysis for Indonesia

4. Discussion: Cross-Country Comparison

Table 5. Cross-Country Comparative Summary

Metric	Netherlands	Japan	Indonesia
Benchmark company	Umicore	DOWA Holdings	Huayou (proxy)
Total CAPEX	€99.60M	€29.84M	€12.68M
WACC	5.46%	4.75%	8.49%
Base case NPV	€102.00M	€40.38M	€11.87M
Optimistic NPV	€434.75M	€81.36M	€53.19M
Base case IRR	18.55%	21%	22.14%
Optimistic IRR	53.23%	35%	62.46%
Top sensitivity driver	Metal price	Metal price	Metal price

Taken together, the results reveal a consistent trade-off between capital accessibility and operational risk. The Netherlands requires the highest upfront investment (€99.6 million) but offers the largest absolute upside under optimistic conditions (NPV of €434.8 million) within a low-risk financing environment (WACC 5.46%), underpinned by mature circular-economy regulation. Japan occupies a balanced middle position, combining moderate CAPEX (€29.8 million) with the lowest cost of capital of the three countries (WACC 4.75%) and an advanced industrial base for urban mining. Indonesia presents the most accessible entry point (CAPEX of €12.7 million) and the highest percentage IRR under optimistic conditions (62%), but its higher WACC (8.49%) signals materially greater financing and country risk that investors must actively manage.

Viewed as a set, the three cases also illustrate how absolute and relative measures of return can diverge. In absolute terms, the Netherlands generates by far the largest NPV because its large capital base amplifies the euro value of

favourable cash flows once metal prices and utilisation improve; in relative terms, Indonesia generates the largest IRR because its small capital base means that even a modest absolute cash flow translates into a high percentage return. This distinction matters for capital allocation: an investor with access to large amounts of capital and a preference for scale may favour the Dutch market, whereas an investor seeking capital efficiency and rapid payback may find the Indonesian project more attractive despite its higher financing risk. Japan's position between these two extremes, combined with its lowest WACC, suggests it may appeal to investors prioritising a stable, moderate-risk entry into the recycling sector.

A striking commonality across all three markets is that the conservative scenario produced a negative NPV and a No-Go verdict in every country, while the base case and optimistic scenarios reversed this outcome with IRR comfortably exceeding WACC. This indicates that LIB recycling profitability is not an inherent property of the technology but a fragile balance between volatile commodity revenue and substantial fixed costs (Harper et al., 2019), and that achieving at least base-case operational performance is a precondition for viability rather than an optional upside.

Sensitivity analysis further shows that metal price is, without exception, the single most influential variable on NPV across the Netherlands, Japan, and Indonesia, consistent with the view that revenue volatility in battery recycling is driven primarily by commodity market dynamics rather than operational inefficiency alone (Mayyas et al., 2019). Operating expenditure per tonne is consistently the second most influential variable, while plant utilisation reflecting the reliability of feedstock supply and collection infrastructure ranks third in every country. These findings imply that, irrespective of national context, investors and operators should prioritise commodity price risk management (for example through hedging or offtake agreements), disciplined OPEX control, and secure feedstock arrangements as the core levers of project success.

The regulatory contrast described also helps explain part of the cross-country gap in financing cost and feedstock reliability. The Netherlands' EU-mandated collection and recycled-content requirements reduce feedstock uncertainty for Dutch facilities relative to Indonesia, where no equivalent take-back mandate currently exists, which is one plausible contributor to Indonesia's higher country risk premium and WACC. This suggests that policy design, and not only market fundamentals, plays a meaningful role in shaping the investment case for battery recycling, a theme developed further in the policy recommendations.

CONCLUSION, IMPLICATION, AND POLICY RECOMMENDATION

This study compared the financial feasibility of hypothetical 5,000-tonne LIB recycling facilities in the Netherlands, Japan, and Indonesia using NPV, IRR, and WACC across conservative, base case, and optimistic scenarios. The findings demonstrate that financial feasibility is highly context-dependent: no single country is universally superior across all investment dimensions. The Netherlands offers regulatory stability and strong circular-economy infrastructure at high capital cost; Japan provides a balanced combination of moderate investment, low financing cost, and advanced industrial capability; and Indonesia offers the lowest entry cost and the strongest percentage upside but requires careful management of financing risk and feedstock uncertainty.

Investment decisions should be guided by each investor's risk appetite, capital availability, and strategic objectives rather than a search for a single optimal location. No single country is universally superior across all investment dimensions: the Netherlands offers policy certainty and advanced infrastructure at high capital cost, Japan offers cost efficiency and industrial sophistication with the lowest financing risk, and Indonesia offers low entry costs and strong percentage return potential alongside higher financing and operational risk. Given the consistent dominance of metal price risk, investors should consider commodity hedging or offtake agreements to stabilise revenue over the long investment horizon, and should treat operational excellence maximising recovery efficiency, minimising energy consumption, and securing adequate feedstock as a core investment priority rather than an aspirational goal, since every conservative scenario in this study produced a negative NPV regardless of country. For investors weighing entry into an emerging market such as Indonesia specifically, structuring financing to reduce reliance on high-cost local debt for example through blended concessional finance or export credit support may help narrow the WACC gap relative to the Netherlands and Japan and thereby improve the risk-adjusted attractiveness of the investment.

Across all three countries, policymakers can support the sector by (1) establishing mandatory battery collection and take-back systems to secure feedstock supply; (2) introducing investment tax incentives for battery recycling infrastructure to offset high CAPEX; (3) supporting research, development, and technology adoption to improve recovery efficiency; and (4) developing transparent metal price risk-sharing mechanisms to reduce revenue volatility. At the country level, the Netherlands would benefit from deepening its existing circular-economy policy framework; Japan from strengthening urban-mining incentives and feedstock infrastructure; and Indonesia from building enabling infrastructure and de-risking investmentfor example through blended finance or credit guarantees to lower its comparatively high cost of capital.

This study relies on benchmark company data from Umicore, DOWA Holdings, and a Huayou Cobalt proxy, which may not fully capture standalone project-level economics given differences in company scale and product portfolio. A standardised 5,000-tonne capacity was applied across countries to ensure comparability, meaning that economies of scale were not explored. In addition, sensitivity analysis tested variables individually rather than jointly, so it does not capture the compounding effect of simultaneous adverse or favourable shifts for example, a joint decline in metal price and plant utilisation could produce a more severe NPV outcome than either variable in isolation. Future research could incorporate primary data from industry interviews or pilot facilities, examine varying capacity assumptions to assess economies of scale, and apply Monte Carlo or stochastic simulation to capture the interaction of multiple uncertain variables simultaneously. Given the rapidly evolving nature of both the EV market and recycling technology, financial assumptions should also be periodically revisited as solid-state batteries, shifting cell chemistries, and improved hydrometallurgical processes mature and begin to alter established cost and revenue structures (Gaines, 2018).

REFERENCES

Avagyan, V., Camacho, N., Van der Stede, W. A., & Stremersch, S. (2022). Financial projections in innovation selection: The role of scenario presentation, expertise, and risk. International Journal of Research in Marketing, 39(3), 726–746.

Brealey, R. A., Myers, S. C., & Allen, F. (2020). Principles of corporate finance (13th ed.). McGraw-Hill Education.

Creswell, J. W., & Creswell, J. D. (2023). Research design: Qualitative, quantitative, and mixed methods approaches (6th ed.). SAGE Publications.

Damodaran, A. (2025). Country default spreads and risk premiums. New York University Stern School of Business.

DOWA Holdings Co., Ltd. (2024). Integrated report 2024. DOWA Holdings.

Gaines, L. (2018). Lithium-ion battery recycling processes: Research towards a sustainable course. Sustainable Materials and Technologies, 17, e00068.

Harper, G., Sommerville, R., Kendrick, E., Driscoll, L., Slater, P., Stolkin, R., Walton, A., Christensen, P., Heidrich, O., Lambert, S., Abbott, A., Ryder, K., Gaines, L., & Anderson, P. (2019). Recycling lithium-ion batteries from electric vehicles. Nature, 575(7781), 75–86.

International Energy Agency. (2025). Global EV outlook 2025. IEA.

Mayyas, A., Steward, D., & Mann, M. (2019). The case for recycling: Overview and challenges in the material supply chain for automotive li-ion batteries. Sustainable Materials and Technologies, 19, e00087.

Ross, S. A., Westerfield, R. W., & Jordan, B. D. (2022). Fundamentals of corporate finance (14th ed.). McGraw-Hill Education.

Saunders, M., Lewis, P., & Thornhill, A. (2019). Research methods for business students (8th ed.). Pearson Education.

Thompson, D. L., Hartley, J. M., Lambert, S. M., Shiref, M., Harper, G. D. J., Kendrick, E., Anderson, P., Ryder, K. S., Gaines, L., & Abbott, A. P. (2021). To shred or not to shred: A comparative techno-economic assessment of lithium-ion battery recycling processes. Resources, Conservation and Recycling, 170, 105567.

Umicore. (2024). Annual report 2024. Umicore Group.

Yin, R. K. (2018). Case study research and applications: Design and methods (6th ed.). SAGE Publications.