KISAINSTITUTE

GREEN TECHNOLOGY ADOPTION IN INDONESIAN INDUSTRIES: DRIVERS, CHALLENGES, AND PERFORMANCE IMPLICATIONS

Herry Achmad Buchory[1*], Uce Karna Suganda[2], Ijang Faisal[3]

[1,2] Universitas Widyatama, Indonesia

[3] Universitas Muhammadiyah Bandung, Indonesia

[1] *Achmad.Buchory@gmail.com,* [2] *uce.karna@widyatama.ac.id,* [3] *kangijang75@gmail.com*

Abstract

Background: Indonesia faces environmental pressures from rapid industrialization. Green technology adoption offers solutions for reducing emissions and improving resource efficiency, yet adoption remains uneven across sectors.

Aims: This study investigates drivers, barriers, and performance implications of green technology adoption in Indonesian industries.

Research Method: A mixed-methods approach combined surveys of 198 firms across five sectors with 25 in-depth interviews. Data were analyzed using PLS-SEM and thematic analysis.

Results and Conclusion: Regulatory pressure (β=0.38), customer demand (β=0.41), and cost benefits (β=0.35) drive adoption. Major barriers include high costs (71%), lack of expertise (64%), and insufficient support (59%). Adopters reported 26% emissions reduction, 32% energy efficiency gains, 23% water conservation, and 29% waste reduction. Comprehensive policies, incentives, and capacity building are needed to accelerate adoption.

Contribution: This research provides empirical evidence on green technology adoption in developing economies, offering insights for policymakers and industry practitioners.

Keywords: Green Technology, Environmental Innovation, Sustainability, Manufacturing, Indonesia, Technology Adoption

Introduction

Environmental sustainability has emerged as critical strategic imperative for Indonesian manufacturing sectors amid escalating ecological challenges, resource scarcity pressures, and intensifying stakeholder expectations for responsible business

practices. Industrial manufacturing activities contribute approximately 24% of national greenhouse gas emissions while consuming substantial water resources, generating significant waste streams, and creating various forms of environmental pollution. The convergence of environmental degradation concerns, resource constraint realities, and climate change impact urgencies necessitates fundamental transformation in how manufacturing firms conceptualize operations, measure performance, and pursue competitive advantage in increasingly sustainability-conscious markets.

Green technologies encompass diverse innovations enabling environmental performance improvements through cleaner production processes, renewable energy utilization, waste reduction systems, emissions control mechanisms, and circular economy practices. These technological solutions promise multiple benefits including regulatory compliance achievement, operational cost reduction through resource efficiency, competitive differentiation in environmentally-conscious markets, and contribution to broader societal sustainability goals. For Indonesian manufacturers facing mounting environmental pressures alongside persistent cost competitiveness challenges, green technologies represent potential pathways toward reconciling environmental responsibility with economic viability.

However, despite growing awareness of environmental imperatives and expanding availability of green technology solutions, adoption rates across Indonesian manufacturing sectors remain disappointingly suboptimal. Many firms maintain conventional technologies and production practices despite escalating environmental risks, tightening regulatory requirements, and demonstrable green technology benefits documented in existing literature. This adoption-awareness gap suggests that significant barriers—whether financial, technical, organizational, or institutional—impede widespread green technology implementation. Understanding these barrier dynamics alongside adoption drivers provides essential foundation for accelerating sustainable industrial transformation.

Indonesian manufacturing firms operate within unique institutional contexts shaping green technology adoption patterns distinctly from developed economy counterparts. Regulatory frameworks have evolved substantially in recent years, with Ministry of Environment and Forestry establishing increasingly stringent environmental standards and implementing public environmental performance rating programs like PROPER (Program for Pollution Control, Evaluation and Rating). However, enforcement consistency varies considerably across regions and firm sizes, while regulatory capacity limitations challenge comprehensive implementation. Market pressures similarly demonstrate heterogeneity, with export-oriented firms serving international

supply chains facing stricter sustainability requirements than domestic-focused enterprises serving local markets with less demanding environmental expectations.

Resource availability constraints constitute another distinctive emerging market characteristic influencing adoption patterns. Most Indonesian manufacturers operate with limited financial resources, restricted access to formal financing, and constrained technical capabilities compared to multinational corporations or developed economy firms. These resource limitations create particular challenges for green technology adoption given substantial initial investment requirements, technical complexity demanding specialized expertise, and uncertain payback periods creating financial risk concerns. Additionally, technology service provider availability remains limited outside major urban centers, constraining access to implementation support, maintenance services, and technical troubleshooting assistance.

Existing green technology adoption literature has predominantly examined Western developed economy contexts, leaving significant knowledge gaps regarding emerging market adoption dynamics. Institutional theory suggests that regulatory pressures, normative expectations, and mimetic processes drive organizational adoption of environmental practices. However, institutional environment differences between developed and emerging economies—including enforcement effectiveness, stakeholder power dynamics, and cultural orientations toward environmental issues—raise questions about developed economy framework applicability. Similarly, resource-based view posits that green capabilities constitute strategic resources generating competitive advantages, yet resource constraint realities in emerging markets may fundamentally alter capability development processes and competitive advantage mechanisms.

This research addresses these knowledge gaps by examining green technology adoption across Indonesian manufacturing sectors through integrated institutional and resource-based theoretical lenses. The investigation focuses specifically on understanding: what institutional and organizational factors drive green technology adoption decisions among Indonesian manufacturers; what barriers impede implementation despite apparent benefits; how adoption patterns vary across technology types, industry sectors, and firm characteristics; and what performance implications—both environmental and economic—result from varying green technology adoption levels. By examining these questions within Indonesian emerging market contexts, this study generates insights applicable to sustainable industrial development across comparable developing economies facing similar institutional environments and resource constraint realities.

Research Method

This investigation employed cross-sectional survey research design targeting Indonesian manufacturing firms across diverse industrial sectors and geographic regions. The survey approach enabled statistical examination of adoption patterns, driver-barrier dynamics, and performance relationships across broader sample populations than case study methodologies permit, while maintaining practical feasibility constraints compared to longitudinal designs requiring extended timeframes beyond project scope limitations.

The sampling framework targeted manufacturing firms meeting Indonesian government SME and large enterprise definitions: annual revenue exceeding IDR 300 million and employing minimum 5 workers. Industry sector stratification encompassed five major manufacturing categories: automotive components (18% of final sample), chemicals and plastics (17%), food and beverage processing (16%), textiles and garments (15%), electronics (14%), and other manufacturing sectors (20%). This sectoral diversity enabled examination of adoption pattern variations across industries with different environmental impact profiles, regulatory exposure levels, and technological characteristics.

Geographic sampling distribution reflected Indonesian industrial concentration patterns while ensuring representation from multiple regions. Java island, hosting majority of manufacturing activity, contributed 68% of sample firms distributed across Jakarta, West Java, Central Java, and East Java provinces. Sumatra contributed 21% from North Sumatra, South Sumatra, and Lampung. Remaining 11% represented Kalimantan, Sulawesi, and Bali manufacturing clusters. This geographic spread enabled consideration of infrastructure availability variations, regulatory enforcement differences, and market characteristic diversity across Indonesian regions.

Sample recruitment employed multiple approaches maximizing response rates while minimizing selection bias. Initial firm identification utilized Ministry of Industry manufacturing firm databases supplemented by industry association membership directories. Contact establishment proceeded through email invitations explaining research objectives, assuring confidentiality, and requesting participation. Follow-up telephone contacts with non-responding firms enhanced response rates. From 386 firms contacted, 198 provided complete usable responses representing 51.3% response rate—acceptable for organizational surveys addressing sensitive environmental performance topics potentially perceived as exposing compliance shortfalls or competitive weaknesses.

Data collection employed structured questionnaires administered to environmental managers, sustainability officers, or operations directors possessing detailed knowledge of firm environmental practices and technology adoption. Questionnaire design incorporated multiple sections addressing: (1) organizational characteristics including size, age, ownership structure, export orientation, and ISO 14001 certification status; (2) green technology adoption levels across renewable energy systems, waste reduction technologies, emissions control equipment, water treatment innovations, and energy efficiency improvements; (3) perceived adoption drivers encompassing regulatory pressures, customer requirements, cost reduction expectations, competitive positioning motivations, and reputation enhancement objectives; (4) experienced barriers including financial constraints, technical complexity, knowledge gaps, supplier availability, and organizational resistance; (5) environmental performance outcomes measured through emissions intensity, energy efficiency, water consumption, and waste generation metrics; (6) economic performance implications including operational cost changes, revenue impacts, and competitive position assessments.

Measurement instrument development followed established scale adaptation procedures. Green technology adoption items were adapted from Zhu et al. (2013) green supply chain management scales and Albort-Morant et al. (2016) environmental innovation measures, modified for Indonesian manufacturing contexts through expert panel review involving three academics specializing in environmental management and two industry practitioners with sustainability expertise. Adoption driver and barrier items drew from institutional theory and resource-based view frameworks, operationalized through indicators relevant to Indonesian regulatory environments and resource availability contexts. Performance outcome measures incorporated objective metrics where firm records permitted alongside perceptual assessments of performance changes attributable to green technology adoption.

Pilot testing procedures enhanced instrument validity and reliability. Initial questionnaire versions underwent cognitive interviews with five manufacturing managers assessing question clarity, response format appropriateness, and completion time requirements. Revisions addressed ambiguous wording and eliminated redundant items. Subsequent pilot administration to 25 manufacturing firms enabled preliminary reliability analysis, revealing acceptable Cronbach alpha coefficients ($\alpha > 0.75$) for multi-item constructs. Final instrument modifications incorporated pilot feedback regarding question sequencing and instruction clarification.

Statistical analysis procedures addressed multiple research objectives through appropriate techniques. Descriptive statistics characterized sample demographics,

adoption prevalence across technology types, and driver-barrier frequency distributions. Logistic regression examined green technology adoption determinants, with binary dependent variables indicating adoption presence/absence for each technology category and independent variables encompassing organizational characteristics, institutional pressures, and organizational capabilities. Hierarchical model specifications enabled assessment of incremental explanatory power contributed by different predictor categories. Performance impact analysis employed correlation analysis and multiple regression examining relationships between green technology adoption sophistication indices and environmental-economic outcome measures, controlling for firm characteristics potentially confounding performance relationships.

Methodological rigor considerations addressed multiple validity and reliability concerns. Common method bias mitigation strategies included temporal separation between predictor and outcome variable collection where feasible, procedural remedies through questionnaire design emphasizing anonymity and question ordering variations, and statistical remedies through Harman single-factor tests confirming absence of dominant common method variance. Non-response bias assessment compared early versus late respondent characteristics, revealing no significant differences suggesting response pattern independence from firm characteristics. Measurement model assessment confirmed construct reliability, convergent validity (AVE > 0.50), and discriminant validity (Fornell-Larcker criterion satisfaction) prerequisites for structural relationship interpretation.

Results and Discussion

Descriptive analysis revealed moderate overall green technology adoption rates with substantial variation across technology types and industry sectors. Renewable energy adoption, encompassing solar photovoltaic installations, biogas systems, and biomass energy utilization, reached 34% of surveyed firms. Solar adoption predominated due to declining equipment costs, government subsidy program availability, and straightforward implementation requirements compared to biogas or biomass alternatives requiring more complex infrastructure and feedstock management. Waste reduction technology adoption showed 41% prevalence, including recycling systems, material recovery processes, and circular economy initiatives. Higher waste technology adoption rates likely reflect immediate cost saving potential through material recovery and waste disposal cost reduction, creating stronger business case justification compared to technologies delivering primarily environmental rather than financial benefits.

Emissions control technology adoption demonstrated 39% prevalence across surveyed firms, encompassing air pollution control equipment, wastewater treatment systems, and hazardous waste management facilities. Adoption concentration appeared highest among large firms and sectors facing stricter environmental regulations, suggesting regulatory compliance as primary driver for emissions control investments. Water treatment innovation adoption reached 37%, including water recycling systems, treatment process improvements, and water efficiency technologies. Energy efficiency equipment showed highest overall adoption at 52%, spanning LED lighting systems, high-efficiency motors, variable frequency drives, heat recovery systems, and building insulation improvements. The notably higher energy efficiency adoption likely stems from attractive payback periods, relatively low implementation complexity, and immediate operational cost reduction visibility enhancing management support for adoption.

Industry sector analysis revealed significant adoption pattern variations reflecting differential regulatory exposure, environmental impact characteristics, and technology applicability. Chemical and plastics manufacturers demonstrated highest overall green technology adoption rates (averaging 2.8 technologies per firm), likely driven by stringent environmental regulations governing emissions and waste from chemical processing activities. Food and beverage processing firms showed moderate adoption (2.1 technologies average), concentrating on waste reduction and water treatment technologies addressing organic waste streams and water-intensive production processes. Electronics manufacturers exhibited relatively high adoption (2.6 technologies average), particularly of energy efficiency and emissions control technologies relevant to precision manufacturing requiring controlled environmental conditions. Textile and garment firms demonstrated lower adoption (1.7 technologies average) despite substantial water consumption and chemical usage, potentially reflecting financial constraint severity in price-competitive apparel sectors and limited technology availability specifically addressing textile environmental challenges. Automotive component manufacturers showed moderate-to-high adoption (2.4 technologies average), particularly among export-oriented firms supplying international automotive manufacturers with stringent supplier environmental standards.

Logistic regression analysis examining green technology adoption determinants revealed significant relationships between institutional pressures, organizational capabilities, and adoption likelihood. Regulatory compliance pressures emerged as significant adoption driver ($\beta=0.38$, $p<0.01$), with firms reporting stronger perceived regulatory requirements demonstrating substantially higher adoption probabilities. However, effect magnitude remained moderate rather than dominant, suggesting

regulatory pressures alone insufficient for widespread adoption without complementary motivations or enabling conditions. This finding aligns with institutional theory predictions while highlighting enforcement effectiveness importance—regulatory requirements create adoption pressures only when firms perceive credible compliance verification and meaningful penalty risks.

Customer requirements demonstrated strong positive influence on adoption ($\beta=0.41$, $p<0.001$), particularly pronounced among export-oriented firms serving international supply chains with established supplier sustainability assessment programs. Multinational corporation purchasing policies increasingly incorporate environmental performance criteria, creating market-mediated pressures complementing regulatory requirements. Cost reduction expectations similarly influenced adoption significantly ($\beta=0.35$, $p<0.01$), though primarily for technologies with clear operational savings like energy efficiency equipment rather than emissions control or waste treatment technologies delivering primarily compliance rather than financial benefits. Reputation enhancement motivations showed moderate positive effects ($\beta=0.31$, $p<0.05$), concentrated among larger firms and branded manufacturers where stakeholder perceptions significantly impact market positioning.

Organizational capability variables demonstrated critical enabling roles moderating relationships between external pressures and actual adoption. Top management environmental commitment emerged as particularly influential ($\beta=0.42$, $p<0.001$), with leadership support facilitating resource allocation, organizational change management, and cultural transformation necessary for successful implementation. Financial resource availability showed expected positive effects ($\beta=0.36$, $p<0.01$), confirming that resource constraints constitute binding adoption barriers regardless of motivational pressures. Technical capability levels, measured through workforce skills and engineering expertise, demonstrated significant positive influence ($\beta=0.33$, $p<0.01$), highlighting human capital importance for technology implementation and optimization.

Barrier analysis identified financial investment requirements as overwhelmingly predominant constraint, cited by 71% of respondents as significant or very significant adoption impediment. Green technology implementation often requires substantial capital expenditures—ranging from IDR 50-200 million for basic energy efficiency upgrades to IDR 500 million-2 billion for comprehensive renewable energy or advanced waste treatment systems. These investment levels represent formidable challenges for resource-constrained SMEs operating with limited working capital and minimal access to formal financing. Even for technologies with attractive payback periods, upfront capital requirements create financing gaps when internal cash

generation proves insufficient and external financing remains unavailable or prohibitively expensive.

Technical complexity concerns ranked second among barriers (64% citation rate), encompassing multiple dimensions: integration challenges with existing production systems, operational disruption risks during implementation, ongoing maintenance requirements demanding specialized expertise, and optimization difficulties requiring experimentation and learning. These complexity concerns prove particularly acute for SMEs lacking in-house engineering capabilities or resources to engage external technical consultants. Knowledge and information gaps represented third major barrier category (59% citation), including uncertainty about technology options, limited awareness of performance benefits, incomplete understanding of implementation requirements, and insufficient information about financing options or government support programs.

Environmental performance analysis demonstrated significant positive correlations between green technology adoption sophistication and multiple outcome dimensions. Emissions reduction achievements averaged 26% among firms with advanced green technology adoption compared to basic or non-adopters, driven primarily by pollution control equipment installation and process modifications reducing generation of air pollutants, wastewater contaminants, and hazardous wastes. Energy efficiency improvements showed even stronger effects, with advanced adopters achieving average 32% energy consumption reductions per production unit through equipment upgrades, heat recovery implementations, and process optimizations. These efficiency gains translated directly to operational cost savings while simultaneously reducing carbon footprints.

Water conservation demonstrated 23% average improvement among high green technology adopters, particularly pronounced in water-intensive industries like food processing, textiles, and chemicals. Water recycling systems, treatment process improvements, and consumption efficiency technologies enabled substantial usage reductions alleviating both operational cost pressures in water-scarce regions and environmental impacts from water extraction and wastewater discharge. Waste reduction achievements reached 29% among advanced adopters through material recovery systems, process waste minimization, and circular economy initiatives converting waste streams into valuable by-products or recyclable materials.

Economic performance relationships proved more complex and nuanced than environmental outcomes. Operational cost savings averaged 12-15% among firms with mature green technology implementations, driven primarily by energy efficiency gains

and waste reduction benefits. However, these savings materialized only after initial learning curve periods and optimization efforts—early implementation stages often experienced temporary efficiency decreases and increased costs during technology shakedown and workforce training phases. Revenue impacts showed high variance with no consistent positive relationship, suggesting green technology adoption alone insufficient for revenue growth without complementary marketing capabilities leveraging environmental performance for competitive differentiation.

Competitive advantage enhancement emerged primarily through specific mechanisms rather than universal effects: customer requirements fulfillment enabling retention of environmentally-demanding clients; regulatory compliance achievement avoiding penalties and operational disruptions; cost advantages from efficiency improvements in resource-intensive industries; and sustainability reputation building supporting premium positioning or stakeholder relationship strengthening. These mechanisms proved most valuable for export-oriented firms, branded manufacturers, and companies serving business-to-business markets where purchasing organizations actively assess supplier environmental performance.

Discussion of these findings reveals several important theoretical and practical implications. Theoretically, results extend institutional theory by demonstrating that while regulatory and normative pressures create adoption motivations, organizational capabilities critically mediate pressure-adoption relationships. Resource constraints can effectively nullify external pressures when firms lack financial resources or technical capabilities to respond. This suggests institutional theory requires capability-based contingencies when applied to resource-constrained emerging market contexts. The finding that green technology adoption generates substantial environmental performance improvements but more variable economic benefits also contributes to natural resource-based view by clarifying conditions under which environmental capabilities generate competitive advantages versus operating primarily as stakeholder expectation responses.

Practically, findings inform multiple stakeholder groups navigating green technology adoption challenges. For manufacturing firms, results highlight importance of strategic technology selection aligned with firm-specific environmental challenges, resource availability realities, and capability development priorities rather than comprehensive adoption regardless of contextual fit. Phased implementation beginning with financially attractive technologies like energy efficiency equipment can generate operational savings funding subsequent adoption of compliance-oriented technologies with less immediate financial returns. For technology vendors and service providers, findings underscore needs for financing solution development, implementation support

services reducing complexity barriers, and knowledge transfer programs building client capabilities for effective technology utilization and optimization.

For policymakers, results suggest that while regulatory pressures motivate adoption, financial and technical barrier mitigation requires complementary policy interventions. Subsidy programs, tax incentives, and green financing mechanisms can address capital availability constraints. Technical assistance programs, demonstration projects, and knowledge sharing platforms can reduce information gaps and complexity concerns. Regulatory enforcement consistency improvements enhance compliance pressure credibility while technology standard specifications and certification programs reduce selection uncertainty. Comprehensive policy approaches addressing both adoption motivations and barrier mitigation prove more effective than regulatory requirements alone for accelerating sustainable industrial transformation.

Conclusion

This research provides comprehensive empirical analysis of green technology adoption dynamics within Indonesian manufacturing sectors, revealing complex interplay among institutional drivers, organizational capabilities, implementation barriers, and performance implications. Regulatory compliance pressures, customer environmental requirements, and cost reduction expectations emerge as primary adoption motivators, though their effects depend critically on organizational capabilities including top management commitment, financial resource availability, and technical expertise. Investment cost requirements constitute predominant adoption barrier alongside technical complexity concerns and knowledge gaps, creating particular challenges for resource-constrained SMEs lacking access to financing and technical support.

Green technology adoption sophistication correlates significantly with substantial environmental performance improvements including emissions reduction (26%), energy efficiency gains (32%), water conservation (23%), and waste minimization (29%). Economic benefits prove more variable, with operational cost savings averaging 12-15% among mature implementations but moderated by initial investment requirements, learning curve challenges, and absence of universal revenue enhancement effects. Competitive advantages accrue primarily through specific mechanisms including customer requirement fulfillment, compliance achievement, efficiency-based cost advantages, and reputation enhancement rather than automatically following from adoption.

The study contributes theoretically by extending institutional theory and natural resource-based view into emerging market manufacturing contexts while identifying organizational capabilities as critical mediators between institutional pressures and

adoption outcomes. Methodologically, the large-sample survey design enables statistical generalization while sectoral and geographic diversity support external validity across Indonesian manufacturing contexts. Practically, findings inform firm technology adoption strategies emphasizing strategic selectivity and capability development, technology vendor service offerings addressing barrier mitigation, and policy interventions balancing regulatory pressures with financial and technical support mechanisms.

Future research should examine several important extensions. Longitudinal investigations tracking green technology adoption evolution over time would illuminate temporal dynamics including capability development processes, performance outcome trajectories, and adoption sustainability patterns. Comparative analyses across Southeast Asian manufacturing sectors would enhance understanding of institutional context effects and regional variation patterns. Technology-specific deep dives examining particular green technologies like renewable energy or circular economy systems would generate implementation guidance beyond general adoption pattern insights. Finally, performance mechanism investigations elucidating how green technologies translate into competitive advantages under varying market, industry, and capability conditions would advance both theoretical understanding and practical implementation guidance supporting sustainable industrial transformation in Indonesia and comparable emerging economies.

References

Buchory, H. A., Suganda, U. K., & Aripin, Z. (2024). Dynamics of Cooperation and Competition Strategies in Performance Determination. KISA Institute, 1(4), 1-18.

Aripin, Z., Matriadi, F., & Ermeila, S. (2023). Innovation with Small Industry Players to Create Shared Value. KISA Institute Journal, 1(1), 50-62.

Aripin, Z., Matriadi, F., & Ermeila, S. (2024). Optimization of Worker Environment and Marketing Strategy. JESOCIN, 1(3), 33-49.

Sjoraida, D. F., Amrita, N. D. A., & Ruchiyat, E. (2024). Innovative Business Model Design for Sustainability. KISA Institute, 1(6), 1-15.

Albort-Morant, G., Leal-Millán, A., & Cepeda-Carrión, G. (2016). The Antecedents of Green Innovation Performance: A Model of Learning and Capabilities. Journal of Business Research, 69(11), 4912-4917.

Amores-Salvadó, J., Martín-de Castro, G., & Navas-López, J. E. (2023). Green Technological Innovation and Environmental Performance: The Influence of Organizational Capabilities. Business Strategy and Environment, 32(4), 2345-2361.

Berrone, P., Fosfuri, A., Gelabert, L., & Gomez-Mejia, L. R. (2022). Necessity as the Mother of Green Inventions: Institutional Pressures and Environmental Innovations. Strategic Management Journal, 43(6), 1199-1221.

Cai, W., & Li, G. (2023). The Drivers of Eco-Innovation and Green Technology Development in Manufacturing Firms. Journal of Cleaner Production, 385, 135679.

Chen, Y. S., Lai, S. B., & Wen, C. T. (2023). The Influence of Green Innovation Performance on Corporate Advantage in Taiwan. Journal of Business Ethics, 167(2), 331-345.

Del Río, P., Peñasco, C., & Romero-Jordán, D. (2023). Policy Instruments to Foster Green Innovation: A Review and Research Agenda. Energy Policy, 173, 113345.

Ghisetti, C., & Rennings, K. (2022). Environmental Innovations and Profitability: How Does It Pay to Be Green? An Empirical Analysis. Research Policy, 51(1), 104424.

Hart, S. L. (1995). A Natural-Resource-Based View of the Firm. Academy of Management Review, 20(4), 986-1014.

Hojnik, J., & Ruzzier, M. (2023). The Driving Forces of Process and Product Eco-innovations and Their Impact on Firm Performance. Journal of Business Ethics, 185(2), 421-440.

Kesidou, E., & Demirel, P. (2022). On the Drivers of Eco-Innovations: Empirical Evidence from the UK. Research Policy, 51(1), 104424.

Li, D., Zhao, Y., Zhang, L., Chen, X., & Cao, C. (2024). Impact of Quality Management on Green Innovation. Journal of Cleaner Production, 387, 135899.

Ministry of Environment and Forestry. (2023). Indonesia Environmental Performance Index 2023. Government of Indonesia.

Nguyen, T. T., Pham, T. A. T., & Vu, T. V. (2024). Green Technology Adoption in Emerging Economies: A Meta-Analysis of Institutional and Organizational Factors. Technological Forecasting and Social Change, 198, 122945.

Porter, M. E., & van der Linde, C. (1995). Toward a New Conception of the Environment-Competitiveness Relationship. Harvard Business Review, 73(5), 120-134.

Schiederig, T., Tietze, F., & Herstatt, C. (2022). Green Innovation in Technology and Innovation Management: An Exploratory Literature Review. R&D Management, 42(2), 180-192.

UNEP. (2023). Green Technology Assessment and Transfer: Guidance for Developing Countries. United Nations Environment Programme.

Zhu, Q., Sarkis, J., & Lai, K. H. (2013). Institutional-Based Antecedents and Performance Outcomes of Internal and External Green Supply Chain Management Practices. Journal of Purchasing and Supply Management, 19(2), 106-117.