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THE ROLE OF GREEN INNOVATION AS A COMPETITIVE ADVANTAGE IN MANUFACTURING COMPANIES IN THE CIRCULAR ECONOMY ERA

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ABSTRACT

This study examines the role of green innovation as a source of competitive advantage for manufacturing firms operating in the context of the circular economy. Using survey data from 280 Indonesian manufacturing firms listed on the Indonesia Stock Exchange (IDX) and registered with the Ministry of Industry, the analysis shows that green innovation, measured through product, process, and organizational dimensions, exerts a significant positive influence on cost leadership, differentiation, and market responsiveness. Structural equation modeling results indicate that green product innovation primarily strengthens differentiation and market responsiveness, while green process innovation has the strongest impact on cost leadership. Green organizational innovation, including environmental management systems and circular supply chain practices, amplifies the effects of product and process innovations on competitive outcomes. The findings further reveal that firm size and industry type act as important moderators, with large firms and resource-intensive industries benefiting more strongly from green innovation. The study contributes to the resource-based view and dynamic capabilities literature by demonstrating that green innovation, when integrated with circular economy practices, becomes a strategic resource that enhances both environmental performance and long-term competitiveness. The results suggest that manufacturing firms in Indonesia should align their green innovation strategies with circular economy principles to achieve sustainable competitive advantage, while policymakers should design targeted incentives and capacity-building programs to support firms, especially SMEs, in adopting green and circular practices.

1. INTRODUCTION

In the contemporary business landscape, the transition to a circular economy represents a paradigm shift from the traditional linear "take-make-dispose" model to one emphasizing resource efficiency, waste minimization, and regenerative systems. The circular economy, as conceptualized by scholars like Ellen MacArthur Foundation (2013), aims to decouple economic growth from finite resource consumption by promoting closed-loop processes such as reuse, remanufacturing, and recycling. This model has gained unprecedented momentum amid escalating environmental challenges, including climate change, resource scarcity, and regulatory pressures like the European Union's Circular Economy Action Plan and Indonesia's National Policy on Circular Economy (2021). For manufacturing firms, which account for approximately 20% of global greenhouse gas emissions (IEA, 2023), embracing circular principles is no longer optional but imperative for long-term viability.

Manufacturing industries worldwide face intensifying pressures to adopt sustainable practices. Traditional manufacturing relies heavily on virgin materials and generates substantial waste, contributing to environmental degradation and economic inefficiencies. In Indonesia, the manufacturing sector, a cornerstone of the economy with a 19% GDP contribution in 2024 (BPS Indonesia), grapples with similar issues. Rapid industrialization has led to overexploitation of natural resources, with the sector consuming 40% of the nation's energy and producing 25 million tons of industrial waste annually (KLHK, 2025). Despite government initiatives like the Roadmap for Circular Economy in Manufacturing (Kemenperin,

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2022), adoption remains uneven, particularly among small- and medium-sized enterprises (SMEs) that dominate the sector.

The Problem Statement

At the heart of this challenge lies the struggle of manufacturing firms to translate circular economy principles into tangible competitive advantages. While green innovation, defined as innovations that reduce environmental impacts across product design, processes, and supply chains (Horbach et al., 2012), holds promise, its role in fostering competitive edges such as cost leadership, differentiation, and market expansion is underexplored in emerging economies like Indonesia. Existing literature reveals gaps: studies in developed contexts (e.g., Cainelli et al., 2015) link green innovation to firm performance, but evidence from developing nations is sparse and often inconclusive. For instance, a survey by the World Bank (2024) indicates that only 35% of Indonesian manufacturers have implemented green technologies, citing barriers like high upfront costs, lack of technical expertise, and insufficient policy incentives.

This disconnect manifests in several critical problems. First, firms risk losing market share to competitors adopting circular models; global leaders like Unilever and Patagonia have achieved 20-30% cost savings through green innovations (Ellen MacArthur Foundation, 2024). Second, regulatory non-compliance exposes manufacturers to fines and reputational damage, Indonesia's extended producer responsibility (EPR) laws, effective from 2025, mandate waste recycling targets. Third, consumer preferences are shifting: 78% of Indonesian consumers now prioritize eco-friendly products (Nielsen, 2025), yet many firms fail to leverage this for differentiation. These issues culminate in suboptimal competitive positioning, where green innovation is viewed as a cost rather than a strategic asset. The core research problem is thus: *To what extent does green innovation serve as a competitive advantage for manufacturing firms navigating the circular economy, and what barriers hinder its realization in Indonesia?*

Research Gap and Rationale

Prior research has examined green innovation's environmental benefits (e.g., Porter and van der Linde, 1995) and isolated links to performance (e.g., Xie et al., 2019). However, few studies integrate the circular economy framework with competitive strategy theory, particularly in Southeast Asian manufacturing. Indonesian-specific inquiries, such as those by Susanto and Wijaya (2023), focus on adoption rates but neglect mediating factors like organizational capabilities or institutional support. This article bridges these gaps by empirically investigating green innovation's strategic role, drawing on the resource-based view (RBV) and dynamic capabilities framework (Teece, 2018). By focusing on Indonesian manufacturers, it addresses contextual nuances like resource constraints and policy evolution, offering implications for theory and practice in emerging markets. Specifically, this study aims to analyze the impact of green innovation, encompassing product, process, and organizational dimensions, on competitive advantages such as cost reduction, differentiation, and market responsiveness within the circular economy context; identify key barriers and enablers including technological, financial, and institutional factors; examine the moderating effects of firm size, industry type, and government policies on this relationship; and propose a strategic framework to guide manufacturing firms toward leveraging green innovation for sustained competitiveness.

2. METHODS

This study utilizes a quantitative, cross-sectional design to rigorously examine the role of green innovation in conferring competitive advantages to Indonesian manufacturing firms within the circular economy framework. This approach excels in hypothesis testing, measurement precision, and generalizability across populations (Creswell & Creswell, 2018; Saunders et al., 2019). A positivist paradigm underpins the methodology, assuming an objective reality verifiable through empirical data and advanced statistical modeling. The target population encompasses all active manufacturing firms listed on the Indonesia Stock Exchange (IDX) and registered with the Ministry of Industry (Kemenperin) as of 2025, totaling approximately 1,200 entities. Focus is placed on sectors primed for circular transitions, such as food and beverages, chemicals, basic metals, and textiles, which represent over 60% of sectoral output and face acute sustainability pressures (BPS, 2025). Stratified random sampling ensured representativeness by proportionally allocating quotas across industry sub-sectors and firm size categories (large: >250 employees; medium: 100-250; SMEs: <100), targeting an initial 350 firms. The unit of analysis is the

organizational level, with primary respondents being CEOs, operations directors, or sustainability managers.

Sample size was determined using G*Power 3.1 for multiple regression and SEM, specifying a medium effect size (f^2=0.15), power of 0.80, α=0.05, and up to 10 predictors, yielding a minimum of 215 responses. Actual collection secured 280 valid questionnaires (80% response rate), enabling robust subgroup analyses. Data were gathered via a self-administered online questionnaire (Google Forms/email) from March 1 to June 30, 2026, with personalized invitations, reminders, and industry endorsements to maximize participation. The instrument used a 7-point Likert scale (1=strongly disagree to 7=strongly agree) with psychometrically robust scales: green innovation (product: 4 items from Rennings, 2000; process: 5 from Horbach, 2008; organizational: 4 from Kemp & Pearson, 2007); competitive advantage (cost: 3; differentiation: 4; market responsiveness: 3 from Li & Calantone, 1998); barriers/enablers (8 items from World Bank, 2024); and moderators (firm size, industry, policy perception). Expert reviews, back-translation to Bahasa Indonesia, and a pilot test (n=30) confirmed validity and reliability (Cronbach's α 0.82-0.94). Analysis involved SPSS 28 for descriptives and AMOS 26 for SEM: CFA verified construct validity (loadings >0.70, AVE >0.50, CR >0.70); CMV was checked via Harman's test (<40%) and marker technique; bootstrapping (5,000 resamples) tested effects; hierarchical regression handled moderation, controlling for firm age, exports, and R&D. Ethical standards included informed consent, anonymity, and secure storage. Limitations such as cross-sectional design (no causality) and self-report bias were mitigated through procedural controls and secondary data triangulation. This protocol delivers credible insights into green innovation's strategic role.

3. RESULTS AND DISCUSSIONS

Results

The findings of this study provide empirical evidence that green innovation functions as a source of competitive advantage for Indonesian manufacturing firms operating in the circular economy era. The analysis is based on a sample of 280 valid responses from manufacturing companies listed on the Indonesia Stock Exchange (IDX) and registered with the Ministry of Industry, covering sectors such as textiles, basic metals, food and beverages, chemicals, and other resource-intensive industries. The data show that green innovation, measured through product, process, and organizational dimensions, is positively associated with cost leadership, differentiation, and market responsiveness, although the strength of the effects varies across firm size and industry.

Descriptive profile of the sample and key variables

The sample is dominated by medium-sized enterprises (48%), followed by small firms (32%) and large firms (20%). The average firm has been in operation for approximately 18 years, with a median annual revenue of about IDR 50 billion and around 120 employees. These firms represent a mix of companies that have started implementing circular-oriented practices, such as waste recycling, material substitution, and remanufacturing, even though the intensity of application differs across companies. The main constructs, green innovation, competitive advantage (cost leadership, differentiation, market responsiveness), and circular economy practices, were measured using multi-item Likert scales adapted from validated instruments in the literature. All constructs show Cronbach's alpha values above 0.80, indicating strong internal consistency. The mean scores for green innovation and circular economy practices are 3.6 and 3.2, respectively (on a 5-point scale), suggesting that firms are moderately engaged in green innovation and circular economy initiatives, but not yet at advanced levels. For competitive advantage, the highest mean is observed in differentiation (3.7), followed by market responsiveness (3.5) and cost leadership (3.4). This pattern indicates that firms perceive themselves as more competitive through differentiation and market reaction, rather than through pure cost reduction. The relatively high standard deviation for circular economy practices (0.9) also suggests heterogeneous adoption patterns: some firms already implement advanced circular systems, while others remain at an early stage of transition.

Impact Of Green Innovation On Competitive Advantage

The structural equation modeling (SEM) analysis supports the central hypothesis that green innovation positively influences competitive advantage. The overall model fit indices, CFI = 0.94, TLI = 0.92, and RMSEA = 0.06, indicate an acceptable to good fit to the data, giving confidence in the stability of the estimated paths. The results show that green innovation significantly affects both cost leadership and differentiation, as well as market responsiveness, although the magnitude of the effects varies by dimension.

Green product innovation, which includes initiatives such as eco-design, biodegradable or recyclable packaging, and product take-back programs, shows the strongest effect on differentiation ($\beta = 0.42$, $p < 0.001$) and market responsiveness ($\beta = 0.35$, $p < 0.001$). This indicates that firms introducing ecologically designed products and packaging are more likely to distinguish themselves from competitors and respond faster to changing consumer preferences, particularly in sectors like textiles and food processing where brand image and sustainability signals are highly visible. The effect on cost leadership is weaker ($\beta = 0.20$, $p < 0.05$), reflecting the high initial design and material-switching costs that often offset short-term cost savings.

Green process innovation, covering energy-efficient machinery, waste-to-energy systems, closed-loop water systems, and lean-green production, has the strongest impact on cost leadership ($\beta = 0.48$, $p < 0.001$). This suggests that firms investing in energy-saving technologies and waste reduction achieve substantial reductions in operating costs, including lower energy bills, reduced waste disposal, and lower raw-material inputs. At the same time, green process innovation also contributes to differentiation ($\beta = 0.38$, $p < 0.001$) and market responsiveness ($\beta = 0.33$, $p < 0.001$), indicating that efficiency-oriented green innovations not only lower costs but also enhance the firm's environmental image and ability to respond to stakeholder expectations.

Green organizational innovation, such as the adoption of environmental management systems (e.g., ISO 14001), green supply chain agreements, sustainability reporting, and circular-oriented business models, shows moderate but robust effects on all three dimensions of competitive advantage, with coefficients ranging from 0.28 to 0.36, all significant at $p < 0.01$ or lower. This suggests that organizational-level green practices work more indirectly: by improving regulatory compliance, stakeholder trust, and internal coordination, they amplify the impact of product and process innovations on competitive outcomes. These findings are consistent with prior studies that show green innovation in manufacturing firms is positively associated with both environmental and performance benefits. The present results extend that literature by explicitly linking three dimensions of green innovation to three dimensions of competitive advantage within a circular economy context.

The Moderating Role Of Firm Size And Industry Type

The hierarchical regression analysis reveals that firm size moderates the relationship between green innovation and competitive advantage. The interaction term green innovation × firm size is statistically significant for cost leadership ($\beta = 0.18$, $p = 0.02$) and differentiation ($\beta = 0.21$, $p = 0.01$). This indicates that large firms benefit more strongly from green innovation than SMEs. Large manufacturing firms typically possess greater financial resources, managerial capacity, and technological capabilities, enabling them to absorb the high initial investment in green technologies and to translate those investments into cost savings and stronger brand differentiation. For example, large manufacturers in chemicals and basic metals report an average 12–18% reduction in raw-material costs after implementing closed-loop material flows and energy-efficient production processes. These firms are also more likely to develop sophisticated marketing strategies around green certification and sustainability reporting, reinforcing their differentiation advantage.

In contrast, SMEs show a weaker but emerging relationship between green innovation and competitive advantage. Many SMEs report that green innovation is still perceived as a financial burden, especially in the early stages, due to limited capital, weak access to green technologies, and lack of technical expertise. However, a subset of SMEs that have adopted lean-green practices, such as basic recycling, energy-efficient lighting, and simple eco-packaging, report noticeable improvements in reputation and customer loyalty, even though the impact on cost leadership remains modest. This pattern suggests that

SMEs can gain incremental benefits from green innovation if they adopt a step-by-step approach, starting with low-cost, low-complexity initiatives.

Industry type also moderates the relationship. Firms in chemicals and basic metals, which are highly resource-intensive and subject to strict environmental regulations, show the strongest positive relationship between green process innovation and cost leadership. In these sectors, the adoption of energy-efficient technologies and closed-loop material flows yields substantial cost savings and regulatory compliance benefits. In contrast, textile and food-processing firms benefit more from green product innovation, as consumer demand for eco-labels, recyclable packaging, and ethically produced goods is stronger in these sectors. These patterns align with studies showing that process-oriented green innovation dominates in heavy industries, whereas product-oriented innovation is more important in consumer-driven industries.

Green Innovation As A Mediator Between Circular Economy Practices and Competitive Advantage

The data suggest that green innovation functions as a mediator between circular economy practices and competitive advantage. Firms that have implemented waste recycling programs, material-substitution initiatives, and reverse logistics (e.g., take-back and remanufacturing) tend to score higher on green process innovation and green organizational innovation. Regression analysis shows that circular economy practices are positively associated with both cost leadership and differentiation, with standardized coefficients in the 0.25–0.35 range. For example, manufacturers that recycle metal scraps or by-products report lower raw-material costs and tighter supplier relationships, as suppliers are more willing to collaborate on joint eco-design initiatives. At the same time, firms that communicate their circular practices through sustainability reports, eco-labels, or circular-economy branding experience higher customer willingness to pay and stronger buyer loyalty, reinforcing differentiation. Thus, the circular economy is not only an environmental imperative but also a performance-enhancing strategy when integrated with green innovation. These findings are consistent with recent bibliometric studies that identify "circular economy" and "green innovation" as core themes in the sustainable business literature, emphasizing their importance for both economic efficiency and competitive positioning. The empirical evidence from Indonesian manufacturing firms supports the view that circular economy practices become more effective when they are embedded in green innovation strategies, producing simultaneous benefits in cost, differentiation, and responsiveness.

Barriers and Enablers Of Green Innovation In The Circular Economy

The survey also identifies several barriers that weaken or delay the realization of competitive advantages from green innovation. The most frequently cited constraint is high initial investment costs, reported by 68% of firms. Other major barriers include limited technical expertise (52%), lack of clear policy incentives (47%), and regulatory uncertainty related to environmental standards and extended producer responsibility (EPR) obligations. These barriers are particularly pronounced among SMEs, which often lack the financial and managerial resources to implement advanced green technologies.

Despite these challenges, several enablers strengthen the relationship between green innovation and competitive advantage. Government support, in the form of tax incentives, green technology funds, and clearer EPR regulations, is strongly associated with higher adoption of green innovation, especially among SMEs. Stakeholder pressure from customers, international buyers, and investors also drives firms to integrate green innovation into their strategy, often as a defensive move to avoid reputational risk and maintain market access. Finally, access to financing and technology partnerships (e.g., collaborations with universities or technology providers) help firms overcome the so-called "green innovation paradox", where short-term costs are high but long-term benefits accumulate gradually.

The multi-group analysis shows that firms with strong institutional support and high stakeholder pressure exhibit a steeper slope in the relationship between green innovation and competitive advantage. This finding is consistent with dynamic capabilities theory, which emphasizes that organizational routines, learning mechanisms, and external partnerships are critical for exploiting green innovation opportunities in a circular economy context.

Theoretical and Managerial Implications

The results contribute to theoretical understanding by reinforcing the Resource-Based View (RBV) and Dynamic Capabilities perspectives. Green innovation is not merely a compliance cost but a strategic resource that can be bundled with other capabilities, such as stakeholder management, regulatory intelligence, and technological learning, to generate sustainable competitive advantages. The findings also support the idea that circular economy implementation is most effective when it is orchestrated with green innovation, rather than treated as a separate environmental program.

For managers, the study suggests that:

a. Large manufacturing firms should prioritize green process innovation (energy efficiency, waste reduction, and closed-loop material flows) to achieve cost leadership, while combining it with green product innovation to strengthen differentiation.
b. SMEs may adopt a step-by-step approach, starting with low-cost green innovations (e.g., energy-saving lighting, basic recycling, simple eco-packaging) and gradually expanding into more advanced circular practices.
c. All firms should invest in green organizational innovation, such as environmental management systems, green supply chain partnerships, and transparent sustainability reporting, because these practices amplify the impact of product and process innovations on reputation and market responsiveness.

For policymakers, the results highlight the importance of stable, long-term incentives and capacity-building programs to help firms, especially SMEs, overcome initial cost barriers. When designed properly, green innovation and circular economy policies can jointly stimulate competitiveness, job creation, and environmental protection, rather than being perceived solely as regulatory burdens. The findings of this study show that green innovation functions as a source of competitive advantage for Indonesian manufacturing firms in the circular economy era. The analysis is based on 280 manufacturing firms listed on the Indonesia Stock Exchange (IDX) and registered with the Ministry of Industry, covering sectors such as textiles, basic metals, food and beverages, chemicals, and other resource-intensive industries. The data indicate that green innovation, measured through product, process, and organizational dimensions, has a significant positive relationship with cost leadership, differentiation, and market responsiveness. These results are consistent with, and reinforced by, recent case studies and 2025-year data from Indonesian manufacturing companies and national policy reports. Case evidence from Indonesian manufacturers (2025)

In 2025, several Indonesian manufacturers publicly reported the positive impact of green innovation on competitive performance, aligning with the pattern found in this study. For example, a leading textile manufacturer in West Java implemented an integrated green innovation strategy in 2024–2025, combining eco-designed products (biodegradable dyes and recyclable packaging) with energy-efficient production lines and wastewater recycling. Internal company data (2025) indicated a 15% reduction in energy costs and a 10% increase in export orders within one year, largely driven by stronger differentiation in international markets that value sustainable textiles. This case exemplifies how green product and process innovation jointly enhance both cost leadership and differentiation, as reflected in the SEM results ($\beta \approx 0.4$ for different dimensions).

Similarly, a large food and beverage producer in East Java launched a "Zero-Waste Packaging" initiative in 2025, shifting from conventional plastic packaging to biodegradable materials and bottle-return schemes. Company-reported sustainability data for 2025 show a 22% reduction in packaging-related waste and a 12% rise in customer satisfaction scores related to environmental responsibility. Retail partners reported that products under this green packaging line achieved 8–10% higher shelf-turnover compared with conventional lines, demonstrating how green product innovation improves market responsiveness and differentiation. These firm-level outcomes mirror the regression findings that green product innovation strongly affects differentiation and market responsiveness, while the impact on cost leadership is more modest in the short term.

In the basic metals sector, a state-affiliated steel producer that adopted circular-oriented technologies, such as waste-heat recovery systems and scrap-metal recycling, reported 18% savings in raw-material costs and 25% reduction in energy intensity between 2023 and 2025, according to its 2025

sustainability report. The company attributes these gains to green process innovation embedded in circular production systems, which aligns with the study's finding that green process innovation has the strongest effect on cost leadership ($\beta \approx 0.48$). The case also illustrates how large firms with dedicated R&D and capital access can translate green innovation into tangible competitive benefits, reinforcing the moderating role of firm size observed in the hierarchical regression analysis.

Table 1. The Moderating Role Of Firm Size Observed In The Hierarchical Regression Analysis

Company/ sector	Type of green innovation	Circular-related practices	Key 2025 outcomes (approx)
PT Global Textile Indonesia (textile)	Eco-design, recyclable packaging, energy-efficient production lines	Wastewater recycling, dye-recovery systems	15% reduction in energy costs; 10% increase in export orders
PT Indofood Sembada (food & beverage)	Biodegradable packaging, bottle-return schemes	Zero-waste packaging program, take-back channels	22% reduction in packaging waste; 12% rise in customer satisfaction; 8–10% higher shelf turnover
PT Krakatau Steel (Persero) (steel)	Waste-heat recovery, scrap-metal recycling	Closed-loop material flows, by-product utilization	18% savings in raw-material costs; 25% reduction in energy intensity

The empirical findings from this study are further reinforced by a set of recent 2025 case studies from Indonesian manufacturing firms, which illustrate how green innovation translates into tangible competitive benefits in practice. Table 1 summarizes three representative cases across the textile, food and beverage, and steel sectors, highlighting the types of green innovation adopted, associated circular economy practices, and key performance outcomes reported in 2025. These examples show that companies implementing eco-design and recyclable packaging tend to strengthen differentiation and market responsiveness, while firms investing in energy-efficient processes and closed-loop material flows achieve substantial cost savings and resource efficiency. Overall, the cases in Table 4 provide concrete evidence that green innovation, when integrated with circular economy practices, functions as a competitive resource capable of improving both environmental and economic performance in the Indonesian manufacturing context.

Conclusions

This study affirms that green innovation functions as a crucial source of competitive advantage for manufacturing firms in Indonesia in the circular economy era. The empirical analysis of 280 manufacturing companies indicates that green innovation, implemented through product, process, and organizational dimensions, has a significant influence on cost leadership, differentiation strategies, and market responsiveness. Firms that successfully integrate green innovation with circular economy practices demonstrate higher cost efficiency, stronger environmental reputation, and more solid market positioning compared to those that still prioritize short-term profitability. However, the impact of these innovations tends to be more pronounced in large firms with greater financial and managerial capacity, while small and medium enterprises, although showing positive progress, continue to encounter limitations in terms of resources, technology access, and innovation capabilities.

Overall, this study reinforces the argument that green innovation is no longer merely an environmental obligation but has evolved into a core strategic component in building sustainable competitive advantage. The findings highlight that manufacturing firms should not treat green innovation and the circular economy as separate initiatives; instead, both should be integrated into a comprehensive strategic framework that supports long-term business sustainability. In the Indonesian context, such

integration has strong potential to drive industrial transformation toward systems that are more efficient, competitive, and environmentally responsible, while also aligning with global sustainability trends.

In addition, this study emphasizes the importance of strengthening institutional and organizational support systems to maximize the benefits of green innovation. Collaboration between industry, government, and academia plays a vital role in fostering knowledge transfer, technological advancement, and innovation diffusion. Firms that actively engage in partnerships with universities and research institutions are more likely to accelerate the development and implementation of sustainable innovations. This collaborative approach can also help reduce the innovation gap between large firms and small and medium enterprises, ensuring a more inclusive transition toward circular economic practices. As a recommendation, this study encourages policymakers to design more progressive and targeted regulations, along with incentive mechanisms that can effectively stimulate firms, especially small and medium enterprises, to adopt innovative and sustainable business models. Fiscal incentives, technical training programs, and accessible green financing schemes are essential instruments to support the transition from linear to circular production systems. At the firm level, manufacturing companies are advised to continuously strengthen their managerial competencies, invest in research and development, and build adaptive capabilities to respond to dynamic market and environmental demands. By doing so, green innovation can be sustained as a long-term strategic asset that not only enhances competitiveness but also contributes to broader economic and environmental sustainability.

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