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Bridging the gap: Organizational readiness and the adoption of energy efficiency innovations in Indonesia's building sector

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ABSTRACT

This paper examines the low adoption of energy efficiency and renewable energy (NRE) technologies in the Indonesian building industry, a sector with a growing energy demand and a promising potential for sustainable practices. Focusing on office buildings, hotels, and residential buildings in Jakarta, the study considers the enablers and barriers to technology adoption. The paper examines 26 UTAUT and E-Readiness factors using a combination of principal component analysis (PCA), K-means clustering, and logistic regression. The factors include behavioral intention, social influence, performance expectations, and organizational readiness. The results show three types of adopters early, pragmatic, and late characterized mainly by organizational readiness and expected performance. Early adopters demonstrate high awareness, resources, and intention to use retrofitting technologies, while late adopters are deterred by perceived complexity and unpreparedness. The findings suggest that internal and external readiness and expected performance improvements significantly accelerate adoption. The study finds that tailored policy incentives, such as targeted tax breaks or subsidies, are critical in overcoming behavioral and organizational barriers. These results enable better strategies to improve energy efficiency and renewable energy innovation in the Indonesian building sector.

Contribution/Originality: The study classifies building stakeholders in Jakarta into three distinct groups early, pragmatic, and late adopters based on their organizational readiness and performance expectancy, offering a clearer understanding of adoption patterns.

1. INTRODUCTION

With its rapid economic growth, substantial infrastructure is needed, primarily to support the movement of the economic engine. The need for infrastructure growth will be balanced with significant energy investment. However, energy needs have always been an obstacle for many governments, especially Indonesia (Asia-Pacific Economic Cooperation, 2012; Golove & Eto, 1996). The massive energy demand is caused by increased activities, which also increases the number of customers, where the increase is an ongoing problem (Eang, 2015; PT Perusahaan Listrik Negara (Persero), 2014; Respati, 2016). Behind the increasing demand for energy and limited supply, there are great opportunities that are still untapped for energy efficiency in various sectors in Indonesia, such as the transportation sector, the industrial sector, the commercial building sector, the household sector, and other sectors (ASEA Brown

Boveri, 2013; Oberman, Dobbs, Budiman, Thompson, & Rossé, 2012). The office and building industry is the second largest energy-consuming sector after the manufacturing industry, where the potential for energy savings is expected to be utilized and will open up great business opportunities. According to previous research, energy efficiency innovations and new renewable energy innovations in this sector can be applied by establishing several government actions such as disclosure, building valuation, and data collection (Eang, 2015; Oberman et al., 2012).

This step can stimulate and help owners or managers of offices and buildings to understand current energy consumption, help financial institutions to better understand risks and opportunities, and provide insights for future policymaking (International Partnership for Energy Efficiency Cooperation (IPEEC), 2014; Nadel et al., 2013). Providing accurate and informative disclosure regarding the current development of efficient energy innovation and New Renewable Energy Innovation is critical. Of course, the database of efficiency energy innovation and New Renewable Energy Innovation must constantly be updated (Nadel et al., 2013). The government can also spur the implementation of disclosure and assessment of energy efficiency innovations and New Renewable Energy Innovation through incentives by using the tax structure as a sweetener for companies to participate in energy efficiency innovation and New Energy Innovation programs and encourage projects on a larger scale (Nadel et al., 2013).

Previous research found that behaviour towards the acceptance of energy efficiency products and New Renewable Energy Innovation was more dominant than the general norm (Ha & Janda, 2012). So, general social norms do not directly have a dominant effect on determining the behaviour of organizations and individuals regarding energy efficiency (Lingyun, Rui, Hualong, & Xiaohua, 2011). The approach of social norms to changing the behaviour of the use of energy efficiency products and New Renewable Energy Innovations, especially those directly related to the success of clean and healthy environmental campaigns, is primarily determined by the existence of government support (Horne & Kennedy, 2017). However, this is in contrast to the situation in China, where his research (13) found that government policies do not affect the decision of homeowners in China to achieve energy efficiency. To overcome the problem, (14) Suggest a *win-win* model that is consistent with the principles that can be accepted by the market, either by the government or building owners, where one of them is an improvement in the cost-of-benefit analysis in overcoming conflicts in financing policies that can facilitate the practice of replacing efficiency energy products and New Renewable Energy Innovation products or commonly known as *Retrofitting*. Top fees *Retrofit* must be made more transparent so that investment in *Retrofit* can be rated better (Torgal, Buratti, Kalaiselvam, Granqvist, & Ivanov, 2016).

While there is an excellent opportunity to achieve energy efficiency, the acceptance of *retrofit* innovation remains an anomaly; despite the growing interest in the value of energy efficiency, all stakeholders need to be more enthusiastic about existing *retrofitting*. There have been many previous studies on the business readiness of an organization, how individuals or organizations adopt or accept technology, what factors affect the desire of managers or owners in the Office and Building Industry Sector, and whether the perceived benefits will weaken or strengthen a transaction, as well as what factors can strengthen customers to confirm use (*actual use*). This research will fill the gap and confirm variables that are still controversial or inconsistent. The term *market barrier* in energy efficiency and New Renewable Energy Innovation in the office and building industry refers to the existence of an efficiency gap in energy, which is a situation where opportunities that are proven to have the potential of energy efficiency products and New Renewable Energy Innovation are not taken advantage of by building owners or managers, or by energy users for unclear reasons.

Theoretical approach *Behaviour Economics* is widely used to understand people's behaviour in adopting energy efficiency technologies and complex New Renewable Energy Innovations (Claudy & O'Driscoll, 2008), including their decisions regarding such adoption behaviour (Frederiks, Stenner, & Hobman, 2015). Application from the psychology and *Behaviour Economics* aspect that focuses on customer-directed communication patterns can improve energy efficiency behaviours (Frederiks et al., 2015). Nasip and Pradipto (2016) emphasized that the pattern of energy efficiency adoption behaviour and the adoption of New Renewable Energy Innovation are not only determined by the tendency to adopt technology in society but also by the character of individuals who are oriented towards a healthy and friendly environment. Behaviour is a determining factor for office and building owners in adopting and wanting to pay for energy efficiency (Prete et al., 2017). Meanwhile, social and environmental concerns affect control behaviour based on income, education, and age. (20) giving the opinion that the 'desire' behaviour in deciding on a building management system is based on satisfaction, *perceived ease of use* and *perceived usefulness*.

From everything explained earlier, this study aims to discover the existing obstacles and why it is challenging to accept energy efficiency technologies and programs and New Renewable Energy Innovations in Indonesia. In addition to the obstacles that need to be known, this study aims to evaluate what variables affect the office and building industry sector in accepting Energy Efficiency Innovation and New Renewable Energy Innovation for *retrofitting*. As explained in the background of this study, four factors may influence the building industry's acceptance of energy efficiency technology innovations and the retrofitting of new renewable energy innovations. Therefore, this study will examine the following: 1) Will business readiness affect office and building managers' acceptance of energy efficiency technology innovations and new renewable energy innovations? 2) Will the energy efficiency technology of New Renewable Energy Innovation in the market today affect the desire of office and building managers to *retrofit*? 3) Can the company's business readiness affect the desire of office and building managers to *retrofit*? 4) Can the company's business readiness influence office and building managers to confirm *retrofitting*?

This research will fill the gap and confirm the variables that need to be more controversial or consistent with the principles of energy efficiency innovation and New Renewable Energy Innovation in Indonesia. It also explores market barriers to energy efficiency and New Renewable Energy Innovation in the office and building industry, which refers to an efficiency gap in energy. Contribution from the article: This study is expected to contribute to the development of energy efficiency innovations and New Renewable Energy Innovations to avoid unnecessary energy use and significant expenditures and reduce emissions. The study also identified the need for increased awareness of efficient energy use by society and industry. These insights will inform research and contribute to developing effective strategies to improve energy efficiency and clean energy in Indonesia's electricity sector.

2. LITERATURE REVIEW

More environmentally friendly energy management in the construction sector is changing drastically towards sustainable development. The International Energy Agency (2022) reports that 26% of energy-related CO_2 emissions and 30% of energy consumption worldwide are caused by buildings. Implementing energy efficiency and replacing renewable energy in this sector is very promising. Zhang (2021) conducted a thorough investigation that showed that renewable energy technology can reduce building-related carbon emissions by up to 70%. Ishtiaque, Estoque, Eakin, Parajuli, and Rabby (2022) underline that even switching to renewable energy in buildings can help slow the effects of climate change. Energy-efficient building solutions can reduce energy use by 20–30% through government intervention, according to an empirical study published by the U.S. Department of Energy Lawrence Berkeley National Laboratory (2021). Published in the Journal of Cleaner Production, Pérez-Lombard, Ortiz, and Pout (2008) show that integrated techniques that combine energy efficiency and renewable energy technologies can provide much more significant reductions in carbon emissions than a single solution.

For this reason, comprehensive energy efficiency policies require diverse execution strategies. Demand-side management systems can reduce energy use by up to 15% in commercial and residential buildings, according to research by the International Energy Agency (2022). According to Parks and Helmers (2022), Smart Home Market Report, about 45% of American homes have incorporated innovative energy management technology. According to Navidi, El Gamal, and Rajagopal (2023) that coordinating Distributed Energy Resources (DERs) for grid reliability can significantly reduce both the infrastructure upgrades needed to support future increases in DER and electrification penetrations and peak load. Zhang (2021) underlines in Applied Energy that long-term energy storage technologies may lower grid-related carbon emissions by 40% by enabling more efficient integration of renewable energy sources.

Effective energy transformation relies heavily on cooperative methods. A thorough investigation in Energy and Social Sciences Research by Bridge (2022) shows that legislative frameworks and multi-stakeholder methods can increase the adoption rate of renewable energy by up to 35% in the construction industry. Energy management is constantly changing along with technological developments. Chen and Liu (2022) revealed in IEEE Transactions on Smart Grid that Internet of Things (IoT) technology can increase energy efficiency by 22–27%. Meanwhile, research conducted by the Building Performance Institute Europe supports more possibilities for integrated monitoring systems in lower energy use. The development of technology in construction is significant. Published in Renewable and Sustainable Energy Review, Rodrigues, Santos, and Costa (2021) showed that creative technologies, including 3D printing and Building Information Modeling (BIM), can reduce building waste by up to 40% and improve overall energy efficiency in building design and construction.

Globally, research shows a high potential for renewable energy growth. With solar and wind technologies playing an important role, the International Energy Agency (2022) predicts that by 2030, renewable energy capacity may triple. Strategic renewable energy spending could reduce global carbon emissions by 45% by 2030, according to Rockström (2021) in Nature Climate Change. Although the direction is encouraging, problems remain. The International Energy Agency (2022) observes that ongoing global problems and economic uncertainty have slowed the world's progress in energy efficiency. However, the study also underlines the possibility of sustainability for policy interventions and technological advancements to drive changes in implementing energy efficiency equipment and sustainable energy sources.

3. METHODS

This study explain the implications of both qualitative and quantitative research results. Initially, it starting from Mapping PCA Variables in Energy Retrofit Adoption. This PCA analysis examines 26 variables influencing energy retrofit adoption decisions. The variables span eight conceptual groups, providing a comprehensive framework for understanding adoption behavior. The Behavior-Actual to Use (ATU) variables categorize adopters as early movers, mid-late movers, or laggards, capturing the temporal dimension of adoption.

Behavioral Intention (BI) means a set of transactional intentions and holding patterns of a product by firms or individuals. Though the Effort Expectancy (EX) variable assesses a product's usability efficiency, maintenance issues, and recycling issues, Performance Expectancy (PE) is concerned with perceived benefits like benefits and suitability for use. Social Influence (SI) is a variable concerned with issues of social status and green attitudes due to pressure from society. The Facilitating Condition (FC) factor is a condition variable that encourages firms or individuals to adopt, e.g., tax relief, energy prices, incentive tariffs, and the availability of resources. Organizational Readiness (OR) is a variable of the company's internal readiness through commitment, awareness, and availability of resources. Finally, the External Readiness (ER) variable factor reflects market conditions, infrastructure, and supporting industry components that facilitate adoption in the larger ecosystem. For this reason, the Principal Component Analysis (PCA) and K-means clustering methods will reduce dimensions and identify patterns for all variables used in this study.

PCA, K-Means clustering, and Logistic Regression were also performed based on the UTAUT and E-Readiness model variables taken from the theoretical model that combines the TCE, TRA, TPB, TAM, TAM2, UTAUT, and E-Readiness models (Venkatesh, Morris, Davis, & Davis, 2003). The UTAUT theory helps explain adoption behavior regarding stakeholders. This theory is also needed to evaluate customer behavior (TRA & TPB) on innovation adoption. The PCA and K-Means clustering approach is used to analyze which variable is more dominant than the others. The research explores the behavior of energy efficiency innovation at the organizational and individual levels. This study attempts to integrate those two models. Innovation adoption in individuals includes the determinants of adoption by considering the decision as a diffusion innovation process so that innovation adoption can take on a multi-stage process (Rogers, 1962). Table 1, the operational variables of this research are as follows:

Table 1. Operational variables.

Variables	Model / Theory	Indicators
Behavior-actual to use (ATU)	Unified acceptance and use of technology (UTAUT) model (Venkatesh et al., 2003).	Y1.1. Use the retrofit - early mover
		Y1.2. Use the retrofit - mid late mover
		Y1.3. Use the retrofit - laggards
Behavioral intention (BI)		X1.1 Intent to transact
		X1.2. Unplanned to transact
		X1.3. Intent to return
"Performance expectancy (PE)		X2.1. Relative advantage and outcome expectations
		X2.2 Saving purposes
		X2.3. Perceived usefulness and fitness for purpose
Effort expectancy (EX)		X3.1. Ease of use
		X3.2. Ease of maintenance
		X3.3. Ease of recyclability
Social influence (SI)		X4.1. Perceived greenness
		X4.2. Social status/Significance adoption
		X4.3. Importance of recyclability
Facilitating condition (FC)		X5.1. Resources
		X5.2. Taxes or tariffs
		X5.3. Energy prices
		X5.4. Incentives of promotional policies
Organization readiness (OR)	E-Readiness model (Venkatesh et al., 2003)	X7.1. Commitment
		X7.2. Awareness
		X7.3. Human resources
		X7.4. Business resources
External readiness (ER)		X8.1. Market forces
		X8.2. Infrastructure
		X8.3. Supporting industries

This study employed a purposive sampling technique, targeting specific building management professionals in the DKI Jakarta area. From 150 questionnaires distributed, 103 respondents completed and returned the survey, representing a response rate of 68.7%. The research scope was limited to the business environment of office buildings, hotel buildings, and apartments within the DKI Jakarta area. Only buildings that had been established for over two years were included in the study. DKI Jakarta was selected as the research area because it represents a region that can effectively influence technology adoption movements in other regions of Indonesia. The primary respondents targeted in this study were building owners, operational managers, building administrators, and building managers representing owners and investors. These criteria included the duration of employment at the building management company and the length of time in their current position at the time of answering the questionnaire. In this study, the authors only limit the research area to the business environment of office buildings, hotel buildings, and apartments spread across the DKI Jakarta area, which has been established for over two years. The selection of the DKI Jakarta region is based on the reason that the DKI Jakarta region can represent an area that can lobby the technology adoption movement to other regions. This strategic selection ensures that findings from this study may have broader implications for technology adoption practices throughout Indonesia's building management sector.

4. RESULT

4.1. PCA and Cluster Analysis

The PCA analysis reveals that the first principal component (PC1) explains 42.88% of total variance, with the first five components cumulatively explaining 69.93% of the total variance in the dataset - Table 1.

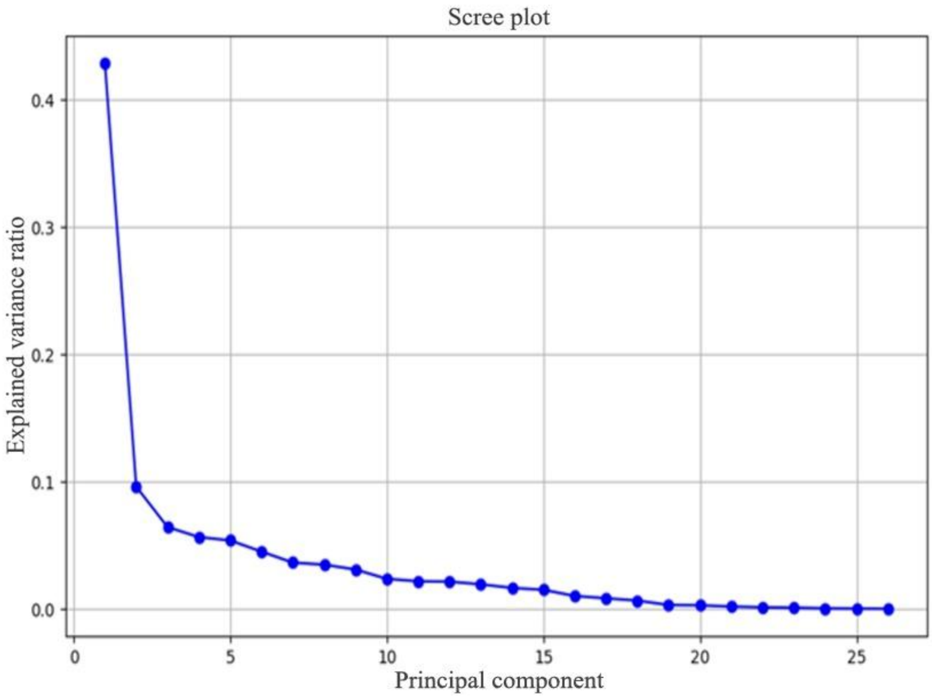

Figure 1. Component contributions.

Table 2. Component contributions.

Principal component	Variance explained	Cumulative variance
PC1	42.88%	42.88%
PC2	9.60%	52.48%
PC3	6.43%	58.91%
PC4	5.64%	64.55%
PC5	5.38%	69.93%

Figure 1 and Table 2 reveal that using just five principal components captures approximately 70% of the total variance in the dataset. This represents a significant data compression while retaining the majority of the information. More notably, the first two components alone explain 52.48% of the variance, with PC1 contributing a substantial 42.88%. This suggests a dominant underlying pattern in the data that PC1 effectively captures. Secondary patterns captured by PC2-PC5 are less pronounced but still significant, collectively explaining approximately 27% of additional variance. These components likely represent more subtle relationships and secondary structures within the data. While less influential than PC1, these dimensions may capture important nuances that should not be overlooked, particularly for applications requiring higher precision.

Figure 2 shows that PC1 has the strongest loadings (variables 21, 23, and 25) from Organization Readiness (OR) and External Readiness (ER) variables. This component represents the foundational environmental and structural conditions necessary for technology adoption. The prominence of readiness variables in PC1 suggests that preparedness both within organizations and in terms of external support systems forms the primary dimension along which adoption capabilities vary. Organizational readiness likely encompasses factors such as available resources, technical infrastructure, and staff capabilities, while external readiness may include vendor support, the regulatory environment, and industry standards. The co-location of these variables in PC1 indicates that internal and external preparedness tend to vary together, potentially reflecting how organizations with strong internal capabilities are also better positioned to leverage external support structures.

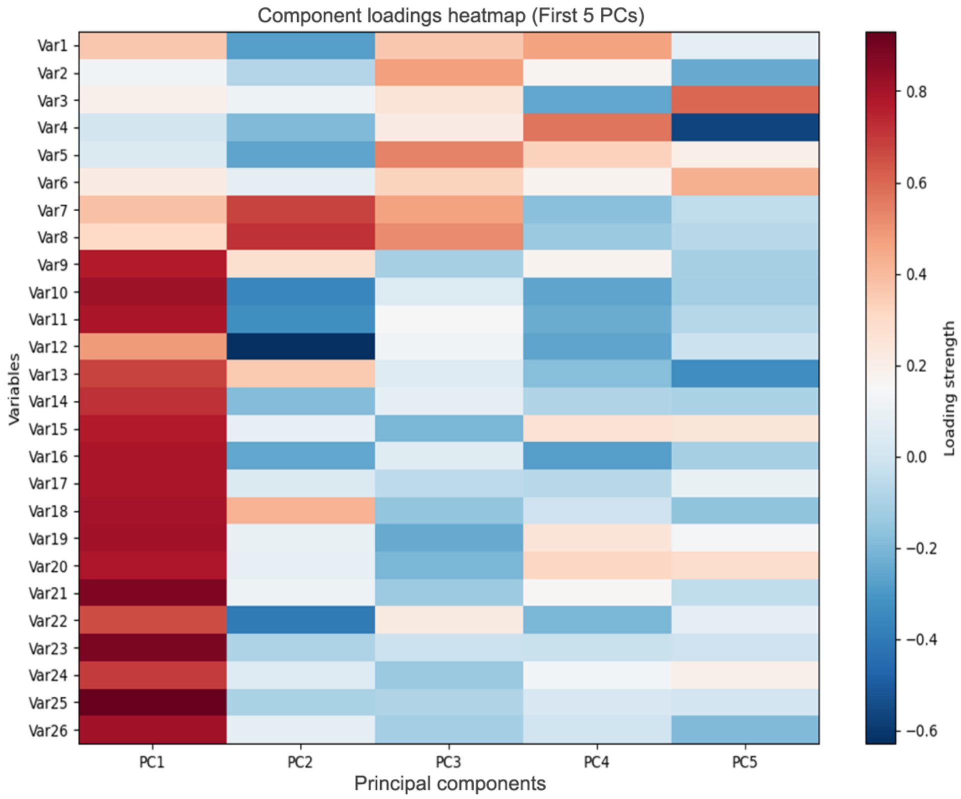

Figure 2. Component loading analysis.

PC2 features notable contributions (variables 7 and 8) from Performance Expectancy (PE) variables. This dimension captures variation in how stakeholders anticipate benefits and outcomes from technology adoption. Performance expectancy typically encompasses expectations about productivity improvements, efficiency gains, and strategic advantages that might result from new technology implementation. The emergence of performance expectancy as a distinct second component suggests that, after accounting for basic readiness factors, differences in expected outcomes constitute the next most significant source of variation. This separation is meaningful—it indicates that performance expectations vary somewhat independently from organizational readiness, potentially reflecting differences in organizational goals, market positions, or leadership visions.

The cluster analysis was performed and revealed three distinct adopter groups. The analysis was based on principal components explaining 52.48% of the variance (PC1: 42.88%, PC2: 9.60%). Both the elbow method and silhouette analysis confirmed that three clusters optimally represent the data structure Table 3.

Table 3. Cluster characteristics.

Variable group	Early adopters (Cluster 1)	Pragmatic adopters (Cluster 2)	Late adopters (Cluster 3)
Behavior-actual to use (ATU)	High	Medium	Low
Behavioral intention (BI)	High	Medium	Low
Performance expectancy (PE)	Very high	Medium	Medium
Effort expectancy (EX)	High	Medium	Low
Social influence (SI)	High	Medium	Low
Facilitating condition (FC)	High	High	Medium
Organization readiness (OR)	Very high	Medium	Low
External readiness (ER)	High	Medium	Low

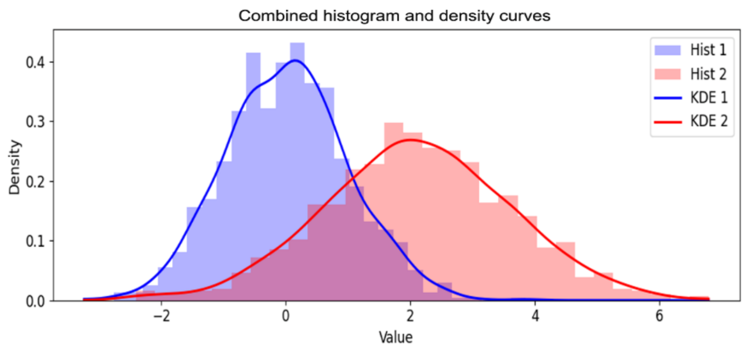

Figure 3. Distribution visualizations.

Figure 3 reveals distinct technology adoption patterns between user groups. Early/Pragmatic Adopters (blue distribution) cluster around lower values, peaking near zero with higher density (0.4), suggesting consistent adoption behaviors. Late Adopters (red distribution) demonstrate a rightward shift centering around 2.5 with broader variance extending to 6, indicating more diverse and delayed adoption triggers. This clear separation enables effective targeting strategies based on adoption propensity measurements. The "Early Adopters" cluster exhibits high scores across most dimensions, particularly in Performance Expectancy and Organizational Readiness, demonstrating their proactive approach and strong behavioral intention. "Pragmatic Adopters" display moderate scores overall but place greater emphasis on Facilitating Conditions, suggesting that practical considerations of resources, taxes, and incentives drive their decisions.

Organizational readiness emerges as the most influential factor in distinguishing between early/pragmatic and late adopters, with awareness (β=0.76) being the strongest predictor overall and becoming a key driver of technology adoption timing. Performance expectancy follows as the second most critical variable group, where relative advantage (β=0.59) significantly influences adoption decisions. The data suggest that organizational understanding and commitment, combined with perceived benefits and resource availability, primarily determine whether an organization will adopt technology early or late, Figure 4.

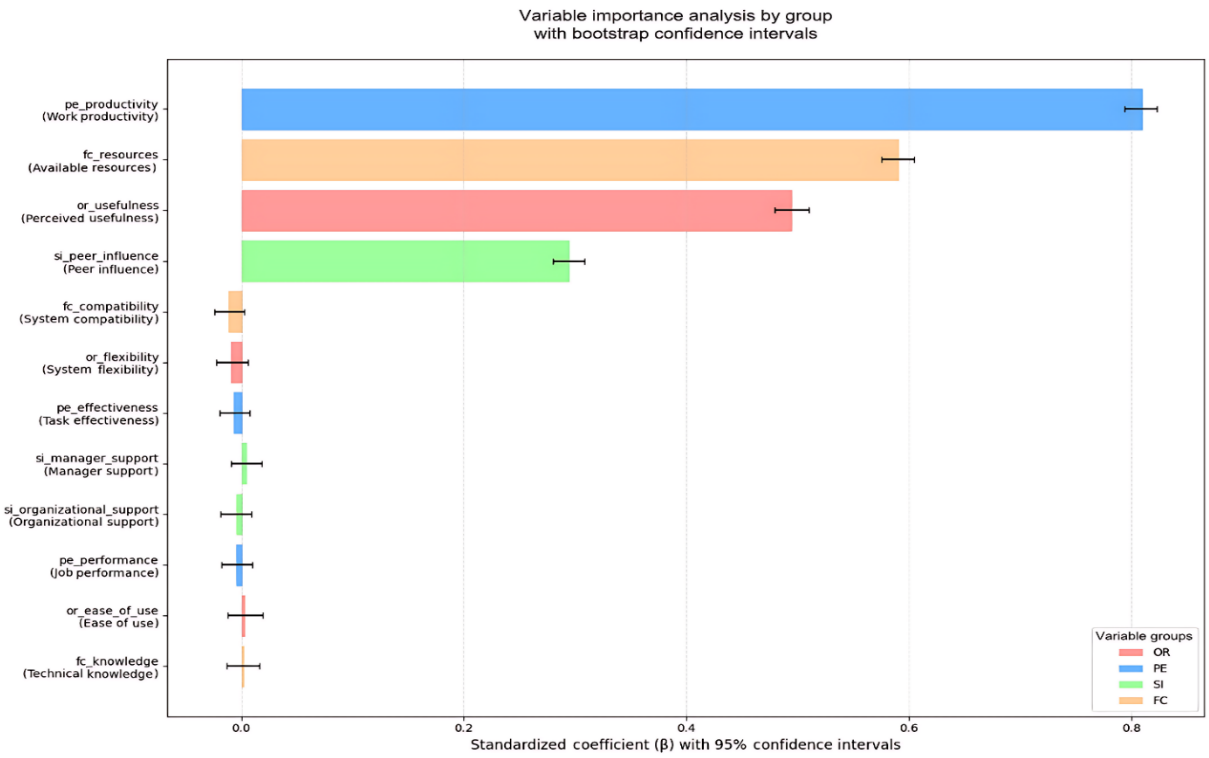

Figure 4. Variable importance plot analysis for adopter.

"Late Adopters" show lower scores on Behavioral Intention and Organizational Readiness, with heightened concern for Effort Expectancy, indicating their hesitancy stems from perceived difficulties in implementation. The clustering reveals a clear progression across all variable groups, with Early Adopters consistently scoring highest and Late Adopters lowest. Notably, Performance Expectancy remains moderate even among Late Adopters, suggesting they recognize potential benefits despite implementation concerns. Facilitating Conditions show the least variation between clusters, highlighting the universal importance of practical enablers in adoption decisions regardless of adopter category.

4.2. Early vs. Late Technology Adoption: A Logistic Regression Analysis

The research analyzes the key discriminators between early/pragmatic and late technology adopters through logistic regression analysis. The study uses all the initial variables as predictors by combining Clusters 1 and 2 (coded as 1) and keeping Cluster 3 separate (coded as 0). This two-code approach simplifies the identification of the crucial factors in terms of adoption time, and this can be a critical influence for focused marketing campaign planning and product development activities. This model is shown to work effectively for both categories according to Table 4. Class 1 is better than Class 0 in precision (0.85 vs 0.83), recall (0.88 vs 0.79), and F1-score (0.86 vs 0.81). Balanced metrics show that the predictions are reliable for both classes, with Class 1 being better able to identify true positives without precision loss. This is an indication of a good binary classification model.

Table 4. Classification report.

	Precision	Recall	F1-Score
Class 0	0.83	0.79	0.81
Class 1	0.85	0.88	0.86

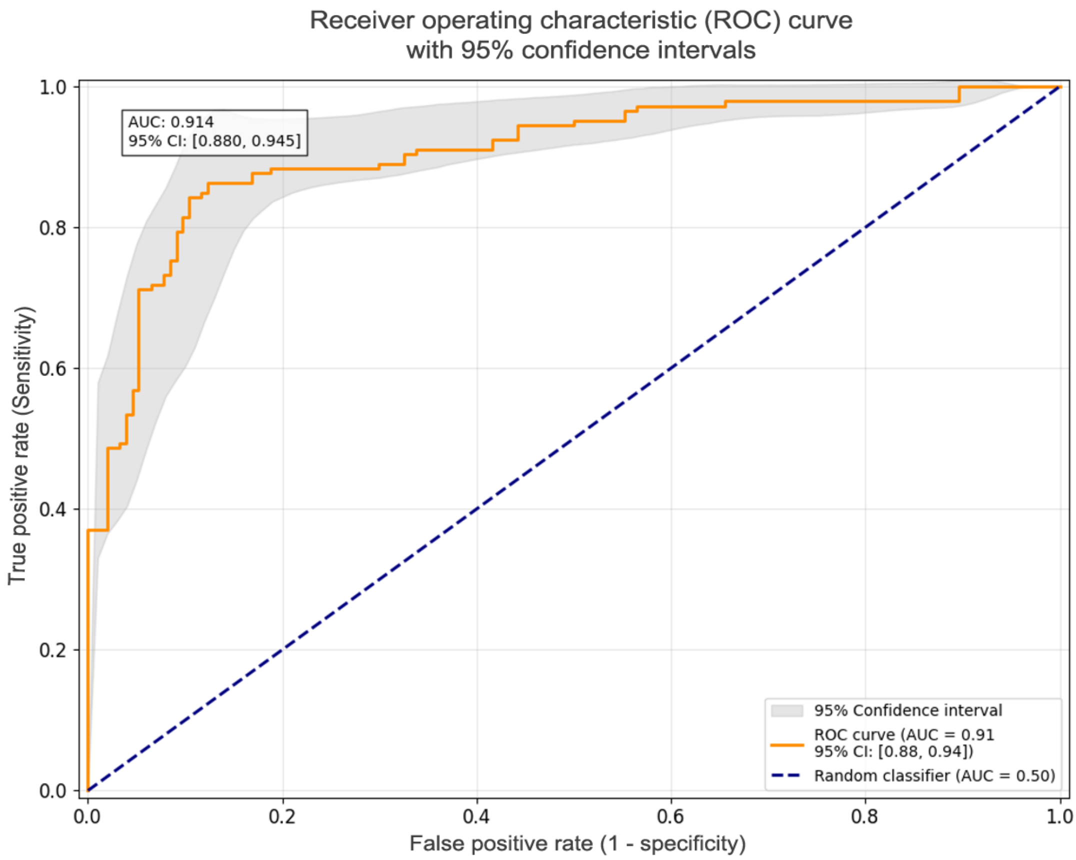

Figure 5. ROC curve analysis for adopter classification.

This ROC curve contrast (Figure 5) emphasizes the better separation capability of an Early/Pragmatic versus Late adopters' logistic regression model. With an excellent AUC measure of 0.914 (95% CI: [0.89, 0.94]), the model is significantly better than random classification. The steep early rise of the curve indicates great sensitivity in identifying Early/Pragmatic Adopters with highly maintained specificity for the Late Adopters. The narrow confidence interval guarantees the robustness of these results. The model's well-balanced performance characteristics—high true positives at minimal false positives make it a valuable predictive tool for adoption pattern identification. Such robust discriminability can inform directed marketing initiatives and adoption stimulation programs among different consumer segments.

5. DISCUSSION

PCA analysis offers several accounts of technology adoption. Several factors from readiness to expectations precede potential causal leaps in technology adoption. Organizational and external organizational readiness appear to be solid foundations for building performance expectations, which influence behavioral intentions and use in the adoption process. The PCA framework is consistent with a stepwise technology implementation model emphasizing preparation before action. A firm may have high readiness and low aspirations for organizational performance or high aspirations but moderate readiness. This independence means that these dimensions may be addressed differently through interventions to address issues, an approach used to facilitate adoption. The multidimensional structure revealed by PCA suggests the possibility of identifying different adoption profiles or typologies based on organizational position early, pragmatist, and late adopters. Some organizations may have high expectations and readiness but low usage (indicating implementation limitations), while others may have moderate readiness but high usage (indicating successful implementation with limited resources).

These findings have several practical applications for technology adoption initiatives. This three-factor adoption model provides a diagnostic tool for evaluating technology adoption readiness. Organizations can measure their position on each factor to identify specific strengths and weaknesses to improve more effectively. Interventions can be developed for each problematic factor. Readiness gaps can be closed with investments in capabilities or infrastructure; expectation issues can be supported by communication programs focused on tangible rewards; and behavioral issues require training programs or reward systems. By tracking measures over time for these variables, organizations will be better able to see them move along the adoption curve, with the understanding that progress will vary by stage of adoption.

Meanwhile, Cluster Analysis uncovered methods that can be tailored based on three groups of adopters. For Early Adopters, adoption should capitalize on their high readiness by using leading resources and positioning them to influence peers. On the other hand, Pragmatic Adopters are most open to pragmatic authentication, which requires precise ROI calculations, step-by-step implementation guidance, and the removal of barriers to installation. Late Adopters need more support resources to address their organization's efforts and readiness limitations. This requires making strategic decisions to maximize the potential of adoption at each stage of development. Strategic decisions can start with Early Adopters, creating momentum and success stories that can influence Pragmatic Adopters, and strong interventions can be made for Late Adopters based on accumulated learning.

The level of support must also be segmented and tailored to the particular needs of each cluster, calibrated with ongoing adoption measures. Most importantly, the communication strategy must be specific to a cluster, emphasizing the correct benefits through the appropriate channels, technical innovation for Early Adopters, useful outcomes for Pragmatic Adopters, and ease for Late Adopters. In the final step, the excellent discriminatory ability of the logistic regression model across adopter groups translates into significant practical benefits for decision-making in strategies. With high levels of strong classification confidence and good performance, as seen from the short 95% confidence intervals, organizations can safely incorporate this model into their framework of adoption strategy.

To better match the ideal application, organizations can rank the adopter predictions in terms of confidence and accuracy in selecting the classification threshold from the best point of the ROC curve. This application tier involves a cost-benefit analysis when selecting the operating point for various business scenarios. This ROC model is beneficial in the early detection of potential uses so that the organization can carry out more appropriate resource allocation and targeted intervention approaches. Organizations can mobilize efforts to capture the highest segment with the right strategy. Periodic validation and organizational performance must be achieved to ensure the continued implementation of the model. Organizations also need to take into account the process of implementation to determine possible deviations and adjust the model once new adoption patterns are formed. The high AUC value (0.914) and narrow confidence interval of the model make it a very reliable instrument for strategic planning in technology diffusion settings.

6. CONCLUSION

This study identifies organizational and behavioral barriers, rather than technical or financial ones, as the major hindrances to adopting energy efficiency and renewable energy technologies. Closing this gap requires cooperation that encompasses considering the specific requirements of all sectors, institution-building, and creating an enabling environment to facilitate change. The results of this study provide a solid basis for future planning to stimulate broader adoption, which will enable Indonesia's energy sector to transition to a cleaner, more efficient electricity system. The study also examines the long-standing issues of embracing energy efficiency and Renewable Energy (NRE) innovations in the Indonesian construction sector. Without the surging demand for energy and the potential for economic and environmental benefits, adopting retrofit technology and green energy measures remains low. The outcomes of this research demonstrate that organizational and behavioral factors are more influential in adoption decisions than previously established. The bounded rationality theory is applied to explain the decision-making process of building managers and stakeholders.

The adoption decisions are not based on precise economic calculations but rely on abbreviated information, perceptions of risk, and institutional routines. This creates a disconnect between the benefits of effective energy technologies and their actual implementation on the ground. This research confirms that adoption is not merely a matter of feasibility alone but largely hinges on internal readiness, perceived benefits, and enabling external conditions. Logistic regression analysis, cluster analysis of K-Means, and PCA show that firms are distributed into three adopter types: Early, Pragmatic, and Late. Every cluster shows varying organizational preparedness, behavioral intentions, and performance targets. Early adopters will likely be confident in their capacity to accept aggressive and clever innovations. While late adopters trail behind because they see the complexity or lack of in-house support, pragmatic adopters are driven by more practical concerns like cost and simplicity.

The present study has both theoretical and practical implications. Theoretically, it adds to the understanding of how behavioral models can be integrated with organizational and technology acceptance models to explain the complexity of innovation diffusion in the energy sector.

The study underscores the need to understand not only the economic rationale of decision-making but also the softer factors like readiness, foresight, and organisational behavior. At a practical level, the study provides reflective analysis to corporate managers and policymakers.

First, early movers can be catalysts by being role models whose impact and motivation others can follow.

Second, the design of energy policy and programs should transcend just economic incentives and include mechanisms that raise organizational capability, raise awareness, and simplify implementation processes. Interventions appropriate to each group of adopters have to be developed. For example, while early adopters can have better solutions and pilot initiatives, pragmatic and late adopters may require lower-profile procedures, training, and more specific communication of return on investment.

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