International Journal of Computations, Information and Manufacturing (IJCIM) 4(2) -2024

Contents available at the publisher website: GAFTIM.COM

International Journal of Computations, Information and Manufacturing (IJCIM)

Journal homepage: https://journals.gaftim.com/index.php/ijcim/index

Impact of Energy Management Systems on Cost Management: with Mediating role of Technological Advancements in Renewable Energy Sector

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A R T I C L E I N F O

Keywords:
Energy Management Systems, Cost Management, Technological Advancements, Renewable Energy, Energy Monitoring, Automation, Data Integration, Budgeting, Cost Optimization, Expense Tracking, ENMS

Received: Aug, 18, 2024
Accepted: Oct, 28, 2024
Published: Dec, 25, 2024

A B S T R A C T

Impact of Energy Management Systems on cost management within the renewable energy sector is examined in this research, while focusing on technological advancements as the mediating role. Quantitative research design is applied by using secondary data analysis and structured questionnaires from renewable energy organizations, implementing ENMS. Data is collected from 67 organization with 200 energy management professionals/managers and analyzed to examine the relationships between technological advancements, cost management and Energy Management Systems. The research findings suggest that Energy Management Systems improve cost management significantly by enhancing budgeting accuracy, facilitating effective expense tracking and optimizing energy usage. Technological advancements further amplify aforesaid benefits by serving as a crucial mediator which enhances effectiveness and efficiency of ENMS. Organizations are recommended to invest in Energy Management Systems to achieve operational efficiency and substantial cost savings. Continuous workforce training and investment in research and development are key to boosting benefits of ENMS as well as in maintaining a competitive edge within the renewable energy sector.

1. INTRODUCTION

Energy Management Systems has transformed the way renewable energy sector operates (Rathor & Saxena, 2020; Yu et al., 2022). ENMS has modified the monitoring, controlling, and management systems through data integration and real-time energy management (Digitemie et al., 2024; Ghenai et al., 2022; Zhang et al., 2022). Besides, organizations employ leading-edge technologies under ENMS to facilitate automation, enhance energy efficiency and optimize cost all at the same time (Hussain et al., 2021). Despite the significant potential, ENMS' direct impact on cost management within renewable energy sector remains obscure. Moreover, technological advancements as a mediator also require thorough investigation in this relationship. For shareholders, developing a clear understanding regarding these dynamics is crucial to maximize ENMS benefits as well as drive sustainable growth within the renewable energy sector.

1.1. Problem Statement and Research Gap

The renewable energy sector is confronting substantial challenges in managing its operational costs whilst attempting to gain sustainability and higher efficiency (Ahmad et al., 2021; Gawusu et al., 2022). ENMS is offering promising solutions through comprehensive data integration and advanced automation (Himeur et al., 2023; Khan et al., 2022). Nevertheless, a notable gap in the empirical research regarding the influence of these systems on cost management is observed. Also, the scope of technological advancements as a mediator in this relationship remains unknown.

By understanding these factors, this research provides detailed analysis of ENMS' efficacy on cost management as well as the critical role of technological innovations in improving the overall development of an organization. Furthermore, the findings offer constructive insights for sector's participants, allowing them to leverage technological advancements and Energy Management Systems to achieve sustainable energy solutions.

1.2. Research Questions

2. What is the impact of Energy Management Systems on cost management and technological advancements within the renewable energy sector?
3. What is the role of technological advancements as mediator in the relationship between cost management and Energy Management Systems (ENMS)?
4. How do factors such as adoption speed, Research and Development investment and innovation rate influence ENMS' efficacy within the renewable energy sector?

1.3. Research Objectives

1. To examine Energy Management Systems impact on cost management within the renewable energy sector.
2. To understand the mediating role of technological advancements in the relationship between cost management and ENMS.
3. To investigate how adoption speed, Research & Development investment and innovation rate influence ENMS' effectiveness and implementation in optimizing costs.
4. To provide actionable insights for renewable energy sector's shareholders and to propose recommendations for improving cost management through technological advancements and Energy Management Systems (ENMS).

2. THEORETICAL FRAMEWORK

2.1. Energy Management Systems (ENMS)

Energy Management Systems are sophisticated platforms where integrated technologies are used to optimize, control and monitor energy usage within an organization (Wu et al., 2021). Such systems apply software, communication networks and sensors to analyze as well as collect real-time data from various energy assets, enabling efficient energy consumption and distribution (Ahmad & Zhang, 2021). These systems allow organizations to enhance energy efficiency, reduce operational costs and automate energy management processes (Hasan & Trianni, 2020). ENMS helps organizations in managing energy storage, supporting grid stability and integrating renewable energy sources. By this means, ENMS contributes to improve cost management and support sustainable energy practices in both commercial as well as industrial sectors.

Energy Monitoring: Energy monitoring implies continuous analysis and tracking of energy utilization within an organization or facility (Cai et al., 2022; Manfren et al., 2021). Utilizing metering systems, sensors devices and energy monitoring systems for the collection of real-time data on usage of energy provides insights on to the consumption patterns, inefficiencies and peak demand periods (Khan et al., 2022). In this way, organizations find areas for optimizing operational processes, reducing energy costs as well as energy savings (Wang et al., 2020).

Automation and Control: Automation and control help organizations employ technology to processes and operate systems with slight or least human intervention (Coombs et al., 2020; Haleem et al., 2021). Through automation, organizations deploy intelligent systems which autonomously adjust, optimize and monitor energy consumption efficiently (Bathla et al., 2022; Mischos et al., 2023; Vijayan et al., 2020). Whereby, control system regulates and operates organizations' energy-consuming devices, ensuring that the processes are efficiently undertaken within the predefined parameters (Hohne et al., 2020).

Data Integration: Merging data from various sources to facilitate organizations through comprehensive analysis with a unified view is exclaimed as data Integration (Argelaguet et al., 2021; Boehm et al., 2021). It aggregates information from different energy sensors, devices and systems into an integrated platform. The holistic approach leads to effective decision-making because it provides an overall perspective of an organization's efficiency, performance and energy usage (C. Li et al., 2022).

2.2. Cost Management

Cost management is a method of controlling, reducing and planning expenses of an organization to maximize efficiency and profitability (Dahal, n.d.). It involves the implementation and identification of strategies to reduce energy costs, enhance financial performance and optimize energy consumption (Rounaghi et al., 2021). Efficient cost management includes forecasting, monitoring and budgeting energy expenses by investing in environmentally friendly practices and technologies (Reis et al., 2023). It also tracks savings from energy conservation measures as well as includes energy procurement management and favorable energy tariffs negotiation. Basically, cost management facilitates organizations maintain competitiveness to achieve long-term business sustainability

- *Budgeting:* Budgeting is the development of a fiscal plan which outlines projected expenses and income of an organization for a specific period (Anderson et al., 2020; Homauni et al., 2023; Kuntadi & Puspasari, 2023). It involves setting expenditure limits, allocating resources and forecasting energy costs to several energy-related activities. It further helps an organization identify cost-saving prospects, guarantee availability of funds and manage energy expenses, for critical investments and energy projects.

Cost Optimization: Cost optimization implements and identifies policies to minimize organization's expenses while improving and maintaining quality and performance (Chaurey et al., 2023). It focuses on improving energy efficiency, lowering energy costs and reducing energy consumption (Wang et al., 2020). It is achieved by augmenting operational processes, employing renewable energy sources and advancing fuel-efficient equipment.

Expense Tracking: Expense tracking is an organized recording and monitoring of all the financial outflows occurring within the organization (Brown et al., 2020). For example, comprehensive track of energy-related expenditures, such as eco technologies investment, cost of maintenance and utility bills are preserved through expense tracking(Gawusu et al., 2022). Insights into the spending patterns help organizations guarantee accurate financial reporting as well as identify saving opportunities.

2.3. Technological Advancements

Technological advancements are the implementation and development of new and unique technologies (Abed et al., 2020). It improves products, services and processes through innovation in energy monitoring automation, data analytics and renewable energy technologies (Ahmad & Zhang, 2021). It also improves the reliability, sustainability and efficiency of energy systems (Ahmad et al., 2021). Besides, these advancements reduce costs, support renewable energy sources incorporation and progressively effects energy management practices (Gawusu et al., 2022). Technological advancements continuity fosters innovation, creates unique opportunities and drives sector growth to achieve environmental goals as well as optimize energy usage.

Innovation Rate: The measurement of frequency and speed at which innovative products, processes and technologies are adopted and developed within an organization is stated as innovation rate (Dani & Gandhi, 2022; Lagorio et al., 2022; Muharam et al., 2020). It indicates rapid advancements in technologies such as energy monitoring, automation, and renewable energy systems (O. Ali et al., 2023).

Adoption Speed: Adoption speed is the percentage at which new systems, practices and technologies are integrated and accepted routinely within an organization (Al Hadwer et al., 2021). Through this feature, implementation of advanced technologies such as automation, renewable energy technologies and Energy Management Systems is achieved (Zafar et al., 2020). It indicates an approach which embraces improved energy efficiency and innovation (Soorige et al., 2022).

Research and Development (R&D) Investment: Research and Development (R&D) investment allocates resources to innovation and systematic investigation of unique products, processes and technologies (Gutterman, 2023). It emphasizes enhancing energy efficiency, integrating renewable energy sources and utilizing advanced energy solutions (Soltanisehat et al., 2019). Significant research and development investment improves competitive advantage, supports sustainable growth and drives technological breakthroughs (Sarpong et al., 2023).

2.4. Sector's Description

Renewable Energy Sector

Dubai is pursuing its clean energy strategy ambitiously, ensuring that 75% of its energy generation is coming from clean sources by 2050.

This has positioned the city as a cosmopolitan hub in the renewable energy sector (UAE Government, 2024). This strategy comprises of five key pillars including legislation, infrastructure, funding, eco-friendly energy mix and capacity building. To meet the rising energy demand of the sector and renewable energy sector, UAE government is committed to invest over $163 billion by the year 2050 (International Trade Administration, 2024). Dubai is expected to contribute 90% of the UAE's renewable energy capacity by 2025, emphasizing the importance of renewable energy. Dubai is achieving its Net Zero Carbon Emissions Strategy 2050 and Clean Energy Strategy 2050, planning for 100% clean energy by midcentury. The city is also set to exceed its short-term objective of 25% clean energy by 2030, aiming 27% (Al Tayer, 2024). Dubai's leadership and governance in the renewable energy sector serves as a model for others and underlines its commitment to sustainability.

3. REVIEW OF LITERATURE

3.1. Impact of Energy Management Systems on Cost Management

Energy Management Systems (ENMS) has surfaced as a significant tool in the renewable energy sector, predominantly due to its potential to influence cost management (Ahmad & Zhang, 2021). ENMS integrates sophisticated technologies to optimize the usage of energy and reduce operational costs (Alsharif et al., 2021; Zafar et al., 2020). It further facilitates real-time analytics into supporting organizations to not only identify inefficiencies, but also implement corrective measures and energy consumption patterns for substantial cost saving (Himeur et al., 2023).

Energy monitoring is a critical factor of ENMS, as it provides continuous analysis and tracking of energy consumption (Rathor & Saxena, 2020). This ability enables organizations to make well-informed decisions that reduce costs and enhance energy efficiency (Agrawal et al., 2023; Economidou et al., 2020; Kozlovska et al., 2023; Patterson et al., 2022). Alternatively, automation and control in ENMS allows efficient operation of the energy systems with least human intervention (Van Thillo et al., 2022). In this way, organizations adjust their energy usage according to the real-time data to reduce manual errors and guarantee optimal performance (Mischos et al., 2023).

Expense tracking in ENMS implies recording and monitoring of all financial outflows correlated to providing transparency, accountability and energy consumption (M. Ali et al., 2021; El Hafdaoui et al., 2024; Mickovic & Wouters, 2020). Efficient expense tracking helps organizations ensure that energy costs remain within the budgeted limit (Hohne et al., 2020). Research suggests that ENMS certainly effects cost management through improved automation, energy monitoring, data integration, expense tracking and enhanced budgeting (Amrutha Raju et al., 2021). These systems help organizations through optimized energy usage and reduced costs to accomplish sustainable financial performance(Muqeet et al., 2022; Thirunavukkarasu et al., 2022).

Based on the literature review, following hypothesis is proposed:

H1: Energy Management Systems have a positive impact on cost management.

3.2. Impact of Energy Management Systems on Technological Advancements in Cost Management

ENMS influences technological advancements in cost management significantly within the renewable energy sector (Ammari et al., 2022; Elia et al., 2021). According to observation, automation, energy monitoring and data integration within ENMS facilitate substantial developments in cost management practices (Aguilar et al., 2021; M. Ali et al., 2021; Mahapatra & Nayyar, 2022). Another foundational component of ENMS is energy monitoring, which offers real-time data about an organization’s energy consumption allowing implementation of innovative energy-saving measures and informed decisions (M. Ali et al., 2021; González et al., 2021; Gorina et al., 2024; Himeur et al., 2022). This capacity encourages swift identification and continuous improvement, which is then addressed through technological solutions.

Automation and control are significant elements of ENMS, permitting efficient operations through the utilization of advanced technologies (Mahapatra & Nayyar, 2022; Mohd Aman et al., 2021). Automated systems adjust energy usage dynamically established on real-time data to reduce manual errors and optimize performance (Himeur et al., 2023). It drives high-tech invention by launching sophisticated strategies for operational efficiency and energy savings (Coombs et al., 2020; Haleem et al., 2021).

One of the major factors in driving technological advancements is the speed of adopting ENMS (M. Ali et al., 2021). Prompt adoption enables organizations to encourage integration of the recent innovations in energy management systems to achieve superior outcomes in cost management (Feng et al., 2022; Vanlalchhuanawmi et al., 2024). ENMS' implementation is facilitated by R&D investment, fostering the development of creative solutions to enhance its overall efficiency (Agrawal et al., 2023; Ifeanyi Ibekwe et al., 2024; Mainar-Toledo et al., 2022).

Considering the above literature review, subsequent hypothesis is suggested:

H2: Energy Management Systems positively contribute to technological advancements on cost management.

3.3. Impact of Technological Advancements on Cost Management

Technological advancements profoundly impact cost management, enhancing cost optimization, expense tracking and budgeting significantly (Arumugam et al., n.d.; Jejeniwa et al., 2024; Suwarno et al., 2023). Integration of advanced technologies facilitates more efficient and accurate cost management practices, leading to financial benefits (Kitsantas et al., 2020). Amongst the fundamental ways technological advancements enhance cost management is through improved budgeting capabilities (Vigneault et al., 2019). Analytical tools and advanced software help create a more realistic and precise budget by leveraging predictive analytics and real-time data (Mathrani & Lai, 2021; Nwaimo et al., 2024; Rangineni et al., 2023). This precision in budgeting eventually helps managers avoid overspending, identify potential cost-saving prospects and allocate resources effectively ((CA) & Gujral, 2024; Suwarno et al., 2023).

Technological advancements play a critical role in cost optimization as Machine Learning and other advanced technologies enable organizations to evaluate large volumes of data (Aoun et al., 2021; C. Li et al., 2022; Rathore et al., 2021; Soori et al., 2023). It also helps in optimizing operational processes and identifying inefficiencies (Javaid, Haleem, Singh, & Suman, 2022). For example, Artificial Intelligence can help in cost savings significantly by pinpointing areas to minimize energy consumption and areas to optimize production workflows (Sircar et al., 2021). The adoption speed and innovation rate of modern technologies further expands their influence on cost management (Elia et al., 2021; Feng et al., 2022). Organizations that integrate and adopt new technologies quickly, stay ahead of competition and incessantly enhance their cost management practices (Nand et al., 2023; Shahid et al., 2021; Tariq et al., 2021). Additionally, significant R&D investment drives development of leading-edge technologies. It ensures that organizations access efficient tools and technologies for cost management (Carly Jackson et al., 2022; Elia et al., 2021).

Considering the above, following hypothesis is proposed:

H3: Technological advancements have a positive impact on cost management.

3.4. Mediating Role of Technological Advancements in the Relationship Between Cost Management and Energy Management Systems (ENMS)

Technological advancements boost ENMS' abilities by enhancing effectiveness through improved budgeting, efficient expense tracking and cost optimization (Kelechi et al., 2020; Milton, 2024; Mustafa, 2024). ENMS relies on innovative technologies for real-time automation, data integration and energy monitoring (Ahmad & Zhang, 2021; Meliani et al., 2021). Energy monitoring within ENMS benefits from advanced technologies such as data analytics and improved sensor technology (Dai et al., 2021; Zafar et al., 2020). It provides real-time and accurate data, assisting organizations to identify and implement inefficiencies quickly for corrective measures (J. Li et al., 2023; Pandiyan et al., 2023; Ponnusamy et al., 2021). The aforesaid process contributes directly to cost management by enhancing operational efficiency and reducing energy wastage.

Automation and control in ENMS are enhanced significantly by technological advancements (Digitemie et al., 2024). Innovations in Artificial Intelligence and Machine Learning enable sophisticated automation systems which dynamically regulate use of energy based on real-time data (Alanne & Sierla, 2022; Ibrahim et al., 2020). It optimizes energy consumption and reduces manual errors leading to substantial reduction in expenditures (Farzaneh et al., 2021; Olatunde et al., 2024). Data integration in ENMS is mediated by technological advancements (Altohami et al., 2021; Rasheed, 2024). Whereby, improved integration technologies and data processing enables accurate and comprehensive data aggregation from several sources (Ikegwu et al., 2022; Krishnamurthi et al., 2020). This integrated view leads to informed decision-making and advanced analytics, crucial for efficient cost management (C. Li et al., 2022). Integrated data systems enable expense tracking and better budgeting by offering detailed insights into financial outflows and energy usage patterns (Zheng et al., 2024).

Research and Development investment drives technological advancements (Ding et al., 2020; Miroshnychenko & De Massis, 2020; Rukanova et al., n.d.). Steady and sustained R&D investment ensures integration of latest innovations, making ENMS effective in managing costs (Andrei et al., 2022; Gallegos et al., 2024; Shafiullah et al., 2022). Organizations adopting advanced ENMS leverage unconventional technology for operational efficiency and enhanced financial performance (Ifeanyi Ibekwe et al., 2024). Thereby, technological advancements mediate the relationship significantly involving cost management and Energy Management Systems. Reflecting on the aforesaid, following hypothesis is put forward:

H4: Technological advancements mediate the relationship between Energy Management Systems and cost management.

3.5. Research Model

Figure 1 below displayed the hypothesized relationship of the study constructs.

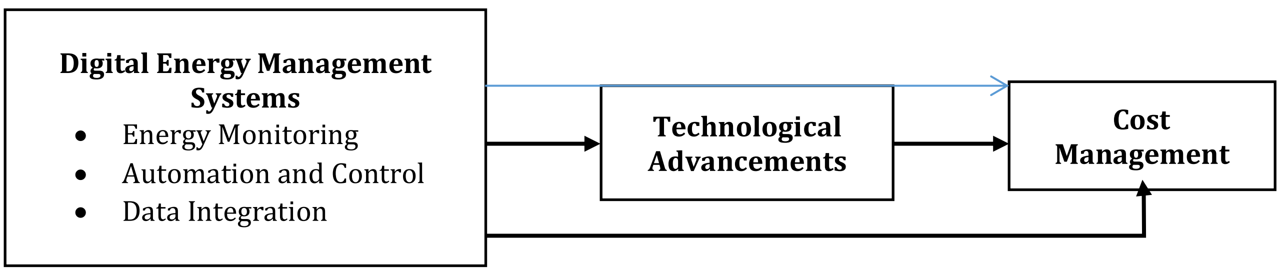

Figure 1: Conceptual Model

4. METHODOLOGY

4.1. Research Design & Philosophy

By adopting a Positivist research philosophy, this research emphasizes quantifiable data and objective analysis to examine the relationship amongst technological advancements, cost management and ENMS. Quantitative research design is utilized to test the proposed hypothesis that technological advancements act as a mediator impacting ENMS on cost management. This approach enables statistical analysis to measure the mediating effects as well as establish causal relationships. For data collection, structured questionnaires are used which involve Likert scale items so as to measure the perceptions of technological advancements, cost management practices and ENMS effectiveness. The questionnaires are distributed by electronic means for efficient data collection and broad reach. In addition, to verify survey findings, secondary data from energy usage reports and organization financial records is analyzed.

4.2. Population and Sample

The chosen population for conducting this research includes energy management professionals/managers within 67 organizations implementing ENMS. Stratified random sampling is employed for this research to ensure representation across manufacturing, commercial buildings and utilities. Sample size for this research is 200 respondents as it provides sufficient set of data for reliable statistical analysis.

4.3. Unit of Analysis

Unit of analysis focused for this research paper is organizations' energy management professionals/managers. Each organization using ENMS, cost management practices and technological advancement is examined. By focusing on different organizational levels, this research identifies patterns to draw conclusions which can be applied across different industries.

5. DATA ANALYSIS

Table 1 indicates the demographic profile of the respondents with 70 percent being male and the rest 30 percent female. Participants in the age category 35-44 years constituted 45 percent, 45-54 years 25 percent and 25-34 years 20 percent with only 10 percent in the age bracket of 55 years and above. Regarding working experience, 50 percent of the respondents had 5 10 years' experience in the area of energy management, 35 percent had experience above 10 years and 15 percent had lesser than 5 years of experience. The sample was only dominated in terms of job role by energy managers/engineers (60%), with sustainability/compliance officers (25) and senior management/executives (15) a close second and third respectively. Such a distribution shows that the respondent pool is one with a lot of professional experience and technical knowledge in energy management, which enhances the relevance and the credibility of the research findings.

Table 2 is the result of convergent and discriminant validity of the constructs. The Average Variance Extracted (AVE) values of all constructs, Digital Energy Management Systems (0.61), Technological Advancements (0.62), and Cost Management (0.66) was above the minimal threshold of 0.50 and achieving sufficient convergent validity. The values of Composite Reliability (CR) were even higher than the desired level of 0.70 and ranged between 0.85 and 0.88, and the values of Cronbach Alpha (CA) were also above 0.80 which is a confirmation of strong internal consistency. The Fornell-Larcker criterion was used to determine the discriminant validity since the square root of AVE of each construct was higher than its correlation with the other constructs (e.g., DEMS = 0.78 > 0.58 and 0.55). The findings affirm the construct reliability and construct distinctiveness so that the measurement model is valid.

The Table 3 regression analysis shows that there exist significant correlation between the constructs studied. Energy Management Systems positively and significantly influenced Cost Management (8 = 0.156, p < 0.001) but even more importantly Technological Advancements (8 = 0.642, p < 0.001). Moreover, Cost Management were affected by Technological Advancements affecting it positively (B = 0.642, p < 0.001). The partial mediation effect of Technological Advancements on the connection between Energy Management Systems and Cost Management was also evident and significant (β = 0.26, p < 0.001). The above findings lead to the conclusion that the direct benefits of adopting energy management systems are the direct benefit in improved cost management but with the advent of technological advancements, the efficiency of the energy management system increases significantly, giving a high priority to innovation in terms of strategy to achieve cost efficiency.

Table 1: Respondents profile

Category	**Sub-category**	**Frequency (n)**	**Percentage (%)**
Gender	Male	140	70%
	Female	60	30%
Age Group	25–34 years	40	20%
	35–44 years	90	45%
	45–54 years	50	25%
	55 years and above	20	10%
Years of Experience in Energy Management	Less than 5 years	30	15%
	5–10 years	100	50%
	More than 10 years	70	35%
Job Role/Designation	Energy Manager/Engineer	120	60%
	Sustainability/Compliance Officer	50	25%
	Senior Management/Executive	30	15%

Table 2 convergent and discriminant validity

Construct	**AVE**	**CR**	**CA**	**DEMS ($\sqrt{AVE}$ = 0.78)**	**TA ($\sqrt{AVE}$ = 0.79)**	**CM ($\sqrt{AVE}$ = 0.81)**
Digital Energy Management Systems (DEMS)	0.61	0.85	0.81	**0.78**	0.58	0.55

Technological Advancements (TA)	0.62	0.86	0.82	0.58	**0.79**	0.51
Cost Management (CM)	0.66	0.88	0.84	0.55	0.51	**0.81**

Table 3 Regression coefficients

Hypothesis	**Relationship**	**Path Coefficient (β)**	**T-Value**	**P-Value**	**Decision**
H1	Energy Management Systems → Cost Management	0.156	4.02	0.000	Supported
H2	Energy Management Systems → Technological Advancements	0.642	8.45	0.000	Supported
H3	Technological Advancements → Cost Management	0.642	5.73	0.000	Supported
H4	Energy Management Systems → Technological Advancements → Cost Management (Indirect Effect)	0.26	4.57	0.000	Mediation Supported

5.1. Structured Model Measurement

The figure 2 illustrates a structural equation model (SEM) showing the relationships between three latent constructs: DEMS (Decision-Making Skills), CM (Crisis Management), and TA (Team Adaptability). The path coefficients indicate that DEMS has a strong positive effect on TA (β = 0.642) and a weaker positive effect on CM (β = 0.156). CM also has a strong positive effect on TA (β = 0.642), suggesting a possible mediating role of CM between DEMS and TA. The model's explained variance (R^2) values show that DEMS accounts for 56.4% of the variance in CM and that DEMS and CM together explain 41.2% of the variance in TA. The measurement model indicators (outer loadings) for all constructs are generally above the acceptable threshold of 0.7, with a few slightly lower values (e.g., CM2 = 0.410, TA6 = 0.560), indicating that most observed variables reliably measure their respective latent constructs. Overall, the model highlights that strong decision-making skills enhance both crisis management and team adaptability, with crisis management also directly contributing to adaptability.

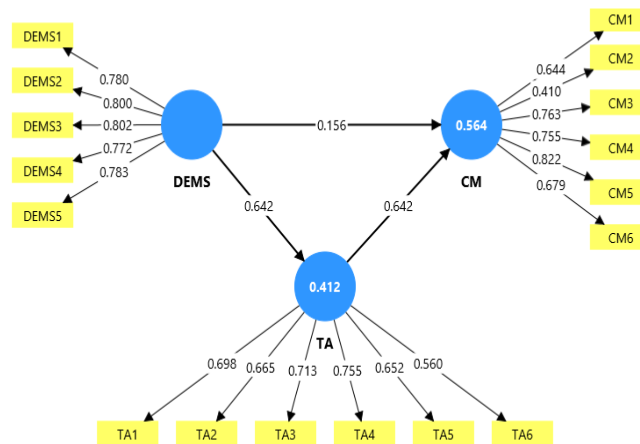

Figure 2: Structured Equation Model

6. DISCUSSION ON RESULTS

The result that Energy Management Systems (ENMS) implementation results in better cost control is consistent with previous studies in that, structured energy management can curb wastage, maximize resources, and make operations more efficient. The research by Zhang et al. (2021) and Abubakar et al. (2020) proves that enterprises that implement ENMS can methodically locate their inefficiency, take corrective actions, and reduce their energy expenditures. This cost saving is commonly attained due to constant supervision, standardization of energy activities and implementation of performance standards that have direct impact of improved budget control and cost savings. Furthermore, other studies conducted previously show that such gains are not limited to direct cost savings, but can also create long-term competitiveness with sustainable operations.

The fact that ENMS significantly influences technological progress proves previous studies that the implementation of energy management frequently requires introducing new tools, methods, and innovations into the organizational processes. Garcia-Sanz-Calcedo et al. (2018) note that a legacy system is often needed to be upgraded, state-of-the-art monitoring tools are to be deployed, and digital energy optimization solutions are to be utilized to support the implementation of ENMS. These advancements in technology not only make the operations modern, but also aid in the effective control of costs as they improve the efficiency of work and minimize the inefficiencies. According to the literature, the organizations taking the advantage of the innovations entailed by ENMS achieve not only the operational agility but also the competitive edge, as well as a strong position in the markets that become more technology-reliable.

A strong correlation between automation, analytics tools and new software and better cost management outcomes is also in line with previous research on the importance of digital solutions to operational efficiency. Chofreh et al. (2019) and Khalid et al. (2021) also stipulate that automation and advanced analytics help to make data-driven decisions, minimize human error, as well as optimize the process. These tools can assist managers in making immediate corrective actions by giving proper and instantaneous inputs of energy consumption and cost trends leading to enormous cost savings. Also, including smart solutions in the ENMS processes will guarantee constant improvement as it is one of the best practices in energy management and cost management systems.

The observation that technological advancements fully mediate the positive effect that ENMS has on cost management is congruent with the findings by other authors who revealed that the success of energy management outcomes is subject to the successful adoption of enabling technologies. According to the research results provided by Tanaka (2019) and Lopes et al. (2020), the framework ENMS offers the basis on which cost-saving measures can be implemented, but the real improvement in the cost management comes only when organizations adopt the advanced technological tools to this framework. This mediation proposes that ENMS are not likely to give the best cost benefits on their own without the surrounding innovations that include automatic monitoring systems, predictive analytics, and optimization software. As such, the potential of cost management of ENMS can only be fully utilized when an organization is committed to advancement in terms of technology.

7. CONCLUSION

This research interprets the significance of Energy Management Systems on cost management within the renewable energy sector. It further highlights the mediating effect of technological advancements. Through the fundamental functionalities of automation, data integration and energy monitoring, ENMS facilitate cost savings substantially by identifying inefficiencies, providing actionable insights and optimizing energy consumption for well-versed decision-making. Technological advancements, such as Artificial Intelligence and enhanced data analytics improve ENMS' efficiency, ultimately allowing cost optimization, accurate expense tracking and precise budgeting. The adoption speed, continuous investments in research and development and rapid innovation rate are most important in strengthening ENMS.

The findings from this research affirm that technological advancements complement ENMS' full potential, leading to superior outcomes for cost management within the renewable energy sector.

- **Recommendations**

Organizations within the renewable energy sector are suggested to prioritize ENMS' execution for significant cost reductions and optimized energy management. Investing in innovative and advanced technologies impact capabilities of ENMS greatly, ensuring sophisticated automation, data integration and energy monitoring.

Continuous investment in the field of research and development is also recommended as it maintains a competitive edge within the global market. Organizations should also emphasize different training programs for workforce proficiency so that they can utilize advanced systems successfully. Furthermore, promoting continuous improvement and innovation within organizations helps them to adapt new technologies swiftly as well as integrate them into cost management strategies seamlessly.

By following the above-mentioned recommendations, organizations can achieve financial sustainability, contribute to advancement and enhance cost management practices within the renewable energy sector.

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