

Original Article

Business Strategies for Pumped Storage Hydropower Development

Jia G. Villajuan¹ , Jonah Faye Gaspar² 

Author Information:

¹Doctor of Philosophy in Business Administration, Wesleyan University Philippines, Cabanatuan City 3100
<https://orcid.org/0009-0009-0867-8370>

²Faculty, Graduate School, Wesleyan University Philippines, Cabanatuan City 3100
<https://orcid.org/0009-0002-5586-9320>

Corresponding Author:

jvillajuan@gmail.com

Article History:

Date received: May 14, 2026

Date revised: June 30, 2026

Date accepted: July 8, 2026

Recommended citation:

Villajuan, J., & Gaspar, J.F. (2026). Business strategies for pumped storage hydropower development. *Journal of Interdisciplinary Perspectives*, 4(8), 107-116.
<https://doi.org/10.69569/jip.2026.260>

Abstract. Pumped storage hydropower projects play a crucial role in supporting renewable energy integration, enhancing grid stability, and strengthening energy security. However, limited research exists on how business strategies address the strategic, operational, regulatory, and market-related challenges associated with pumped storage hydropower development. This study assessed the effectiveness of business strategies for pumped storage hydropower development by evaluating strategic factors through SWOT analysis, examining competitive forces using Porter's Five Forces Model, and identifying implementation challenges affecting project success. A descriptive-predictive quantitative research design was employed involving 100 engineers, project managers, regulatory personnel, and other professionals engaged in hydropower projects in selected project sites across Central Luzon and Southern Luzon, Philippines. Data were collected through a structured questionnaire and analyzed using descriptive and inferential statistical tools. The findings revealed that organizations possessed strong internal capabilities, particularly in project coordination and regulatory compliance. Nevertheless, procedural delays and communication gaps remained significant internal weaknesses. External opportunities were driven by the growing demand for renewable energy and continued infrastructure expansion, while major threats included regulatory changes, climate-related risks, and market volatility. The study further found that competitive factors, particularly buyer influence and the threat of substitute technologies, significantly affected the effectiveness of business strategies. Operational challenges were primarily associated with safety management, documentation requirements, and stakeholder coordination. Regression analysis confirmed that strategic factors and competitive forces were significant predictors of the effectiveness of business strategy. The study concludes that successful pumped storage hydropower development requires organizations to strengthen internal coordination, proactively manage external risks, and respond effectively to competitive pressures. Enhancing stakeholder engagement, risk management practices, operational efficiency, and strategic planning can improve project implementation and contribute to the long-term sustainability of pumped storage hydropower initiatives.

Keywords: *Competitive forces; Energy business strategy; Pumped storage hydropower; Strategic management.*

The global transition toward cleaner and more reliable energy systems has increased demand for large-scale energy storage technologies to support the growing integration of renewable energy sources. While solar and wind energy have become important components of the global energy mix, their intermittent and variable nature poses challenges to maintaining a stable, continuous electricity supply. Without adequate energy storage systems, surplus electricity generated during periods of low demand may be wasted, while shortages may occur during peak demand periods. Consequently, energy storage has become a critical component of grid reliability, renewable energy integration, and the advancement of low-carbon energy systems (Malik et al., 2025).

Among the available energy storage technologies, Pumped Hydro Energy Storage (PHES) is widely recognized as one of the most mature, efficient, and technically feasible solutions for large-scale applications. PHES stores excess electricity by pumping water from a lower reservoir to an upper reservoir during periods of low electricity demand and releases the stored water through turbines to generate electricity when demand increases. Previous studies have highlighted the high efficiency, long operational lifespan, and substantial storage capacity of PHES, making it essential for maintaining grid stability and supporting renewable energy integration (Luo et al., 2019; Rehman et al., 2020; Maio et al., 2024). In addition, PHES provides valuable ancillary services such as frequency regulation, voltage support, and load balancing, which enhance power system reliability and reduce dependence on fossil fuel-based electricity generation (Papathanasiou et al., 2024).

While PHES has been widely studied for its technical, economic, and environmental benefits, limited research examines the strategic business dimensions of its implementation, particularly in developing countries. Most existing studies focus on engineering performance, energy efficiency, environmental impacts, and financial feasibility, while relatively little attention has been given to the business strategies required to successfully develop and implement pumped storage projects. This gap is particularly important because PHES projects involve substantial capital investments, lengthy planning and construction periods, complex regulatory requirements, environmental compliance obligations, and extensive stakeholder coordination.

Beyond engineering challenges, PHES implementation is shaped by strategic commercial considerations such as financial planning, market positioning, stakeholder engagement, risk management, and revenue optimization. The success of these projects depends not only on technical capabilities but also on an organization's ability to effectively manage its resources and respond to external environmental pressures. The Resource-Based View (RBV) Theory suggests that organizations can achieve sustainable competitive advantage by effectively utilizing their internal resources and capabilities, including technical expertise, financial capacity, managerial competence, and organizational knowledge (Barney, 2021). Applying this perspective to PHES development highlights the importance of strategic management in ensuring project success and long-term sustainability.

The need to investigate business strategies is particularly relevant in the Philippine context, where hydro energy projects face challenges related to financing, regulatory compliance, environmental concerns, infrastructure limitations, and stakeholder expectations. These conditions require project developers and decision-makers to formulate strategies that align internal organizational capabilities with external industry demands. Understanding how strategic factors influence project implementation can help organizations improve project outcomes and enhance the viability of pumped storage initiatives.

Industry practitioners, particularly engineers, project managers, and regulatory personnel involved in hydropower projects, possess valuable insights into implementation challenges, operational risks, stakeholder concerns, and strategic decision-making processes. Their experiences can provide a deeper understanding of the strengths, weaknesses, opportunities, and threats affecting pumped storage development, as well as the competitive forces that influence project success within the hydro energy sector.

This study investigates strategic business approaches for implementing pumped storage hydropower projects in the hydro energy sector. Specifically, it examines strategic factors using a SWOT analysis, evaluates industry competition through Porter's Five Forces, and identifies implementation challenges that affect project success. The findings are expected to provide actionable insights for project developers, engineers, policymakers, and stakeholders in designing strategies that enhance project feasibility, implementation effectiveness, and long-term sustainability. By integrating strategic management concepts into energy infrastructure research, this study advances sustainable energy development in the Philippines. It expands existing knowledge on the business dimensions of pumped storage hydropower projects and offers practical guidance for organizations seeking to

improve project implementation and strengthen the role of renewable energy in the country's energy transition.

Methodology

Research Design

This study employed a descriptive-predictive quantitative research design. The descriptive component was used to determine the respondents' profile, assess the effectiveness of business strategies, evaluate the intensity of competitive forces, and identify the challenges encountered in implementing pumped storage hydropower projects. The predictive component examined whether SWOT factors and Porter's Five Forces significantly influenced the effectiveness of business strategies in project implementation. This design was appropriate because it allowed the examination of existing conditions and relationships among variables without manipulation. Moreover, predictive analysis was necessary to determine the extent to which strategic factors affected the effectiveness of business strategy.

Research Participants

The study involved 100 engineers, project managers, regulatory personnel, and other professionals engaged in pumped storage hydropower and related hydro-energy projects in selected project sites across Central Luzon and Southern Luzon, Philippines. Total enumeration sampling was employed because the population of qualified personnel was relatively small and accessible, allowing comprehensive coverage of all eligible respondents and minimizing sampling bias.

The inclusion criteria required participants to be currently employed in, or to have previous experience with, hydropower or pumped storage projects and to hold responsibilities in planning, operations, management, engineering, or other technical functions. Individuals who were not directly involved in hydro-energy projects or who declined participation were excluded from the study. Respondents were identified through coordination with hydropower organizations, professional networks, and referrals to ensure that participants possessed relevant knowledge and practical experience.

Research Instruments

Data were collected using a structured survey questionnaire developed from an extensive review of the literature on pumped storage hydropower development, strategic management, SWOT analysis, and Porter's Five Forces framework. The instrument was designed to capture the key factors influencing the development and implementation of pumped storage hydropower projects as well as the strategic and competitive conditions affecting the industry. The instrument consisted of four sections. The first section gathered the socio-demographic and professional profiles of the respondents. The second section assessed strategic factors based on the SWOT framework. The third section evaluated industry dynamics using Porter's Five Forces Model. The fourth section examined the challenges encountered in implementing pumped storage hydropower projects. All items were measured using a four-point Likert scale. To establish content validity, the instrument was reviewed by experts in strategic management, business research, and energy project development. A pilot test was conducted among individuals with characteristics similar to the target respondents but who were not included in the final study. The instrument obtained a Cronbach's alpha coefficient of 0.92, indicating excellent internal consistency and reliability.

Data Gathering Procedure

Prior to data collection, the researcher secured approval from the PhD in Business Administration Program Head and obtained permission from the concerned hydropower organizations. Qualified participants were identified based on the established inclusion and exclusion criteria. Each participant received an informed consent form explaining the study's objectives, the voluntary nature of participation, the confidentiality of responses, and the right to withdraw at any stage without penalty. Data collection was conducted over a four-week period through face-to-face and facilitated survey administration. Respondents were given sufficient time to complete the questionnaire. Upon retrieval, the completed questionnaires were checked for completeness and accuracy before being encoded and prepared for statistical analysis.

Data Analysis

The collected data were processed and analyzed using the Statistical Package for the Social Sciences (SPSS). Frequency and percentage distributions were used to describe the respondents' profile. The weighted mean and standard deviation were used to assess the effectiveness of business strategies, the intensity of competitive forces,

and the challenges encountered in project implementation. Regression analysis was employed to determine whether SWOT factors and competitive forces significantly predicted the effectiveness of business strategies. In the regression model, business strategy effectiveness served as the dependent variable, while SWOT factors and competitive forces were treated as independent variables. Prior to conducting regression analysis, the assumptions of normality, linearity, and multicollinearity were examined to ensure the validity and reliability of the results.

Ethical Considerations

The study was conducted in accordance with the ethical principles governing research involving human participants. Ethical clearance was obtained from the appropriate university research and ethics review authority prior to data collection. Informed consent was secured from all participants before their involvement in the study. Participation was entirely voluntary, and respondents were informed of their right to withdraw at any time without consequence. To protect privacy and confidentiality, no personal identifiers were included in the research report. All data were securely stored and used exclusively for academic and research purposes. The researcher likewise ensured that participation in the study did not expose respondents to professional, personal, or reputational risks.

Results and Discussion

Profile of the Respondents

Table 1 presents the demographic and professional characteristics of the respondents. Most participants were between 36 and 40 years old, indicating that the study primarily captured the perspectives of professionals in their productive and decision-making years within the hydro energy sector. The relatively balanced representation of male and female respondents reflects increasing diversity in technical and renewable energy-related occupations.

Table 1. *Distribution of the Respondents in Terms of Profile Variables*

Profile Variables	Frequency	Percentage (%)
Age		
25-30 years old	25	25
31-35	28	28
36-40	34	34
41-45	9	9
46 years above	4	4
Sex		
Male	53	53
Female	47	47
Educational Attainment		
Bachelor's Degree	29	29
Bachelor's Degree with Professional License	42	42
Master's Degree	26	26
Doctorate Degree	2	2
Years of Experience in the Hydro Energy Sector		
2 years and below	52	52
3-5 years	24	24
6 and above	24	24
Area of specialization		
Engineer	22	22
Project Manager	5	5
Technical Staff	26	26
Operations Personnel	29	29
Supervisor	18	18

Most respondents possessed professional qualifications, with many holding bachelor's degrees accompanied by professional licenses. This suggests that the participants had the academic preparation and technical competence necessary to evaluate the implementation of pumped storage hydropower projects. In terms of experience, both early-career and experienced professionals were represented, providing a balanced view of project implementation challenges and strategic concerns. The largest groups of respondents were operations personnel, technical staff, and engineers. Their direct involvement in project execution, monitoring, and operational activities strengthens the reliability of the findings, as these professionals regularly encounter the practical realities of hydropower project development. Similar observations were reported by Sinsal et al. (2020) and Kumar et al. (2023), who emphasized the importance of technical and operational expertise in energy infrastructure projects.

The profile distribution indicates that the respondents possessed the necessary educational background, technical knowledge, and practical experience to provide informed assessments of business strategies for pumped storage hydropower development. The presence of professionals from different areas of specialization also allowed the study to capture diverse perspectives on project planning, implementation, operations, and management. Such diversity enhanced the comprehensiveness of the findings, as successful hydropower projects require collaboration among technical, operational, and managerial personnel. Consequently, the respondents were a credible source of information for evaluating the strategic and operational factors influencing pumped storage hydropower projects in the Philippines.

Effectiveness of Business Strategies for the Implementation of Pumped Storage Projects

Table 2. *SWOT Analysis of the Level of Effectiveness of Business Strategies*

Indicators		Mean	SD	Interpretation
Strengths				
1.	The organization provides adequate financial support for project implementation.	3.10	0.30	Agree
2.	The organization utilizes modern and reliable technologies in pumped storage projects.	3.19	0.39	Agree
3.	Employees possess the necessary skills and expertise for project implementation.	3.17	0.38	Agree
4.	Management provides clear direction and support for project activities.	3.15	0.36	Agree
5.	Coordination among departments supports efficient project execution.	3.80	0.40	Strongly Agree
6.	The organization complies effectively with regulatory and safety standards.	3.74	0.44	Strongly Agree
7.	Existing facilities and infrastructure support project implementation.	3.14	0.35	Agree
8.	The organization promotes environmentally sustainable practices.	3.24	0.43	Agree
Grand Mean		3.32	0.11	Strongly Agree
Weaknesses				
1.	Project implementation is affected by delays in approvals and internal processes.	3.79	0.38	Strongly Agree
2.	Communication gaps among teams affect coordination during project execution.	3.54	0.49	Strongly Agree
3.	Changes in project plans or scope create confusion during implementation.	3.32	0.50	Strongly Agree
4.	Limited training opportunities affect employees' ability to adapt to project demands.	2.80	0.37	Agree
5.	Workload and time pressure affect the efficiency of project tasks.	3.67	0.44	Strongly Agree
6.	Delays in the availability of materials or equipment affect project timelines.	3.37	0.50	Strongly Agree
7.	Challenges in coordinating with external stakeholders affect project progress.	2.72	0.42	Agree
8.	Limited monitoring and evaluation systems affect tracking of project performance.	3.18	0.36	Agree
Grand Mean		3.30	0.19	Strongly Agree
Opportunities				
1.	The organization benefits from increasing demand for renewable energy.	3.44	0.50	Strongly Agree
2.	Government support and policies enhance project opportunities.	3.63	0.46	Strongly Agree
3.	Technological advancements improve project performance.	3.48	0.50	Strongly Agree
4.	Opportunities for training and development improve employee competence.	3.51	0.49	Strongly Agree
5.	Partnerships with other organizations support project implementation.	3.28	0.77	Strongly Agree
6.	Expansion of energy infrastructure supports project growth.	3.83	0.35	Strongly Agree
7.	Integration with other energy systems improves efficiency.	3.87	0.39	Strongly Agree
8.	Public support for renewable energy enhances project acceptance.	3.80	0.47	Strongly Agree
Grand Mean		3.61	0.14	Strongly Agree
Threats				
1.	Competition from other energy sources affects project viability.	2.79	0.38	Agree
2.	Changes in government policies affect project implementation.	3.66	0.45	Strongly Agree
3.	Environmental concerns create challenges in project approval.	3.45	0.50	Strongly Agree
4.	Economic conditions affect project funding and operations.	3.61	0.47	Strongly Agree
5.	Rapid technological changes require constant adaptation.	3.43	0.50	Strongly Agree
6.	Natural disasters and climate risks affect operations.	3.72	0.42	Strongly Agree
7.	Resistance from local communities affects project implementation.	3.66	0.45	Strongly Agree
8.	Fluctuations in energy demand affect project sustainability.	3.78	0.38	Strongly Agree
Grand Mean		3.51	0.21	Strongly Agree

The SWOT analysis revealed that organizations involved in pumped storage hydropower development possess strong internal capabilities, with strengths obtaining a grand mean of 3.32 (SD = 0.11). Coordination among departments (M = 3.80, SD = 0.40) and compliance with regulatory and safety standards (M = 3.74, SD = 0.44) emerged as the strongest organizational assets, highlighting the importance of collaboration and regulatory adherence in project implementation. These findings support the Resource-Based View Theory, which emphasizes organizational capabilities as key sources of competitive advantage (Barney, 2021). Despite these strengths, respondents also identified notable weaknesses (M = 3.30, SD = 0.19), particularly delays in approvals and internal processes (M = 3.79, SD = 0.38), workload pressures (M = 3.67, SD = 0.44), and communication gaps (M = 3.54, SD = 0.49). These issues suggest that operational inefficiencies may hinder project execution and organizational

responsiveness.

Opportunities received the highest overall rating ($M = 3.61$, $SD = 0.14$), with integration with other energy systems ($M = 3.87$, $SD = 0.39$), infrastructure expansion ($M = 3.83$, $SD = 0.35$), and public support for renewable energy ($M = 3.80$, $SD = 0.47$) identified as the most promising factors. This indicates that the ongoing renewable energy transition creates favorable conditions for pumped storage development. Threats were likewise perceived as significant ($M = 3.51$, $SD = 0.21$), particularly fluctuations in energy demand ($M = 3.78$, $SD = 0.38$), climate-related risks ($M = 3.72$, $SD = 0.42$), and policy changes ($M = 3.66$, $SD = 0.45$). These findings suggest that while strong internal capabilities and external opportunities support project implementation, organizations must effectively manage operational weaknesses and external uncertainties to ensure long-term project success.

Competitive Forces Shaping Pumped Storage Project Implementation

Table 3. *Competitive Forces Shaping Pumped Storage Project Implementation Based on the Dimensions of Porter's Five Forces*

Indicators		Mean	SD	Interpretation
Threat of New Entrants				
1.	High capital requirements limit the entry of new competitors in the industry.	3.77	0.39	Strongly Agree
2.	Strict government regulations make it difficult for new firms to enter the industry.	2.73	0.41	Agree
3.	The need for advanced technical expertise reduces the likelihood of new entrants.	2.65	0.45	Agree
4.	Existing companies have strong experience that gives them an advantage over new entrants.	2.70	0.43	Agree
5.	Long project development timelines discourage new competitors.	3.26	0.88	Strongly Agree
6.	Limited access to suitable project sites restricts new entrants	2.80	0.37	Agree
7.	Strong relationships with stakeholders make it difficult for new entrants to compete.	3.63	0.46	Strongly Agree
8.	High risk involved in hydro energy projects discourages new investors.	3.30	0.43	Strongly Agree
Grand Mean		3.11	0.18	Agree
Bargaining Power of Suppliers				
1.	Limited number of suppliers affects the availability of materials and equipment.	2.82	0.36	Agree
2.	Suppliers have control over pricing of specialized equipment	2.79	0.38	Agree
3.	Dependence on specific suppliers affects project timelines.	3.56	0.48	Strongly Agree
4.	Delays from suppliers affect project implementation.	3.67	0.46	Strongly Agree
5.	High cost of imported materials increases project expenses.	3.56	0.48	Strongly Agree
6.	Limited alternative suppliers reduce negotiation flexibility.	3.52	0.49	Strongly Agree
7.	Quality of supplied materials affects project performance.	3.57	0.48	Strongly Agree
8.	Long-term supplier contracts influence project operations.	3.66	0.45	Strongly Agree
Grand Mean		3.39	0.27	Strongly Agree
Bargaining Power of Buyers				
1.	Buyers influence pricing of energy services.	3.49	0.49	Strongly Agree
2.	Demand from buyers affects project planning and capacity.	3.65	0.45	Strongly Agree
3.	Buyers require high reliability and efficiency of energy supply.	3.54	0.50	Strongly Agree
4.	Contracts with buyers affect project revenue stability.	3.61	0.47	Strongly Agree
5.	Buyers have options to switch to other energy providers.	3.61	0.47	Strongly Agree
6.	Customer expectations influence operational performance.	3.79	0.38	Strongly Agree
7.	Negotiation terms with buyers affect profitability.	3.67	0.44	Strongly Agree
8.	Buyer demand fluctuations affect project operations.	3.76	0.48	Strongly Agree
Grand Mean		3.64	0.09	Strongly Agree
Threat of Substitute Products or Services				
1.	Alternative renewable energy sources compete with pumped storage projects.	3.63	0.46	Strongly Agree
2.	Advances in battery storage technology reduce dependence on pumped storage.	3.66	0.45	Strongly Agree
3.	Other energy sources offer lower operational costs.	3.57	0.49	Strongly Agree
4.	Availability of substitute energy sources affects demand.	3.83	0.46	Strongly Agree
5.	Technological innovation increases competition from substitutes.	3.78	0.46	Strongly Agree
6.	Policy support for alternative energy sources affects project competitiveness.	3.66	0.50	Strongly Agree
7.	Customers may prefer more flexible or faster energy solutions.	3.80	0.37	Strongly Agree
8.	Cost differences between energy sources influence market choice.	3.67	0.44	Strongly Agree
Grand Mean		3.70	0.18	Strongly Agree
Rivalry Among Existing Competitors				
1.	Competition among energy providers affects project positioning.	2.70	0.43	Agree
2.	Existing competitors influence pricing strategies.	2.63	0.46	Agree
3.	Competition drives improvements in technology and efficiency.	3.76	0.40	Strongly Agree
4.	Market competition affects investment decisions.	3.49	0.81	Strongly Agree
5.	Competition for resources affects project availability.	3.37	0.95	Strongly Agree
6.	Industry competition affects profitability.	3.67	0.44	Strongly Agree
7.	Competitive pressure influences project innovation and performance.	3.84	0.38	Strongly Agree
Grand Mean		3.36	0.22	Strongly Agree

The findings of Porter's Five Forces reveal that the execution of pumped storage projects in the hydro energy sector is driven by intense competition and market forces (Table 3). The average weighted mean of 3.11 (SD = 0.18), interpreted as Agree, regarding the danger of new entrants, indicates that there are entry barriers in the industry, but they are moderate. The high scores for capital requirements (WM = 3.77), stakeholder relationships (WM = 3.63), and project hazards (WM = 3.30) suggest that significant financial investment, well-developed networks, technical experience, and risk management capabilities may deter new entrants to the market. The overall weighted mean for supplier negotiating power was 3.39 (SD = 0.27), indicating "Strongly Agree". This implies that suppliers have significant influence on the project implementation. We also find that supply delivery delays (WM = 3.67), long-term contracts (WM = 3.66), and dependence on certain suppliers (WM = 3.56) are factors that show that the reliability, pricing, and availability of specialized materials or equipment from suppliers might impact project costs, deadlines, and operational continuity. The overall weighted mean for buyers' negotiating power is 3.64 (SD = 0.09), interpreted as Strongly Agree, indicating that buyers have a substantial influence in the industry. Customer expectations (WM = 3.79), demand variability (WM = 3.76), and negotiation terms (WM = 3.67) indicate that buyers influence operational planning, revenue generation, and profitability, especially in an energy market where reliability, affordability, and sustainability are becoming increasingly important.

The highest average weighted mean score (M=3.70, SD=0.18), interpreted as Strongly Agree, was for the threat of substitutes, demonstrating that alternative energy sources impose significant competitive pressure. In view of the availability of other energy sources (WM=3.83), evolving customer preferences (WM=3.80), and technological innovation (WM=3.78), pumped storage projects will still have to prove their worth in terms of reliability, flexibility, cost-effectiveness, and contribution to the integration of renewable energy. Meanwhile, the competitiveness among competitors had a mean of 3.36 (SD = 0.22), indicating a Strongly Agree assessment that competition within the industry remains strong. The identified key competitive factors were innovation (WM = 3.84), efficiency improvements (WM = 3.76), and profitability impacts (WM = 3.67). This implies that organizations need to enhance operational efficiency, strengthen strategic positioning, and build internal capabilities to maintain an edge in the hydro energy market (Barney, 2021). Overall, the findings suggest that the existence of supplier dependence, buyer expectations, alternative technologies, and industry rivalry create significant pressures that should be neutralized through sound business strategies, resilient partnerships, cost control, innovation, or market positioning, despite the high capital requirements and the project complexity that could be barriers to entry.

Challenges Encountered in the Implementation of Pumped Storage Projects

Table 4 illustrates the issues encountered in the development of pumped storage projects in the hydro energy sector. Respondents experienced severe challenges in implementation, with an overall average weighted mean of 3.66 (SD = 0.36), read as Strongly Agree. This reflects the complicated, technical, and multidisciplinary nature of pumped storage projects. Safety concerns were the greatest identified problem (WM = 3.85). Therefore, safety management should be properly enforced when implementing the project due to the technical complexity and risks in the hydro energy infrastructure. Then, errors in documentation (WM = 3.83) and challenges in matching project schedules (WM = 3.78) were reported, which indicates shortcomings in project monitoring, coordination, and information management. This limited access to real time data and the need to maintain quality standards with a weighted mean of 3.78, also implies that decision making, progress tracking and quality assurance may be adversely affected when accurate and timely information is not readily available (International Energy Agency, 2022).

Other important challenges were unexpected site conditions (WM = 3.77), technical delays (WM = 3.67), lack of coordination (WM = 3.66), and difficulties in managing multidisciplinary teams (WM = 3.61), which indicates that the implementation efficiency may be compromised by site-specific risks, technical dependencies, communication issues, and the need to harmonize the work of professionals from different areas of expertise

Table 4. *Challenges Encountered in Implementing Pumped Storage Projects in the Hydro Energy Sector*

	Indicators	Mean	SD	Interpretation
1.	Difficulty in aligning project timelines with multiple project phases and dependencies.	3.78	0.38	Strongly Agree
2.	Challenges in integrating new systems with existing hydro energy infrastructure.	2.85	0.32	Agree
3.	Limited availability of real-time data for monitoring and decision-making.	3.78	0.38	Strongly Agree
4.	Inconsistencies in project documentation and reporting processes.	3.83	0.45	Strongly Agree
5.	Difficulty in managing multidisciplinary teams with different technical backgrounds.	3.61	0.90	Strongly Agree
6.	Safety risks associated with construction and operational activities.	3.85	0.85	Strongly Agree
7.	Challenges in adapting to unexpected site conditions during project implementation.	3.77	0.48	Strongly Agree

8. Limited coordination between on-site and off-site project teams.	3.66	0.68	Strongly Agree
9. Difficulty in maintaining consistent project quality standards across phases.	3.78	0.89	Strongly Agree
10. Delays caused by unforeseen technical issues during construction or operation	3.67	0.67	Strongly Agree
Grand Mean	3.66	0.36	Strongly Agree

The lowest rating was given to system integration (WM = 2.85), interpreted as Agree, which remains a significant concern, as compatibility among technologies, operating systems, and existing infrastructure could affect the project's long-term reliability and performance. The results indicate that implementing pumped storage projects requires more rigorous safety measures, more reliable documentation systems, better coordination of the timetable, greater access to real-time data, and improved interaction between technical and administrative teams.

Regression Analysis

Table 5 presents the regression analysis examining whether the SWOT components significantly predict the effectiveness of business strategies in pumped storage hydropower development. The findings indicate that not all SWOT dimensions significantly influenced the effectiveness of business strategy. Strengths did not emerge as a significant predictor ($\beta = -0.05$, $p = .476$), suggesting that existing organizational capabilities and resources, while important for operational performance, did not significantly account for variation in the perceived effectiveness of business strategies. In contrast, Weaknesses were the strongest and most significant predictor ($\beta = 0.91$, $p < .001$). This result suggests that internal limitations such as coordination issues, inadequate training, communication gaps, and operational inefficiencies substantially affect the effectiveness of business strategies. Organizations with greater internal weaknesses may face greater challenges in successfully implementing strategic initiatives.

Table 5. *SWOT Components as Predictors of the Effectiveness of Business Strategies*

Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Strengths	-0.08	0.11	-0.05	-0.71	.476
Weaknesses	0.86	0.08	0.91	9.88	<.001
Opportunities	0.20	0.08	0.16	2.40	.018
Threats	-0.23	0.07	-0.26	-3.17	.002

Opportunities also showed a significant positive effect on business strategy effectiveness ($\beta = 0.16$, $p = .018$). This finding indicates that favorable external conditions, including increasing demand for renewable energy, infrastructure expansion, technological advancements, and supportive policies, enhance the effectiveness of strategic initiatives by providing avenues for growth and competitive advantage. Meanwhile, Threats exhibited a significant negative relationship with business strategy effectiveness ($\beta = -0.26$, $p = .002$). This suggests that external risks such as regulatory uncertainty, climate-related challenges, market volatility, and competitive pressures reduce the effectiveness of business strategies when not properly managed. The results demonstrate that Weaknesses, Opportunities, and Threats significantly predict the effectiveness of business strategies, whereas Strengths do not. Among the predictors, Weaknesses exerted the strongest influence. Therefore, the null hypothesis stating that SWOT components do not significantly predict the effectiveness of business strategies is partially rejected.

Table 6. *Porter's Five Forces as Predictors of the Effectiveness of Business Strategies*

Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Threats of New Entrants	0.20	0.09	0.30	2.06	.042
Bargaining Power of Suppliers	-0.05	0.07	-0.10	-0.76	.448
Bargaining Power of Buyers	0.51	0.16	0.34	3.19	.002
Threat of Substitute Products or Services	0.39	0.06	0.50	6.33	<.001
Rivalry Among Existing Competitors	-0.07	0.10	-0.11	-0.68	.492

Table 6 presents the regression analysis examining the extent to which Porter's Five Forces predict the effectiveness of business strategies in pumped storage hydropower development. The results indicate that only some of the competitive forces significantly influenced the effectiveness of business strategy. The threat of new entrants was a significant positive predictor of business strategy effectiveness ($\beta = 0.30$, $p = .042$). This finding suggests that the possibility of new competitors entering the hydropower sector encourages organizations to strengthen their strategic planning, enhance operational capabilities, and establish stronger stakeholder relationships to maintain their competitive position. Similarly, the bargaining power of buyers significantly and positively influenced business strategy effectiveness ($\beta = 0.34$, $p = .002$). This indicates that customer expectations, market demand, and buyer influence play an important role in shaping strategic decisions. Organizations may be compelled to improve

service quality, operational efficiency, and value creation to meet evolving market requirements.

Among all predictors, the threat of substitute products or services exerted the strongest positive effect on business strategy effectiveness ($\beta = 0.50$, $p < .001$). This result highlights the importance of alternative energy technologies and competing storage solutions in driving strategic innovation. The presence of substitutes encourages firms to focus on cost efficiency, technological advancement, reliability, and sustainability to remain competitive within the energy sector. In contrast, the bargaining power of suppliers ($\beta = -0.10$, $p = .448$) and rivalry among existing competitors ($\beta = -0.11$, $p = .492$) were not significant predictors of business strategy effectiveness. These findings suggest that supplier influence and competitive rivalry may not have a substantial direct impact on the strategic outcomes examined in this study. The results demonstrate that the threat of new entrants, bargaining power of buyers, and threat of substitute products or services significantly predict the effectiveness of business strategies. Among these factors, the threat of substitutes emerged as the strongest predictor. Therefore, the null hypothesis stating that Porter's Five Forces do not significantly predict the effectiveness of business strategies is partially rejected.

Conclusions

This study concluded that the successful development of pumped storage hydropower projects depended on the alignment of internal organizational capabilities with external industry conditions. Strong coordination, regulatory and safety compliance, technical expertise, and efficient internal processes supported project readiness and implementation, while communication gaps, procedural delays, and operational inefficiencies increased vulnerability to competitive pressures and external uncertainties. The findings further revealed that internal weaknesses, external opportunities and threats, buyer influence, substitute technologies, and potential market entrants significantly influenced the effectiveness of business strategy. These results highlighted the importance of adaptive strategies, proactive risk management, stakeholder engagement, and continuous organizational improvement in achieving project success.

The study also provided practical implications for project developers, policymakers, and educators. Strengthening coordination, monitoring systems, and operational processes can improve implementation efficiency, while streamlined regulatory procedures and enhanced professional training can further support project development. Future research may compare business strategies across renewable energy technologies, examine regulatory differences across countries, and assess the long-term effects of strategic practices on project performance and energy sustainability.

Contributions of Authors

Author 1: Conceived the study, conducted the research, collected and analyzed the data, and prepared the manuscript.

Author 2: Provided academic guidance, research consultation, and technical support throughout the conduct of the study.

Funding

None

Conflict of Interests

No conflict of interest.

Acknowledgment

The author gratefully acknowledges the unwavering support, encouragement, and understanding of her partner, Engr. Gian Prime Rabara, as well as Mama, Papa, and Jhem, and dear friends Cali and Ben, whose steadfast presence and encouragement contributed significantly to the completion of this study.

References

- Barney, J., Ketchen, D., & Wright, M. (2021). Resource-based theory and the value creation framework. *Journal of Management*, 47(7), 1936–1955. <https://doi.org/10.1177/01492063211021655>
- Das, B., Alotaibi, M., Das, P., Islam, M.S., Das, S., & Hossain, M.A. (2021). Feasibility and techno-economic analysis of stand-alone and grid-connected PV/Wind/Diesel/Batt hybrid energy system: A case study. *Energy Strategy Reviews*, 37, 100673. <https://doi.org/10.1016/j.esr.2021.100673>
- Dong, Z., Xia, C., Fang, K., & Zhang, W. (2022). Effect of the carbon emissions trading policy on the co-benefits of carbon emissions reduction and air pollution control. *Energy Policy*, 165, 112998. <https://doi.org/10.1016/j.enpol.2022.112998>
- Grant, R.M. (2019). *Contemporary strategy analysis* (10th ed.). Wiley.
- Hill, C.W. (2020). *Strategic management: Theory and cases* (13th ed.). Cengage Learning. <https://doi.org/10.4324/9780429274671>
- Jaiboon, N., Wongsapai, W., Daroon, S., Bunchuaidee, R., et al. (2021). Greenhouse gas mitigation potential from waste heat recovery for power generation in cement industry: The case of Thailand. *Energy Reports*, 7, 638–643. <https://doi.org/10.1016/j.egyr.2021.07.089>
- Li, X.Z. (2020). Economic evaluation of pumped storage power plants in electricity markets. *Energy Economics*, 88, Article 104753. <https://doi.org/10.1016/j.eneco.2020.104753>
- Maio, M., Marrasso, E., Roselli, C., Sasso, M., Fontana, N., & Marini, G. (2024). An innovative approach for optimal selection of pumped hydro energy storage systems to foster sustainable energy integration. *Renewable Energy*, 236, 120533. <https://doi.org/10.1016/j.renene.2024.120533>
- Malik, F., Abbas, M., & others. (2025). Integrating energy storage technologies with renewable energy sources for sustainable grid operation. *Sustainability*, 17(9), 4097.

- <https://doi.org/10.3390/su17094097>
- Mustafoqulov, A., Farhod, M., Azamov, S., Dilmurod, E., & Gulora, Y. (2025). Analysis of a 10 kW mini pumped hydro storage plant with solar integration in Uzbekistan. *Vibroengineering Procedia*, 60, 260–267. <https://doi.org/10.21595/vp.2025.25789>
- Papathanasiou, A.-F., Pasaniotis, G., & Baltas, E. (2024). Pumped-storage hydropower and hydrogen production as energy storage systems for renewable energy integration. *Discover Energy*, 4, Article 23. <https://doi.org/10.1007/s41207-024-00523-1>
- Rehman, S., Al-Hadhrani, L., & Alam, Md. M. (2015). Pumped hydro energy storage system: A technological review. *Renewable and Sustainable Energy Reviews*, 44, 586–598. <https://doi.org/10.1016/j.rser.2014.12.040>
- Sinsel, S., Riemke, R., & Hoffmann, V. (2020). Challenges and solution technologies for the integration of variable renewable energy sources – A review. *Renewable Energy*, 145, 2271–2285. <https://doi.org/10.1016/j.renene.2019.06.147>
- Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., & Ludwig, C. (2015). The trajectory of the Anthropocene: The great acceleration. *The Anthropocene Review*, 2(1), 81–98. <https://doi.org/10.1177/2053019614564785>
- Waclawik, L. (2025). Demographic influences on energy-related decision-making. *Sustainability*, 17(24), Article 10978. <https://doi.org/10.3390/su172410978>
- Wang, W., Wang, D., Shah, N., & Chen, C. (2020). Flexible operation of solid oxide electrolysis cells in future energy systems: A review. *Renewable and Sustainable Energy Reviews*, 124, 109764. <https://doi.org/10.1016/j.rser.2020.109764>