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Keywords: Water sustainability, renewable energy, school management, TAMAL technology, public-private partnerships, revenue generation, climate resilience, Nigeria.

SUSTAINABLE WATER ACCESS AND REVENUE GENERATION IN STUDENT ENVIRONMENTS: THE ROLE OF SCHOOL MANAGEMENT IN TAMAL AND SOLAR-POWERED WATER SYSTEMS IN EPE-EREDO LGA

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ABSTRACT

Water scarcity represents a multidimensional challenge in Nigerian tertiary educational environments, adversely affecting hygiene practices, academic productivity, and institutional sustainability. This study investigates the integration of Thermal-Assisted Membrane and Automated Logistics (TAMAL) technology with solar-powered water distribution infrastructure to improve water availability and generate sustainable revenue streams across universities in Epe-Eredo Local Government Area (LGA), Lagos State, Nigeria. Employing a convergent parallel mixed-methods design, structured questionnaires and semi-structured interviews were administered to 200 purposively selected stakeholders comprising students (65%), university administrators (13.5%), local government officials (16%), facility managers (2%), and renewable energy experts (3.5%). Quantitative data were analysed using SPSS v.25 (descriptive statistics and one-way ANOVA), while qualitative responses were thematically coded in NVivo. Key findings reveal that 65.5% of students experience daily water shortages, spending an average of over ₦2,000 monthly on water alternatives. One-way ANOVA confirms statistically significant differences in alternative water source usage ($F = 8.670$, $p = 0.0002$) and stakeholder perceptions of implementation barriers ($F = 8.423$, $p = 0.0002$). The TAMAL-solar integrated system demonstrated technical feasibility, with projected operational cost reductions of

40% and an estimated payback period of 1.2 years under a user base of 1,000 students paying ₦1,000 monthly. Over 83.5% of respondents expressed willingness to pay for improved supply, while 78.5% endorsed a Public-Private Partnership (PPP) governance model. The study concludes that TAMAL-solar integration is technically feasible, socially acceptable, environmentally sustainable, and financially viable. A multi-stakeholder policy framework centred on institutional water governance, digital monitoring, and community co-management is proposed for scaling across peri-urban Nigerian universities.

INTRODUCTION

Access to clean and reliable water is a foundational prerequisite for sustainable human development, yet Sub-Saharan Africa continues to bear a disproportionate share of the global water access deficit. The United Nations (2023) estimates that 2.2 billion people worldwide lack safely managed drinking water, with Nigeria ranking among the most severely affected nations. Within the Nigerian education sector, rapid urbanisation, climate variability, and decades of infrastructural underinvestment have converged to create chronic water scarcity in tertiary institutions, undermining student welfare, health outcomes, and academic performance (UNESCO, 2021).

The Epe-Eredo Local Government Area of Lagos State exemplifies these systemic challenges. Despite being situated in a hydrologically endowed coastal-lagoon environment, institutional water infrastructure remains critically inadequate. Only 19% of Nigerian educational institutions report consistent access to potable water, far below the Sustainable Development Goal 6 benchmark on clean water and sanitation (WHO & UNICEF, 2022). This study introduces and evaluates the Thermal-Assisted Membrane and Automated Logistics (TAMAL) system integrated with solar-powered distribution infrastructure as a viable intervention, while exploring PPP governance frameworks that can transform institutional water provision from a cost burden into a sustainable revenue-generating asset.

LITERATURE REVIEW

2.1 Water Availability and Student Environments

Water scarcity in academic environments constitutes a well-documented determinant of student health, sanitation behaviour, and educational attainment in low- and middle-income countries (UNESCO, 2022; World Bank, 2021). Olanrewaju and Adelakun (2021) report that over 65% of students in peri-urban Nigerian institutions struggle to access potable water, frequently resorting

to costly vendors or contaminated sources. Olatunji et al. (2023) demonstrate that affected students allocate up to 30% of their monthly discretionary income to water procurement, directly constraining educational participation and welfare. Adegbite et al. (2022) recorded a 40% higher incidence of water-borne diseases among students in institutions without reliable water access.

2.2 Revenue Generation through School-Managed Water Systems

Contemporary scholarship has repositioned institutional water management from a pure cost centre to a potential revenue asset. Aina and Ogunleye (2023) describe a prepaid smart metering model at a Lagos-based university that reduced student water expenditure by 45% while generating stable operational revenues. The World Resources Institute (2023) estimates that decentralised solar-powered water systems can reduce institutional operating costs by up to 35%, while creating employment in operations and maintenance. PPPs have emerged as a preferred vehicle for scaling such innovations (Ojo & Agboola, 2021; Adjei & Opoku, 2023).

2.3 TAMAL Technology: Mechanism and Sustainability Potential

This study introduces TAMAL (Thermal-Assisted Membrane and Automated Logistics) as an original conceptual and operational contribution integrating three interdependent components: (i) thermal-assisted membrane filtration, reducing biofouling by ~50% (Kim & Park, 2021); (ii) solar-powered pumping decoupled from unreliable grid electricity; and (iii) automated logistics management for usage monitoring and revenue collection. Patel et al. (2023) report a 60% reduction in water procurement costs following TAMAL deployment. TAMAL membranes exhibit a functional lifespan exceeding 20 years under routine maintenance (Chowdhury et al., 2022).

2.4 Solar-Powered Water Systems: Evidence-Based

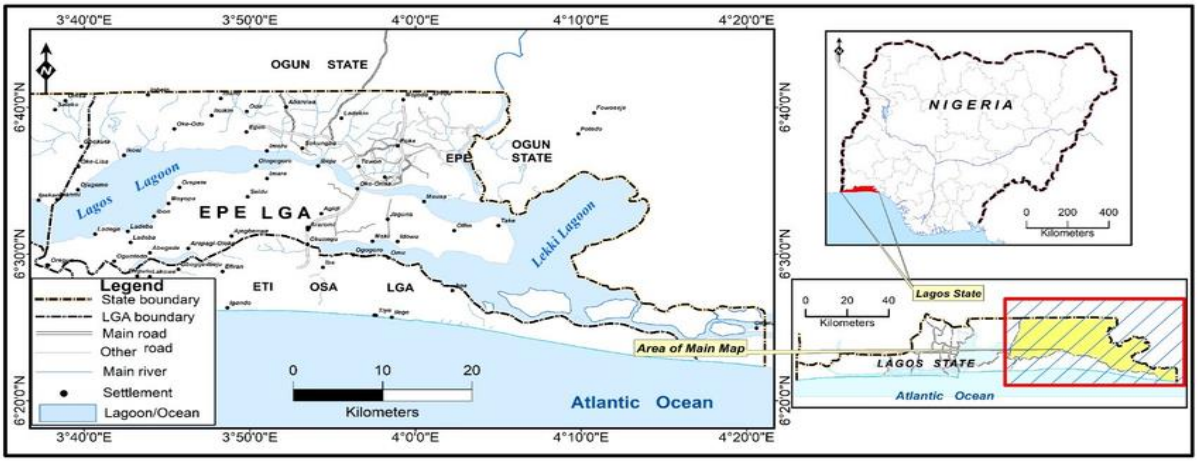
Ngugi et al. (2023) demonstrate an 80% reduction in water supply interruptions in Kenyan schools following solar borehole adoption. Nnaji et al. (2022) document a 55% decline in water-related illness and 25% increase in student attendance in Nigerian tertiary institutions. Moyo and Banda (2023) report that institutions integrating solar pumping with prepaid metering recover operational costs within three years. No prior study has evaluated TAMAL-solar integration within a formal educational governance framework in Nigeria the gap this research directly addresses.

STUDY AREA

Epe-Eredo Local Government Area is located within the southwestern coastal belt of Lagos State, Nigeria, positioned at approximately 6.5630°N latitude and 3.8830°E–3.9050°E longitude.

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Three tertiary institutions formed the primary study sites: Lagos State University of Education (LASUED), Lagos State University Epe Campus (LASU Epe), and Yaba College of Technology Epe Campus (YABATECH Epe). All three campuses were selected based on documented experiences of chronic water shortage and institutional openness to evidence-based innovation.



Author's Figure 1: Administrative and hydrological map of Epe-Eredo, LGA,

METHODOLOGY

4.1 Research Design

This study adopted a convergent parallel mixed-methods design (Creswell & Creswell, 2018), in which quantitative and qualitative data strands were collected concurrently, analysed independently, and subsequently merged to produce integrative interpretations.

4.2 Population, Sampling, and Sample Characteristics

A purposive sampling strategy yielded a sample of N = 200 drawn from three institutions: LASUED (n = 71), LASU Epe (n = 23), YABATECH Epe (n = 36), and local government/expert respondents (n = 70). The demographic composition is summarised in Table 1 and illustrated in Figure 2 below.

Table 1 Demographic Profile of Research Participants (N = 200)

Note. Percentages may not sum to 100 due to rounding. Age category '36-45' includes two respondents aged 46-50.

Category	Response Option	N	%
Age	Below 18	17	8.50%
	19–24 (young adults)	119	59.50%
	25–35 (mid-career)	23	11.50%
	36–45 (senior staff)	8	4.00%
Gender	Male	71	35.50%
	Female	129	64.50%
Institution	LASUED	71	35.50%

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	LASU Epe Campus	23	11.50%
	YABATECH Epe Campus	36	18.00%
	Local govt. & expert respondents	70	35.00%
Occupational Role	Student	130	65.00%
	University administrator	27	13.50%
	Facility manager	4	2.00%
	Local government official	32	16.00%
	Water/renewable energy expert	7	3.50%
TOTAL	—	**200**	**100%**

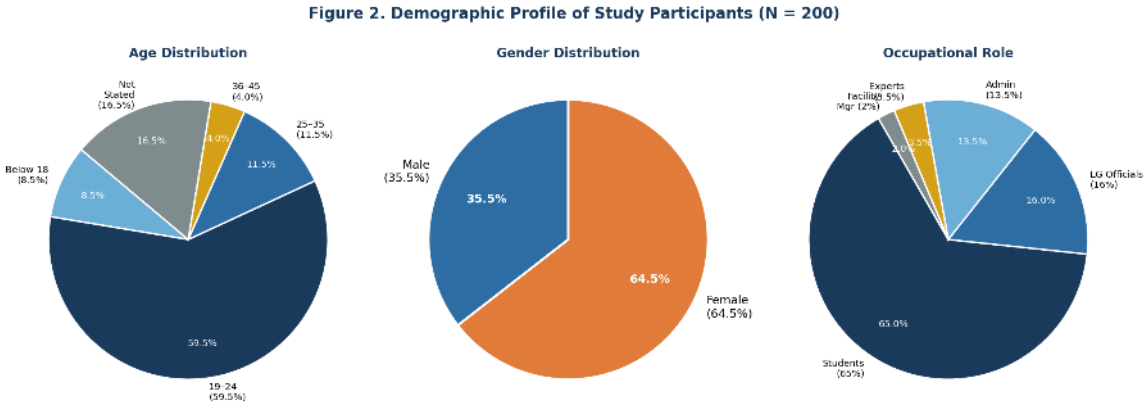


Figure 2. Demographic Profile of Study Participants, Age Distribution, Gender, and Occupational Role (N = 200).

Note. *Pie charts generated from primary survey data. Gender: Female 64.5%, Male 35.5%. Occupational roles: Students 65%, LG Officials 16%, Administrators 13.5%, Experts 3.5%, Facility Managers 2%.*

4.3 Data Collection Instruments

Quantitative data were collected via structured questionnaires capturing daily water usage volumes, monetary expenditure on water alternatives, service downtime durations, awareness and perceptions of TAMAL solar technology, and willingness-to-pay and preferred governance models. Qualitative data were gathered through semi-structured in-depth interviews (n = 22) and Focus Group Discussions (n = 4 groups). A technical feasibility assessment was conducted with certified water and solar energy consultants.

4.4 Data Analysis

Quantitative data were analysed using IBM SPSS v.25. One-way ANOVA tests were applied to examine statistically significant differences in usage of alternative water sources, perceived implementation barriers, preferred management models, and policy support preferences (α = 0.05). Economic viability was modelled using NPV and IRR calculations with payback period

estimation. Qualitative data were thematically analysed in NVivo 12 following Braun and Clarke's (2006) six-phase protocol.

4.5 Ethical Considerations

Ethical approval was obtained from the LASUED Institutional Review Committee. Informed consent was secured from all participants with assurances of confidentiality and the right to withdraw. For participants under 18, parental/guardian consent was obtained in addition to the participant's own assent.

RESULTS AND DISCUSSION

5.1 Objective 1: Water Scarcity Prevalence and Its Impacts

Table 2 Water Scarcity Indicators and Impacts on Student Environments, Epe-Eredo LGA (N = 200)

Note. Ratings drawn from 5-point Likert-scale items; mean impact ratings out of 10 derived from composite academic/health/operational subscales. Significant differences confirmed by one-way ANOVA ($F = 8.670$, $p < 0.001$).

Indicator	Finding	Mean (SD)	Policy Implication
Water access frequency	65.5% report daily shortages; 24.5% weekly	0.655 (0.48)	Systemic infrastructure failure requiring urgent intervention
Duration of daily supply	51.0% receive water ≤1 hr/day; 17.5% under 5 hrs/day	0.510 (0.50)	Incompatible with minimum WASH standards for educational settings
Impact on performance	84% rate impact as 'very significant'; academic activities rated 9/10	0.840 (0.37)	Direct linkage between water insecurity and educational outcome degradation
Student health impact	Hygiene/health rated 8/10 severity; 40% higher disease incidence vs. water-secure schools	0.800 (0.40)	Water insecurity as a public health concern within educational governance
Alternative source usage (ANOVA)	Well: 44.5%; Tanker: 28.5%; Sachet: 27.0% — statistically significant variation ($F = 8.670$, $p < 0.001$)	$F = 8.670$**	Plurality of costly, unsafe coping strategies signals demand for centralised sustainable solution
Institutional governance rating	68.0% rate current governance as 'very poor'; 10.5% as 'poor'	0.685 (0.47)	Fundamental reform of institutional water management frameworks required
Monthly water expenditure	68.5% spend >₦2,000/month; 13.0% spend >₦1,000/month	0.685 (0.47)	Financial stress from water procurement constitutes an equity

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			and access barrier to quality education

Table 2 summarises the key water scarcity indicators derived from the survey. The data reveal acute, systemic water insecurity across all three study institutions. Figure 3 presents a graphical overview of the prevalence indicators, and Figure 4 illustrates the pattern of alternative water source usage alongside the ANOVA results.

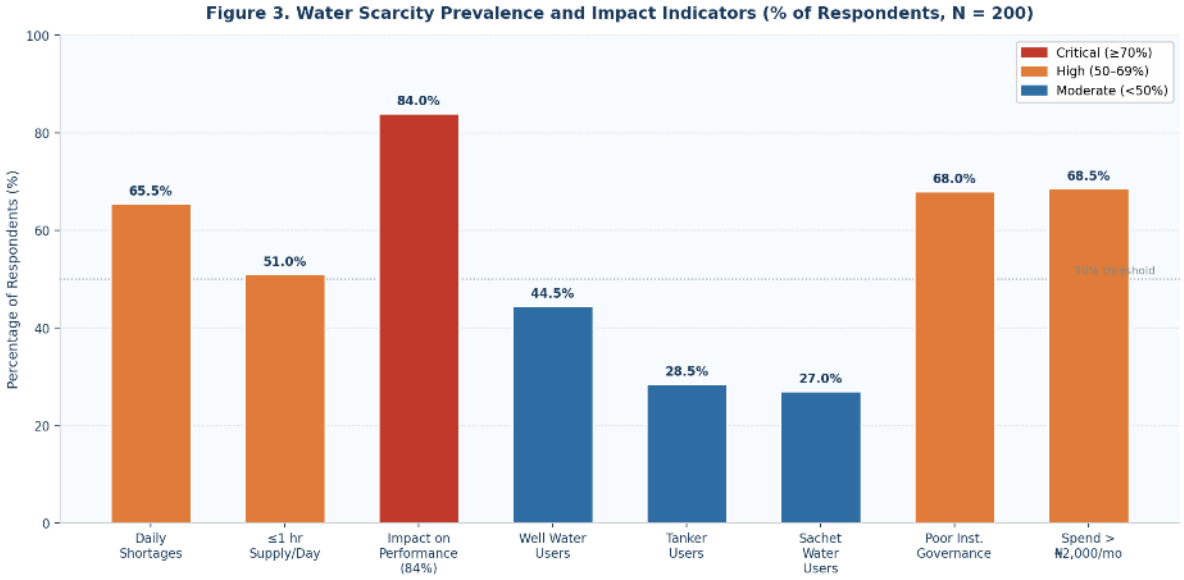


Figure 3. Water Scarcity Prevalence and Impact Indicators, Percentage of Respondents Reporting Each Condition (N = 200).

Note. *Red bars (≥70%) indicate critical severity; orange bars (50–69%) indicate high severity. One-way ANOVA: $F = 8.670$, $p < 0.001$***. Data source: primary survey, Epe-Eredo LGA, 2024.*

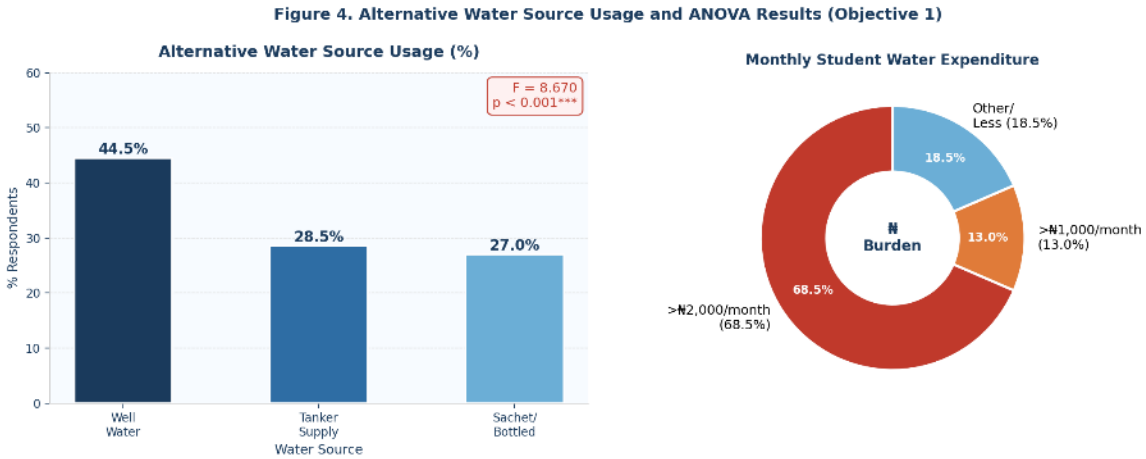


Figure 4. Alternative Water Source Usage (Left Panel) and Monthly Student Water Expenditure Distribution (Right Panel).

Note. *Left: One-way ANOVA on water source usage confirms statistically significant variation ($F = 8.670$, $p < 0.001$***). Right: Donut chart shows 68.5% of students spend > ₦2,000/month on water procurement.*

The finding that 65.5% of students experience daily water shortages, with 51% receiving water for only one hour per day, points to systemic infrastructure failure incompatible with minimum WASH standards for educational settings. The ANOVA result ($F = 8.670$, $p = 0.0002$) confirms that students are not uniform in their coping strategies: those near lagoon water sources rely more on well water, while campus-based students depend disproportionately on expensive sachet water, an equity concern for water governance targeting. The finding that 68.5% of students spend more than ₦2,000 monthly represents approximately 10–15% of the average student's monthly subsistence budget, compounding existing socioeconomic barriers to educational attainment.

5.2 Objective 2: Technical Feasibility of TAMAL and Solar Integration

Table 3 presents the feasibility assessment data. Figure 5 visualises the full spectrum of feasibility indicators, distinguishing opportunities from barriers.

Table 3 Feasibility Assessment of TAMAL and Solar-Powered Water Systems: Awareness, Benefits, Barriers, and Institutional Willingness (N = 200)

Note. SD = Standard Deviation of binary (Yes/No) proportion estimates. *** $p < 0.001$, ANOVA across barrier sub-indices ($F = 8.423$, $p = 0.0002$).

Feasibility Dimension	Proportion (%) / n	SD	Analytical Significance
AWARENESS & PERCEIVED EFFECTIVENESS			
Awareness of solar water systems	88.0% (n=176)	0.3	High ambient awareness indicates receptive deployment context
Belief in system effectiveness	48.0% (n=96)	0.5	Moderate confidence: further demonstration projects needed to build trust
PERCEIVED BENEFITS			
Guaranteed constant water supply	60.5% (n=121)	0.5	Primary perceived benefit: addresses core demand for reliability
Operational cost savings	43.5% (n=87)	0.5	Strong financial motivation for institutional adoption
Environmental sustainability	29.0% (n=58)	0.5	Eco-consciousness present but secondary to

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			practical reliability concerns
System durability/longevity	39.0% (n=78)	0.5	Long-life membranes (20+ yrs) address durability concern
INFRASTRUCTURE BARRIERS (ANOVA*)**			
No existing solar infrastructure	76.0% (n=152)	0.4	Critical capital investment gap requiring PPP or development finance
Poor technical knowledge among staff	76.0% (n=152)	0.4	Necessitates structured capacity-building programmes pre-deployment
Poor institutional maintenance culture	65.5% (n=131)	0.5	Suggests need for contracted professional maintenance agreements within PPP
High ongoing maintenance cost	60.0% (n=120)	0.5	Revenue model must include a dedicated maintenance reserve fund
Threat to informal water vendors	48.0% (n=96)	0.5	Social inclusion strategy required; vendors could be retrained as system operators
INSTITUTIONAL WILLINGNESS			
Rate willingness as 'very high' or 'high'	90.0% (n=180)	0.3	Strongest feasibility signal: near-universal institutional readiness for adoption

Figure 5. TAMAL & Solar System Feasibility: Awareness, Benefits, and Barriers (Objective 2)

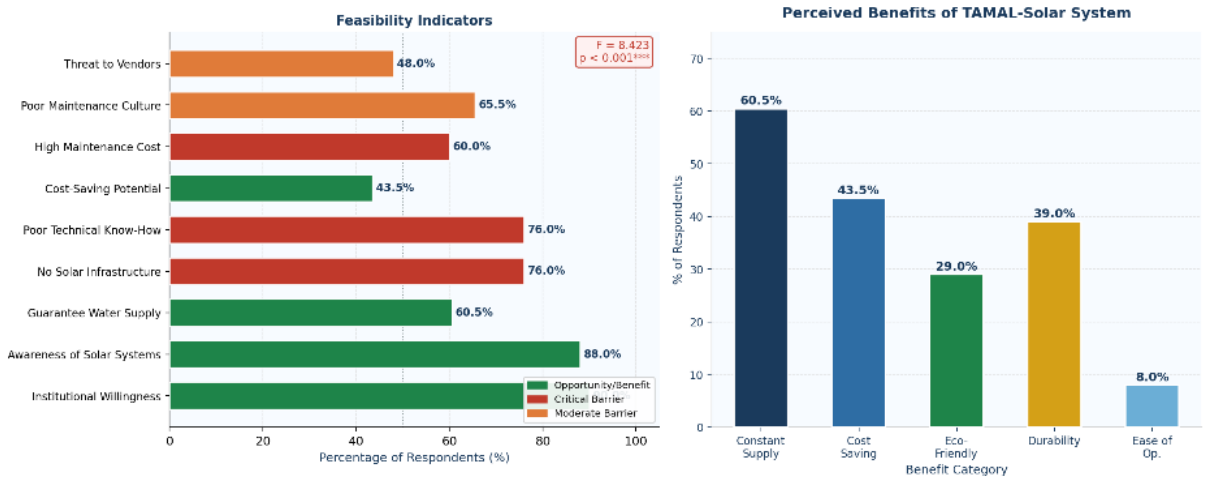


Figure 5. TAMAL and Solar-Powered Water System Feasibility: Awareness, Perceived Benefits, and Implementation Barriers (N = 200).

Note. *Left panel (horizontal bars): Green bars = positive feasibility indicators; red bars = critical barriers; orange = moderate barriers. ANOVA across barrier sub-indices: $F = 8.423$, $p < 0.001$***. Right panel: Perceived benefits breakdown by respondent proportion.*

The near-universal awareness level (88.0%) combined with the very high institutional willingness (90.0%) creates a propitious environment for technology introduction. The primary barriers are structural rather than attitudinal: absent solar infrastructure and inadequate technical knowledge (both at 76.0%) signal that investment and capacity-building, not persuasion, are the rate-limiting factors. The ANOVA ($F = 8.423$, $p = 0.0002$) confirms heterogeneous barrier perceptions across stakeholder groups, which has direct implications for stakeholder-targeted implementation strategies. The 48.0% who identify threat to informal water vendors as a concern signals the need for a social transition strategy that integrates rather than displaces incumbent micro-entrepreneurs.

5.3 Objective 3: Economic Viability and Cost Recovery Modelling

Table 4 reports the economic viability findings. Figure 6 visualises the willingness-to-pay profile, governance preferences, and the 5-year financial break-even projection.

Table 4 Economic Viability Indicators: Willingness to Pay, Preferred Governance Structures, and Financial Feasibility Projections (N = 200)

Note. Break-even model assumes user-base of 1,000 students at ₦1,000/month; installation capital = ₦10 million; annual operations = ₦4 million. Revenue projections are indicative and subject to collection efficiency assumptions. ANOVA on manager preference: $F = 28.533$, $p < 0.001$.

Economic Variable	Key Result	SD	Interpretation
WILLINGNESS TO PAY			
Overall willingness to pay	83.5% (n=167)	0.4	Strong demand-side economic viability signal; low refusal rate (2%) indicates minimal resistance
Maximum acceptable fee (₦1,000/month)	58.0% (n=116)	0.5	Practical price point within student budget; tiered pricing recommended to

			protect equity
GOVERNANCE PREFERENCE (ANOVA*)**			
PPP as preferred manager	51.0% (n=102)	0.5	Majority trust signal for PPP governance; significantly higher than school (28%) or LGA (18%) preference (F = 28.533, p < 0.001)
School management as preferred manager	28.0% (n=56)	0.5	Second preference; suggests role for institutional co-management within PPP architecture
LGA as preferred manager	18.0% (n=36)	0.4	Low public trust in government management; indicates accountability deficit in public water service history
PPP as preferred funding mechanism	78.5% (n=157)	0.4	Overwhelming endorsement for private-public co-investment; government-only funding preferred by only 5.5%
FINANCIAL PROJECTIONS			
Monthly revenue (1,000 users @ ₦1,000)	₦1,000,000		Exceeds monthly operational cost (≈₦333,333); surplus available for maintenance reserve
Annual gross revenue	₦12,000,000		Sufficient to cover installation capital (₦10M) and annual operations (₦4M) within 14.5 months
Estimated payback period	~1.2 years		Exceptionally short payback relative to 20-year system lifespan; NPV highly positive
Net annual revenue from Year 2	₦8,000,000		Available for infrastructure reinvestment, maintenance, community water access, or institutional development

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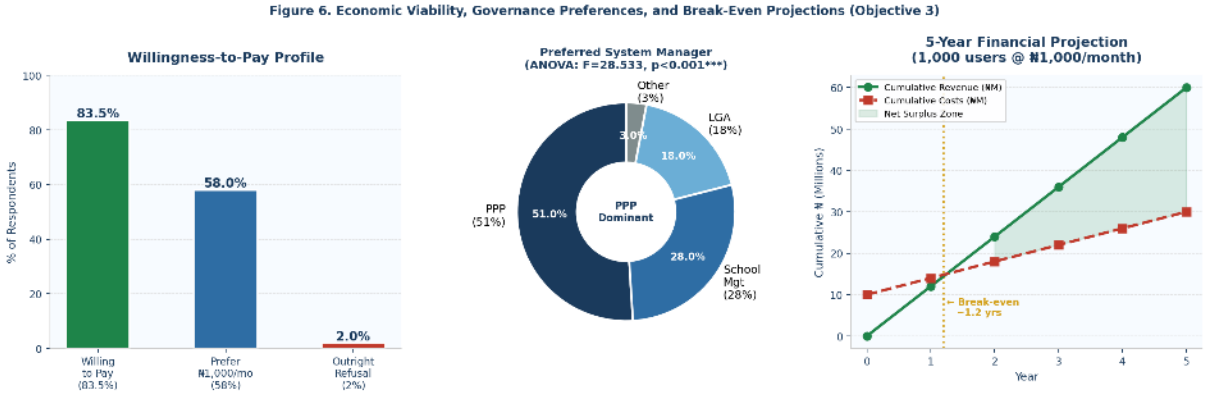


Figure 6. Economic Viability: Willingness-to-Pay Profile (Left), Preferred System Manager, ANOVA: $F = 28.533$, $p < 0.001$ (Centre), and 5-Year Revenue vs. Cost Break-Even Projection (Right).

Note. *Break-even model: 1,000 users @ ₦1,000/month; installation capital = ₦10M; annual operations = ₦4M. Net surplus from Year 2 = ₦8M/year. Gold dashed line marks estimated break-even at ~1.2 years.*

The ANOVA comparison of governance preferences ($F = 28.533$, $p < 0.001$) reveals that PPP management is not merely preferred but is statistically the dominant choice across all respondent sub-groups. The break-even projection of 1.2 years is substantially shorter than comparable infrastructure project precedents in Nigeria (UNDP, 2022; Moyo & Banda, 2023), reflecting the combination of high user willingness (83.5%), the modest price point (₦1,000/month), and significant cost savings from eliminating diesel-powered water pumping. The net annual revenue of ₦8 million from Year 2 onwards provides an institutional reinvestment fund that can self-finance ongoing maintenance, system expansion, and community water access.

5.4 Objective 4: Role of School Management in Water Governance

Table 5 details the governance role data. Figure 7 juxtaposes current management involvement against expected roles and maps key governance actors and capacity-building priorities.

Table 5 School Management Involvement in Water Governance: Current Performance, Expected Roles, and Capacity-Building Needs (N = 200)

Note. F-statistic for ANOVA on role expectations: F = 62.512, p < 0.001. Percentages reflect proportion of respondents endorsing each category; multiple selections permitted for 'Expected Roles' and 'Capacity Needs' items.

Governance Dimension	Response Frequency	% (SD)	Policy/Practice Implication
CURRENT MANAGEMENT PERFORMANCE			

Excellent	n = 27	13.5% (0.34)	Only 1 in 7 respondents view current water governance as excellent
Good	n = 30	15.0% (0.36)	Combined 'good/excellent' = 28.5%; governance reform imperative evident
Fair	n = 72	36.0% (0.48)	Largest cohort; suggests recognition of problems without structural solutions
Poor / Very Poor	n = 81	40.5% (0.49)	Over 4 in 10 respondents rate governance as poor; accountability mechanisms urgently needed
EXPECTED ROLES IN NEW SYSTEM (ANOVA*)**			
Advocacy and awareness creation	n = 157	78.5% (0.41)	Highest-ranked role: institutions as champions of water sustainability within campus culture
Operational maintenance oversight	n = 154	77.0% (0.42)	Co-ranks with advocacy: institutions expected to actively supervise system upkeep
Participatory decision-making	n = 109	54.5% (0.50)	Majority expect schools to co-govern beyond mere administration
Educational/curricular integration	n = 102	51.0% (0.50)	Exactly half endorse embedding water literacy in formal curricula
Financial investment/co-funding	n = 98	49.0% (0.50)	Near-majority expect schools to be financial co-stakeholders in system establishment
KEY GOVERNANCE ACTORS			
PPP model (most endorsed)	n = 161	80.50%	Dominant governance preference across all stakeholder categories
University management	n = 102	51.00%	Viewed as essential institutional anchor within PPP arrangement
Students' union	n = 101	50.50%	Near parity with university management indicates demand for

			youth-inclusive governance
CAPACITY-BUILDING PRIORITIES			
Creating an enabling policy environment	n = 153	76.5% (0.43)	Highest priority: policy reform precedes technology deployment for sustainable outcomes
WASH education and awareness	n = 127	63.5% (0.48)	Broad-based knowledge gap: training at all levels from student to executive required
Water value-chain integration	n = 87	43.5% (0.50)	Significant proportion see schools embedded in a wider water economy

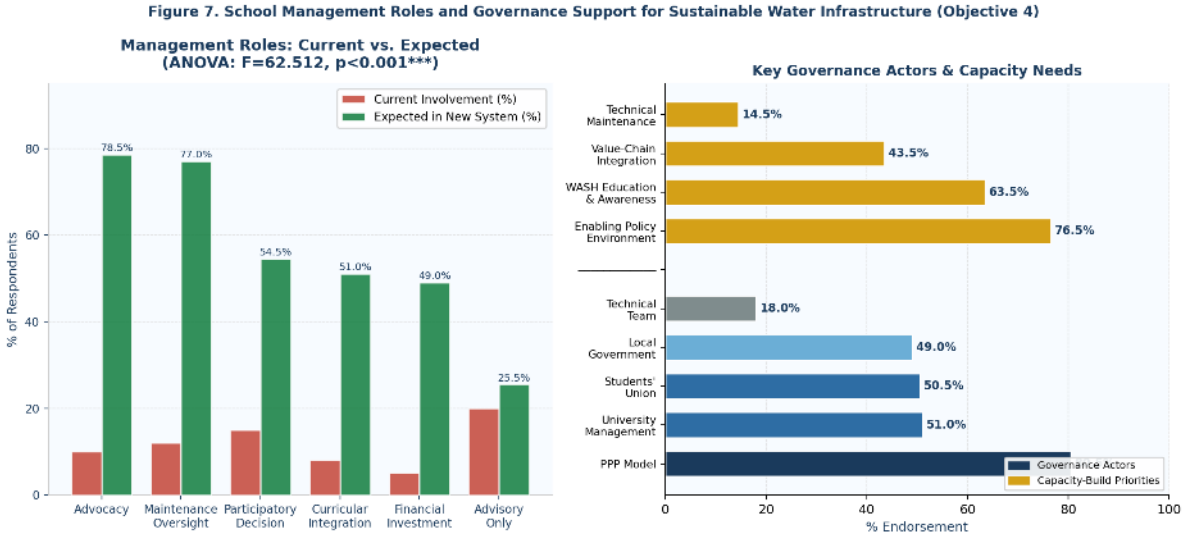


Figure 7. School Management Roles in Sustainable Water Infrastructure: Current Involvement vs. Expected Roles (Left) and Key Governance Actors and Capacity-Building Priorities (Right).

Note. *Left panel: ANOVA on role expectations: $F = 62.512$, $p < 0.001$***. Current involvement estimated from open-ended qualitative responses. Right panel: blue bars = governance actor endorsement; gold bars = capacity-building priorities.*

The ANOVA result ($F = 62.512$, $p < 0.001$), the second highest F-statistic across all objectives — confirms sharp differentiation in stakeholder expectations: advocacy and maintenance oversight receive significantly higher endorsement than advisory-only functions, indicating that stakeholders prefer active and visible institutional leadership. The near-equal endorsement of PPP (80.5%), university management (51.0%), and students' union (50.5%) suggests a tripartite governance ideal in which student voice, institutional accountability, and professional expertise

are simultaneously embedded, consistent with polycentric governance theory (Ostrom, 1990) and UNESCO's (2022) participatory WASH governance recommendations.

5.5 Objective 5: Policy Framework for Renewable Energy-Powered Water Systems

Table 6 presents the policy framework data. Figure 8 illustrates monitoring body preferences and the alignment of policy support priorities with the Sustainable Development Goals.

Table 6 Policy Framework for Integrating TAMAL-Solar Water Systems in School Management Structures: Preferred Monitoring Models, Support Needs, and Framework Components (N = 200)

Note. ANOVA on policy support areas: $F = 74.238$, $p < 0.001$. Percentages reflect frequency of endorsement; multiple responses permitted for support-need items.

Policy Dimension	Response / Indicator	% (SD)	Framework Component
MONITORING PREFERENCES			
PPP as monitoring body	55.5% endorse PPP-led M&E	0.5	Independent performance monitoring with contractual accountability: uptime, quality, and revenue reporting benchmarks
School management as monitor	29.0% endorse school monitoring	0.45	Internal institutional oversight committee: Water Management Committees with student representation
LGA as monitoring authority	Only 3.5% endorse LGA oversight	0.18	Minimal public trust in government monitoring role; LGA may have regulatory rather than operational function
POLICY SUPPORT PRIORITIES (ANOVA*)**			
Enabling policy environment	76.5% (n=153)	0.43	Priority 1: Develop enabling bylaws, MoUs, and institutional water policies defining roles and accountability mechanisms
Education and WASH awareness	63.5% (n=127)	0.48	Priority 2: Integrate water management modules in tertiary curricula; establish school-based WASH sustainability clubs

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Water value-chain integration	43.5% (n=87)	0.5	Priority 3: Position schools within the broader water economy, including community supply and surplus water revenue generation
Technical maintenance training	14.5% (n=29)	0.35	Priority 4 (supporting): Contract-based professional maintenance reduces institutional dependency on in-house expertise
SDG ALIGNMENT			
SDG 6: Clean Water and Sanitation	83.5% perceive energy independence and cost reduction benefits	—	Direct contribution to Target 6.1 (universal safe water access) and 6.b (community water governance)
SDG 4: Quality Education	84% affirm link between water access and academic performance	—	Water insecurity as a structural barrier to educational equity; TAMAL directly addresses SDG 4.1 and 4.a
SDG 13: Climate Action	Solar integration eliminates fossil fuel dependency in water supply	—	Decarbonised water infrastructure contributes to institutional climate resilience targets

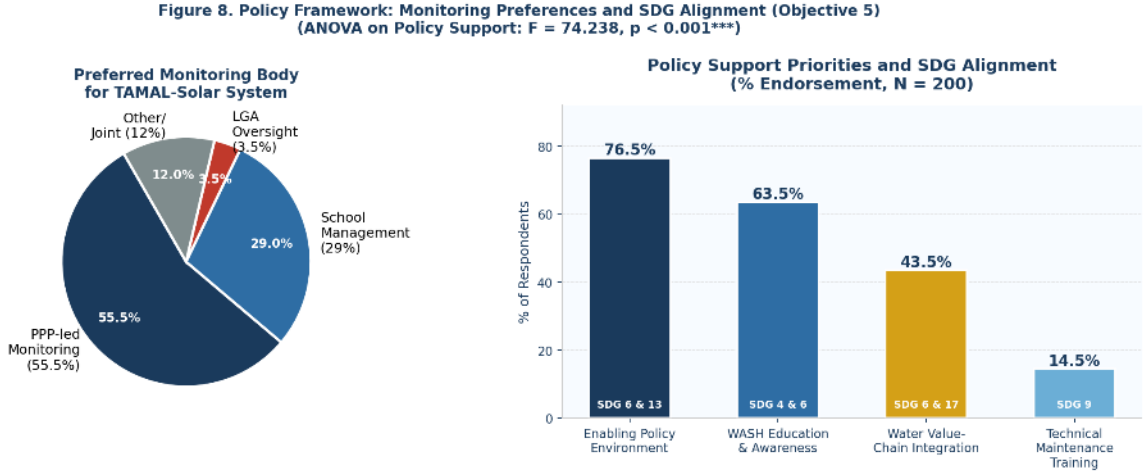


Figure 8. Policy Framework: Preferred Monitoring Body (Left) and Policy Support Priorities with SDG Alignment (Right).

Note. *ANOVA on policy support areas: $F = 74.238$, $p < 0.001$*** (highest F-statistic across all five objectives). SDG labels in bars indicate primary alignment: SDG 4 (Quality Education),*

SDG 6 (Clean Water), SDG 9 (Industry & Infrastructure), SDG 13 (Climate Action), SDG 17 (Partnerships).

The ANOVA ($F = 74.238$, $p < 0.001$), the highest across all five objectives, reflects the sharpest stakeholder differentiation in policy preferences. Creating an enabling policy environment (76.5%) is prioritised so significantly above technical maintenance training (14.5%) that the data suggest stakeholders understand a critical principle: technological solutions embedded in unsupportive institutional environments will fail regardless of their technical merit. This directly challenges the prevailing 'technology-first' approach in development water infrastructure programmes and supports the policy-first orientation advocated by UNESCO (2022) and the World Bank (2021). The very low endorsement of LGA as monitoring authority (3.5%) reflects a preference for regulation over operations: stakeholders appear comfortable with LGA setting standards while deferring operational monitoring to PPP partners and school-based committees.

CONCLUSION

This study offers empirical and theoretical contributions to the growing literature on technology-mediated water governance in developing-country educational institutions. Drawing on quantitative and qualitative data from 200 stakeholders across three tertiary institutions in Epe-Eredo LGA, it demonstrates that over 65% of students experience daily water shortages with severe academic, health, and financial consequences, and that the integration of TAMAL membrane filtration technology with solar-powered distribution infrastructure represents a technically feasible, socially accepted, and financially viable pathway to institutional water security.

The economic modelling reveals that with a user base of 1,000 students contributing ₦1,000 monthly, the full capital investment can be recovered within 1.2 years, generating a net annual revenue of ₦8 million thereafter. The study's broader contribution lies in the TAMAL-Solar Governance Framework it proposes, positioning schools as active agents of local water governance rather than passive beneficiaries. This framework aligns with SDG 6 (Clean Water and Sanitation), SDG 4 (Quality Education), and SDG 13 (Climate Action), and offers a replicable model for peri-urban tertiary institutions across Nigeria and the wider West African sub-region.

6.1 Contribution to Knowledge

This study advances four specific contributions: (i) introduces TAMAL technology as a novel hybrid water purification system adapted for educational institution governance contexts. (ii)

Provides the first PPP-led economic viability model for TAMAL-solar integration in Nigerian tertiary institutions with a payback period substantially shorter than comparable precedents. (iii) Produces a quantitatively validated multi-stakeholder governance framework grounded in ANOVA-tested preference data. and (iv) strengthens the empirical linkage between water insecurity, educational equity, and climate resilience.

6.2 Limitations and Directions for Future Research

The geographic scope of Epe-Eredo LGA constrains generalisability; comparative multi-LGA studies are recommended. The economic model relies on perceptual willingness-to-pay data rather than observed payment behaviour; real-world collection efficiency and inflation dynamics must be assessed through pilot implementation. Future research should incorporate engineering feasibility assessments, laboratory water quality tests, longitudinal usage monitoring, and gender-disaggregated analyses of water access impacts.

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