

Techno-Economic Assessment of Smart Photovoltaic-Water Infrastructure Development for a Residential Community in Peri-Urban Ikorodu, Lagos State, Nigeria

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Abstract: Potable water demand in the peri-urban Lagos State has necessitated the development of strategic combined power and water infrastructure. The techno-economic viability assessment of a smart photovoltaic-water treatment system in peri-urban Ikorodu, Lagos State was effected as an extenuation approach to pervasive insufficient potable water provision under the State's integrated clean water initiatives. An energy technology foresight analysis methodology was used. The study determined an appropriate infrastructural option – a combined 180 kW smart PV, 400 m³/day smart water treatment system requiring 0.65 acres of land and generating 146,000 litres of potable water annually. The smart PV-water plant initiative was considered to have acceptable risk (Payback period between 16.29 to 18.41 years; Return on Investment = 5.43%) and viability at the minimum water price of \$ 2.08/m³. It also had cost savings of \$ 73,000/year relative to the water vendor supply option. The study recommended a reduction in plant operating costs to improve the viability of the smart PV-water treatment system. The study concluded that the smart PV-water treatment system project was technologically attainable, economically viable, and eco-friendly, and consequently recommended its establishment in the study area.

Keywords: Smart photovoltaic-water treatment plant; Urban and regional water planning; South-West Nigeria water infrastructure; Technology and project foresight analysis; Critical power-water infrastructure; Off-grid electric power systems, Mini-grid potable water systems

1.0 Introduction

A modern water supply system is an essential critical infrastructure for a technologically advanced nation. Water is a strategic natural resource for human existence, and water provision is critical to the industrial, agricultural, transport, commercial and housing sectors of the economy [1, 2, 3]. Modern water supply systems are organised as public or privately-owned utilities, and entail drinking water sources, raw water collection locations, water purification facilities, water storage facilities, pumping stations, water distribution systems, and municipal wastewater disposal systems [4, 5, 6]. Improved access to modern water systems has positive implications on the development of people and the economies of their communities; thus, it is imperative for governments to guarantee the provision of this critical infrastructure to their people [6, 7, 8, 9].

Developed States typically showcase advanced water supply systems, with the ability to get drinkable water from any tap on demand [6, 7, 8, 9]. These advanced water supply systems more often than not incorporate smart technologies in enhancing operations for the collection, treatment, distribution, consumption, monitoring, and management of water resources [11, 12, 13, 14]. The advanced water supply system is the desire of developing States; inopportunately, these States exhibit weak water supply systems, lack potable water, and present with limitations of technical inadequacies, restricted financing, uncontrolled population growth, water paucity, environmental contamination, and the unavailability of basic modern, or even advanced, water supply infrastructure [5, 6, 7, 8, 9, 10].

In Lagos State, a sub-national unit of a developing State, Nigeria, a distinguishing feature of the State Development Plan 2052 is the aspiration for a reliable, accessible water supply, and the attainment of advanced municipal water supply infrastructure for sustainable socio-economic development [8, 15, 16, 17]. Lagos State has a daily potable water demand of 2.16 billion litres, yet its public supply system – comprising three major waterworks (Ije, Ishasi, and Adiyen), 27 mini-waterworks, and 10 micro-waterworks – produces only 960 million litres. Just 35% of urban residents receive public water, forcing 65% to depend on informal sources such as wells/boreholes, water vendors, and rainwater [8, 15, 16, 17]. This severe shortfall underscores urgent infrastructure deficits. Public water distribution faces multiple challenges, including pipeline leaks, illegal connections, overuse, and contamination. These issues are worsened by rapid population growth, weak policies, poor infrastructure investment, aging pipelines, climate change, unreliable electricity, and unregulated private wells and boreholes [8, 15, 16, 17].

Lagos State's rapid population growth rate, high urbanization, economic growth, and increase in standard of living have accelerated municipal spatial expansion and advanced new settlements, including the development of peri-urban gated communities with residents in the middle-to-high income bracket.

Lagos State's rapid population growth, intense urbanization, economic expansion, and rising living standards have spurred significant municipal sprawl. This has led to the emergence of new settlements, particularly peri-urban gated communities catering to middle- and high-income residents [18, 19, 20, 21]. These communities' potable water demand further outstrips the municipal water supply, and their residents heavily rely on the previously identified private water sources, which more often than not, are procured at exorbitant rates [22, 23]. The limitations in public critical infrastructure investments foster water utility deficiencies which are projected to fester into the foreseeable future [24].

Specific State efforts for the mitigation of the water utility limitations include formulating, instituting and establishing policy reform and infrastructural development measures – the Lagos Water Supply Master Plan (2011), the Lagos State Water Supply Project (LSWSP), the Lagos State Water Regulatory Commission, and the various State water supply schemes [6, 9, 17, 28, 29, 30]. These measures are aspired to rehabilitate existing and institute new infrastructural projects for increased access to and improved efficiency of the public water supplies, regulate water vendors and other private water system providers, and provide a safe and improved water supply through strategic smart infrastructure development [10, 16, 29, 30, 31]. Existing research on Lagos State's potable water challenges highlights the government's efforts to integrate off-grid solutions into its energy and water policies [8, 16, 17, 24]. Key issues identified include inadequate piped water coverage, risks of groundwater contamination, and limited private sector involvement. Proposed solutions range from off-grid desalination projects to community-based initiatives [8, 15, 17, 24].

The strategic domestic water infrastructure development planning entails targets of 3.12 billion litres/day and US\$ 13 billion in critical investments by 2035, with focus on substantial devolved public and private sector investments (technological and financial) in innovative urban water supply initiatives such as the smart solar powered municipal water infrastructure [24, 25, 26, 28, 29, 30, 31]. A pre-investment assessment of private-public partnership (PPP) in municipal utility infrastructure development has indicated community willingness to pay for water at a reasonable rate [24, 32, 33].

The smart photovoltaic-municipal water infrastructure is a dual smart-technology system – an intelligent water infrastructure powered by a smart photovoltaic system [34, 35, 36, 37]. The configuration is a self-sufficient off-grid structure that supplies electricity to a localized municipal water system for a restricted group of customers, and helps minimize the electricity and water consumption with more efficient and cost-effective monitoring networks [34, 35, 36, 37].

According to EMSD [38], Enhar [39], City Energy [40], Singh and Ahmed [41], Tuser [42], Antzoulatos *et al.*, [43], and Global Water Center [44], the smart photovoltaic-municipal water infrastructure uses inverters, sensors, automated controls, and smart meters to provide real-time data on the energy-water systems. The further reported that the inverters, operational as system intelligence, convert the PV panel DC output to AC; printed circuit board (PCB) designs enable power storage in batteries for when there is no sunlight; Internet of Things (IoT)-enabled sensors measure physical parameters and detect leaks, water losses and system inefficiencies; smart meters track PV power system energy use and water system consumption trends; automated controls control enable remote system operations, maximizing energy production and efficient water distribution. In addition, mobile apps/web portals facilitate billing systems, as well as power and water quality monitoring and control; wireless communication networks connect components and cloud platforms for centralized data storage; and data analytics empowers consumption patterns projections and operations optimization, so as to ensure instantaneous cost-effective sustainable water usage, reliable water quality assurance, and optimum waste reduction.

This infrastructure is considered appropriate intervention technology due to the abundance and reliability of sunlight in Lagos State [45], the equipment's relative affordability, environmental friendliness, and significant potential for employment and wealth creation [38, 39, 40].

Inopportunately, the State reform efforts and water infrastructure development planning schemes have been ineffectual due to the limitations in state and private actor capabilities to adequately execute a robust techno-economic assessment of the critical PV-water infrastructure initiative, which is essential for planning and operation [45, 46]. Consequently, it is imperative to provide this strategic assessment of the smart PV-water infrastructure initiative as a vital policy intervention for the peri-urban residential gated communities in Lagos State.

In this study, a techno-economic assessment of the proposed smart PV-water infrastructure was executed using appropriate engineering project management methods. The specific objectives were to assess the water consumption in a selected residential area; determine the technological specifications for the proposed smart PV-water system; ascertain its techno-economic viability; and examine potential techno-economic, environmental, and policy benefits consequent to its successful deployment.

The study is significant as it provides critical policy intelligence on a novel smart PV-water supply system for Lagos State.

The remainder of this paper is organized as follows: Section 2.0 provides the methodology and materials used in the study, while Section 3.0 presents the results and discussion. Conclusions and recommendations are presented in Section 4.0.

2.0 Materials and Methods

The study utilised an energy technology foresight analysis (ETFA) framework. This framework is a systematic, participatory process encompassing intelligence gathering for informed decision-making vital to the advancement of a desired energy future. Methods are of three natures: Quantitative, Semi-quantitative, and Qualitative, and entail extrapolation, Delphi Techniques, and Strategic assessments, which may be deployed independently or interactively [47, 48, 49, 50, 51].

2.1 Location of Study Area

According to Cityscape [52] and NigeriaGalleria [53], Ikorodu is a city located in north-east Lagos State, Nigeria. The Lagos Lagoon bounds the municipality to the south, Ogun State to the north, and Epe Division to the east. The city (Population: 1 million) is the 12th largest in the country, while its Local Government Area is the second largest in the State. Ikorodu is the fastest growing part-exurb of the Lagos metropolis, consequent to ever-increasing inflow of people from neighbouring areas attracted by its proximity to Lagos, approximately 37 km away, and separated by only the Lagos Lagoon. Ikorodu has significant industrial activities comprising farming, manufacturing, and trading. Ikorodu

comprises many public primary and secondary schools and two tertiary institution – Caleb University and Lagos State University of Science and Technology.

Ikorodu was purposefully chosen for the study because of the significant number of new peri-urban, government-approved, middle-to-high-income, gated communities for the ever-growing city population. Specifically, a proposed Public-Private Partnership (PPP)-based middle-income, gated community, with 155 3-bedroom semi-detached buildings, was purposively selected for the study. Residents in the housing estate will be predominantly middle-income, well-educated (Master's degree or equivalent professional qualification) and have an average of 3 children per family.

2.2 Assessment of Potable Water Consumption in the Selected Gated Community

This section determined potable water consumption in the gated community in peri-urban Ikorodu, Lagos State.

2.2.1 Determination of the population in the selected gated community

Estate Population = Number of Residents per Building X Number of Buildings X 2

...Eqn. 1

2.2.2 Determination of potable water needs in the gated community

Estate Water Needs = Estimated Annual Water Demand X Estimated Water Reserves or Slack ...Eqn. 2

Assuming daily domestic water consumption per capita of 150 Litres [24, 54],

a) *Daily Estate Water Demand = Estate Population X 150L per capita* ...Eqn. 3

b) *Monthly Estate Water Demand = (a) X 30 days per month* ...Eqn. 4

c) *Annual Estate Water Demand = (a) X 365 days per year* ...Eqn. 5

d) *Estimated Water Reserves or Slack:*

i. *Daily Extra Water Supply per Residence = 50 L [24]* ...Eqn. 5

ii. *Daily Extra Water Provision in Estate =*

(i) X Total Number of Residences ...Eqn. 6

iii. *Monthly Extra Water Supply in Estate = (ii) X 30 Days* ...Eqn. 7

iv. *Total Monthly Water Supply to the Estate =*

Monthly Estate Water Demand + Monthly Extra Water Supply in Estate...Eqn. 8

It is assumed that the initial pumping of water into the Estate's water supply system would have a slack of 5 days.

Thus,

Projected Water Reserves for 5 Days =

Daily Estate Water Demand + Daily Estate Extra Water Supply) X 5 Days ...Eqn. 9

2.3 Determination of Technological Specifications for the Proposed Smart PV-Water Treatment System

The technological specifications entail determining the sizes of the water treatment plant and the smart PV system to meet the electric power demand of the water plant.

2.3.1 Estimated daily water demand for water treatment plant design

$$= \frac{\text{Total monthly water demand in estate L/days}}{30 \text{ days}} \quad \dots \text{Eqn. 11}$$

2.3.2 Design specification for smart water treatment plant (SWTP)

Assuming the water treatment plant operates at 75% efficiency,

$$\text{SWTP design specification definition} = \frac{\text{Estimated daily water demand}}{0.75} \quad \dots \text{Eqn. 12}$$

2.3.3 Determining the size of the corresponding smart PV System

Assuming a moderate energy efficient system with electricity requirement of approximately 4 kWh/m³ and operational time of 15 hours/day [24]

$$a. \text{ Daily energy demand} = \text{daily water demand} \times \text{electricity requirement} \quad \dots \text{Eqn. 13}$$

$$b. \text{ Power Load Demand} = \frac{\text{Daily energy demand}}{\text{power system operational time}} \quad \dots \text{Eqn. 14}$$

Assuming the power plant operates at 75% efficiency,

$$c. \text{ Power Plant Sizing} = \frac{\text{Power Load Demand}}{0.75} \quad \dots \text{Eqn. 15}$$

2.3.4 Determination of land area for the smart PV-water treatment system

(a) For the Smart PV Power Plant:

Basic panel area is measured at 9 m²/kW [45]

Added Infrastructure at 15% of basic panel area = Basic panel area $\times$ 1.15
...Eqn. 16

(b) For the Smart Water Treatment Plant:

Basic plant area estimated at 1.54 m²/m³ [24]

Added Infrastructure at 25% of basic plant area = Basic plant area $\times$ 1.25

...Eqn. 17

Total Land Area for Smart PV-Water Treatment System = (a) + (b) ...Eqn. 18

2.4 Techno-Economic Specifications for the Smart PV-Water Treatment System

The techno-economic analysis of the smart PV-water treatment system entailed estimating the total initial investment (sum of capital costs and cash-in-hand) and the total annual operating costs and evaluating the system's economic viability using appropriate techniques. The capital costs include costs for the smart PV-water treatment system, the ancillary buildings and facilities, and the land. The cash-in-hand is equivalent to the total operating costs for one year. The total annual operating costs include costs for labour, energy, materials, depreciation, and other costs) [45, 46, 55, 56, 57, 58].

A project financial management template specifying the proportion of each cost article comparative to the total initial investment and annual operating costs was established based on data from technical reports, expert opinion, manufacturers' and equipment vendors' price lists, local water vendors' rates, and project financial analysis reports [55, 56, 57, 58]. This template was substantiated by engineering project financial management specialists under the Nigerian Society of Chemical Engineers and the Nigerian Society of Engineers (Obafemi Awolowo University, Ile-Ife, branches). Project economic viability analysis entailed determining the levelised costs of water and the Net Present Value (NPV), Payback Period, and Return on Investment of the project [55, 56, 57, 58].

2.5.1 Determination of the initial investment (fixed capital and cash-in-hand)

- i. The water treatment plant cost was determined from the conversion factor detailing average costs for a smart unit at \$ 8.22/m³ [45], entailing the following costs:
 - a. Design and engineering @ 15%
 - b. Equipment and materials @ 50%
 - c. Construction and installation @ 20%
 - d. Smart Features (IoT/Automation) @ 15%
- ii. The power plant cost was determined from the conversion factor detailing average costs for a smart PV system at \$ 1.60/W [45], entailing the following costs:
 - a. Solar panels @ \$ 0.30/W

- b. Inverters @ \$ 0.15/W
 - c. Mounting Structures @ \$ 0.10/W
 - d. Battery @ \$300/kWh
 - e. Balance of systems @ \$ 0.15/W
 - f. Installation and Labour @ \$ 0.30/W
 - g. Smart system integration @ \$ 15,000.00
 - h. Other costs @ \$ 15,000.00
- iii. Land costs were estimated from the cost of residential land in Ikorodu-Lagos at determined \$ 1,510.00 per plot, with 6 plots equivalent to an acre of land [59].
- iv. Costs of ancillary structures (the buildings and facilities) were estimated at 10% of the costs of the smart water treatment plant. This estimate was premised on engineering economics and project management experts' advice.
- v. Cash-in-hand is a working capital type necessary to meet extant, short-term obligations [47, 48]. The cash-in-hand was estimated to be equivalent to the first year's annual operating costs, premised on expert opinion.

2.5.2 Determination of the total annual operating costs

The total annual operating costs, comprising preliminary operating costs and depreciation, were calculated using a determined financial template.

- i. Preliminary operating costs were estimated using the equation:

$$\text{Preliminary Annual Operating Costs} = 10\% \text{ of the Smart PV-Water treatment plant Capital Cost} \quad \dots \text{Eqn. 19}$$

The annual operating costs template, as developed for this study [46, 56, 57, 58]:

Costs	(%)
Depreciation (2.1%)	28.55
Labour	25.50
Energy	18.10
Materials	18.02
Other costs (insurance, taxes, etc)	9.83
<i>Total Operating Costs (Annual)</i>	<i>100</i>

- ii. Depreciation was analysed using the Straight-Line method [55, 57, 58]. The salvage value for the Smart PV-Water Treatment System as well as the administrative buildings and facilities, was assumed at 10% of their initial investment based on engineering project management specialists' recommendations.

$$\text{Salvage Value} = 10\% \text{ of Initial Investment} \quad \dots \text{Eqn. 20}$$

$$\text{Annual Depreciation} = \frac{\text{Initial Investment} - \text{Salvage Value}}{\text{Number of Years}} \quad \dots \text{Eqn. 21}$$

$$\text{Annual Depreciation (\%)} = \frac{\text{Annual depreciation}}{\text{Initial Investment}} \times 100\% \quad \dots \text{Eqn. 22}$$

2.5.3 Determination of levelized cost of the smart PV-water treatment system

The levelized cost of the potable water from the smart PV-water treatment system is the net cost of installing the smart system divided by its expected lifetime potable water output. Basically, it estimates the minimum unit price of potable water needed to break even over its expected lifetime [55, 57, 58].

Levelized Cost of Potable Water Production

$$= \frac{\text{sum of costs over lifetime}}{\text{sum of potable water produced over lifetime}} \quad \dots \text{Eqn. 23}$$

OR

$$= \frac{\text{Initial investment} + \text{Lifetime Operations costs}}{\text{potable water produced/year} \times \text{Project lifespan}} \quad \dots \text{Eqn. 24}$$

The time value of the annual operating costs was assumed to be constant over the project's 25-year lifespan, equal to its costs at Year 1 [55, 57, 58].

Accordingly,

$$\text{Total value of project lifecycle operating costs} = 25 \text{ years} \times \text{First year costs} \quad \dots \text{Eqn. 25}$$

The Present value of a future sum of money is estimated by discounting it at a preferred compound interest rate [55, 57, 58]:

$$\text{Present Value (PV)} = F(P/F, I, N) \quad \dots \text{Eqn. 26}$$

Where,

F = future cash flow, and

(P/F, I, N) = the discounting factor for calculating the time value of money [55, 57, 58].

The Interest Rate (I) of 30% is Nigeria's commercial loan interest rate as determined by the Central Bank of Nigeria (CBN) as of November 30, 2024. The number of years (N) is 1 year.

2.5.4 Determination of the estimated minimum annual revenue for the potable water initiative

With the levelised cost of potable water calculated, and the extant price of vendor purchased water determined, the preferred price per unit of potable water for this study was assumed as the midpoint between these costs.

Consequently, the minimum annual revenue for the potable water initiative to justify it as a going concern is [55, 57, 58]:

$$\text{Minimum annual revenue} = \text{annual potable water production} \times \text{price per unit} \quad \dots \text{Eqn. 27}$$

2.5.5 Determination of Net Present Value, Payback Period, and Return on Investment for the potable water initiative

- i. The Net Present Value (NPV) is a financial metric for evaluating an investment's viability (or otherwise). An investment is considered viable if the NPV is greater than or equal to zero [55, 57, 58].

Net Present Value (NPV)

$$= \text{Total Annual Revenues discounted to the Present} - \text{Total Annual Costs discounted to the Present} \quad \dots \text{Eqn. 28}$$

- ii. The Payback Period depicts the minimum time required for an investment to pay for itself. Shorter payback periods indicate an investment's attractiveness, principally with respect to risk; consequently, the payback period is a veritable tool in project planning and risk assessment [55, 57, 58].

$$\text{Payback Period} = \frac{\text{Initial Investment}}{\text{Annualized expected cash inflow}} \quad \dots \text{Eqn. 29}$$

- iii. The Return on Investment (ROI) is a financial performance metric used for evaluating investment profitability or efficiency. The ROI, presented in percentages, measures an investment's returns relative to its costs. The ROI is also used as a veritable tool in project planning and risk assessment [55, 57, 58].

$$\text{Annual Return on Investment (ROI)} = \frac{\text{Annual Net Profit}}{\text{Initial Investment}} \times 100 \% \dots \dots \dots \text{Eqn. 30}$$

2.6 Analytical Tools

The study adopted an Energy Technology Foresight Analysis (ETFA) framework as its methodological foundation. For Section 2.2 (Assessment of Potable Water Consumption in the Selected Gated Community), the analysis employed industrial process calculation methodologies. Section 2.3 (Determination of Technological Specifications for the Proposed Smart PV-Water Treatment System) incorporated comprehensive plant design calculations. Section 2.4 (Techno-Economic Specifications of the Smart PV-Water Treatment System) utilised engineering economic analysis techniques, including Straight-Line Depreciation, Net Present Value analysis, Levelized Cost of Water (LCoW) technique, Payback Period and Return on Investment assessments, complemented by descriptive statistics for robust financial evaluation.

3.0 Results and Discussions

This section presents the key findings of the research and their interpretation.

3.1 Potable Water Consumption Estimates for the Gated Community

The gated community's population was estimated at 1,550 residents. The community demonstrated a calculated monthly water demand of 6.98 million litres plus 1.70 million litres reserve capacity, yielding a total monthly demand of 8.68 million litres. This equates to 289.33 thousand litres/day (186.67 litres/capita/day) – the assumed benchmark for the PV-water treatment system design. These specifications exceed Nigeria's (20-50 litres) and EU's (50-150 litres) norms but remain below US standards (300-380 litres) [24]. The elevated planning and design parameters are not considered inappropriate as they account for Nigeria's endemic potable water scarcity and municipal water infrastructure failures, necessitating robust storage capacities across built environments.

Table 1: Potable Water Consumption Estimates for the Gated Community in Ikorodu, Lagos State

S/N	Technological Specification	Quantity
1.	Population of Gated Community	1550 people
2.	Domestic Water Needs of Gated Community:	
	a. Daily water demand	
	b. Monthly water demand	232,500 Litres (232.5 m ³)
	c. Annual water demand	6,975,000 L (6,975 m ³)
	d. Monthly water reserve/slack	84,862,500 L (84,862.5 m ³)
	e. Total Monthly Water Needs	1,705,000 L (1,705 m ³) 8,680,000 L (8,680 m ³)
3.	Daily water demand for smart water treatment plant design specification	289,333.33 L (289.3 m ³)
4.	Daily water demand per capita in the Gated Community	186.67 L (0.1867 m ³)

3.2 Technological Specifications for the Smart PV-Water Treatment System

The smart water treatment plant was designed for a nominal capacity of 400 m³/day operating at 75% efficiency (Table 2). System analysis revealed an associated daily electricity demand of 1,600 kWh. Given the planned 15-hour daily operation window, this translates to a required pump power load of 106.67 kW. To meet this demand at 75% conversion efficiency, the photovoltaic system was sized at 177.77 kW (approximated to 180 kW). The integrated PV-water treatment system requires an estimated 0.65 acres (2,631 m²) of land area for installation.

From a technology foresight perspective, the derived technical specifications provide robust foundations for strategic planning of potable water initiatives throughout Nigeria's South-West geopolitical zone, particularly within the Greater Lagos Metropolitan Area. These calculations align with three critical frameworks: (i) regional development priorities, (ii) national water infrastructure agendas, and (iii) the United Nations Sustainable Development Goal 6 (Clean Water and Sanitation). The quantified parameters enable evidence-based decision-making for sustainable water infrastructure deployment across the region.

Table 2: Technological Specifications for the Smart PV-Water Treatment System

S/N	Technological Specification	Quantity
1.	Design specification of a smart water treatment plant assuming 75% efficiency.	386 m ³ /day (approximated to 400 m ³ /day)
2.	Domestic Electricity/Power Supply Demand for the Smart Water Treatment System	
	a. Daily electricity demand for the smart treatment plant @ 4kWh/m ³	1600 kWh/day
	b. Average power load of installed pumps required for 15 hrs/day operations	106.67 kW
3.	Design specification of a smart PV power plant for a water treatment system, assuming 75% efficiency	177.77 kW (approximated to 180 kW)
4.	Land Area for Smart PV-Water Treatment System:	
	a. Smart PV plant (basic panel area + accessories)	1,863 m ² (0.46 acres, 2.76 plots)
	b. Smart water treatment plant (basic area + accessories)	768.75 m ² (0.19 acres, 1.14 plots)
	c. Total land area	2,631.75 m ² (0.65 acres, 3.9 plots) (Approximated to 4 plots)

3.3 Techno-economic Analysis of the Smart PV-Water Treatment System

The smart PV-water treatment system requires a total investment of \$1.83 million, consisting of \$1.63 million in capital expenditures and \$204.2 in available cash reserves. Annual operating costs are projected at \$204.2 thousand, with the most significant expenses being plant and building depreciation (\$58,320) and labour (\$52,080) (Table 3). The levelized water production cost was \$1.58/m³, which is \$1.00/m³ lower than the prevailing rate of \$2.58/m³ in Ikorodu, Lagos. By implementing a consumer price for water at \$2.08/m³, a profit margin of \$0.50/m³ can be achieved, resulting in estimated annual revenue and profit of \$303,680 and \$99,440, respectively, based on an annual production volume of 146,000 m³. Project financial viability is further supported by a positive Net Present Value (NPV) of \$1,834,414.80 over the 25-year lifespan, a payback period ranging between 16.29 and 18.41 years, and a Return on Investment (ROI) of 5.43%, all of which indicate manageable risk. The techno-economic analysis confirms that the smart PV-water treatment system can sustainably supply potable water to the peri-urban gated community in Ikorodu, Lagos, at \$2.08/m³, balancing cost-competitive pricing, managed financial risk, and strong long-term viability. The implementation of the project is technically and economically justifiable and therefore recommended for execution.

Table 3: Techno-Economic Assessment of the Smart PV-Water Treatment System

Costs	(US\$)
<i>Capital Costs</i>	
400 m ³ /day Smart Water Treatment Plant	
180 kW Smart PV System	1,200,000.00
Land	300,000.00
Administrative Building + Facilities	6,040.00
Cash-in-Hand	120,000.00
<i>Total Investment</i>	204,240.00
	1,830,280.00
<i>Operations Costs (Annual)</i>	
Depreciation	58,320.00
Labour	52,080.00
Energy	36,960.00
Materials	36,810.00
Other costs	20,070.00
<i>Total Operating Costs (Annual)</i>	204,240.00
Annual Water Production	
Salvage value of Smart PV-Water System	146,000 m ³
Levelized cost of Water	\$ 304,425.00
Extant price of Water in 25-Litre kegs in Ikorodu	\$ 1.58/m ³
Estimated selling price of Water	\$ 2.58/m ³
Profit margin	\$ 2.08/m ³
Estimated Annual Revenues	\$ 0.50/m ³
Estimated Annual Profits	\$303,680.00
Net Present Value (NPV)	\$ 99,440.00
Payback Period	\$ 1,834,414.80
Annual Return on Investment	16.29 – 18.41 years
	5.43%

3.4 Socio-economic Benefits of the Smart PV-Water Treatment System in peri-urban Ikorodu, Lagos State

The water supply infrastructure in Lagos State remains critically inadequate, forcing residents to depend on alternative sources such as water vendors and private wells/boreholes for domestic needs. Research by Ogundari [24] confirms that households currently pay approximately \$2.58/m³ for vended water. This study's analysis reveals that a proposed smart PV-water treatment system could produce water at a significantly lower levelized cost of \$1.58/m³ – 38.8% cheaper than current vendor prices – demonstrating strong market potential. Even when priced at \$2.08/m³ to ensure project viability, the system would still undercut vendor rates by 19.4%. Implementation would yield substantial economic benefits, including annual savings of \$73,000 for Ikorodu's gated community residents (Table 4), while simultaneously providing reliable access to clean water. Beyond cost advantages, the system would address critical public health needs through guaranteed water quality, representing economic and social improvement over existing water supply solutions.

Table 4: Comparative Costs of Water Consumption: Water Vendor vs Smart PV-Water System

Source of Water	Water Consumption (m ³ /Year)	Cost of Water (\$/m ³)	Total Costs/Yr (\$)
Water Vendor	146,000	2.58	376,680.00
Smart PV-Water System	146,000	2.08	303,680.00
Savings		0.50	73,000.00

4.0 Conclusion and Recommendation

This study evaluated the techno-economic feasibility of implementing a smart PV-powered water treatment system to address potable water needs in Ikorodu, a peri-urban region of Lagos State, as a strategic input to domestic clean water development in Nigeria. Using Energy Technology Foresight Analysis, the research examined water demand, patterns, technical requirements, and economic factors to determine an optimal configuration: a hybrid 180 kW PV system, coupled with a 400 m³/day water treatment plant requiring 0.65 acres of land. The proposed system could produce 146,000 m³ of clean water annually while demonstrating financial viability at a competitive price of \$2.08/m³ –offering \$73,000 in annual savings compared to existing water vending alternatives. While the project shows promising technological feasibility, environmental benefits, and acceptable risk levels (with a 5.43% ROI and 16–18-year payback period), the study suggests enhanced viability further by reducing operational costs, particularly the substantial 30% bank interest rate. The findings strongly support implementing this sustainable water solution in the target community as it effectively combines technical achievability, economic sustainability, and ecological advantages.

Future efforts should prioritize expanding the smart PV-water treatment system to other underserved communities, adapting designs to local conditions through feasibility studies. Research should investigate integrating IoT-based smart water grids and hybrid renewable energy systems to boost reliability. Policy development must focus on creating supportive frameworks and financing mechanisms to enable wider adoption. Long-term monitoring should assess environmental and economic impacts while optimizing costs through innovative financing and scaled deployment. Successful implementation will require community education programs and local technician training to ensure sustainable operation. These combined technical, policy, and social interventions will help scale this sustainable water solution across Lagos State and Nigeria.

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