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GREEN ENERGY AS A SUSTAINABLE SOLUTION TO ENVIRONMENTAL AND INFRASTRUCTURAL DEGRADATION IN ZARIA METROPOLIS: THE MEDIATING ROLE OF PUBLIC HEALTH

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Abstract

This paper examines the role of green energy as a sustainable solution to environmental and infrastructural degradation in Zaria Metropolis, highlighting its impact on public health. With climate change and pollution rising, shifting from fossil fuels to renewable energy is essential for ecological protection and health improvement. A descriptive survey design assessed how green energy adoption reduces airborne pollutants, enhances water quality and sanitation, and strengthens healthcare infrastructure through reliable energy access. From Zaria and Sabon Gari LGAs, 258 households were randomly selected, and 250 respondents across ten wards were sampled using stratified random and purposive techniques. Of the 250 questionnaires, 248 were valid. Data were collected via an expert-validated questionnaire on a modified 4-point Likert scale and analysed using mean, standard deviation, and Pearson correlation at 0.05 significance. Results showed significant correlations with reduced pollution ($r = 0.728$), improved sanitation ($r = 0.517$), and better healthcare ($r = 0.771$). The study recommends investing in solar energy, awareness campaigns, and green financing to enhance health outcomes.

Keywords: Green Energy**,** Airborne pollutants, Water quality, Healthcare infrastructure

Introduction

Over the past two decades, the global urgency for sustainable energy strategies has intensified, particularly in developing nations where weak infrastructure and environmental degradation have significantly affected public health (Akorede et al., 2023; Amin et al., 2024). In Nigeria, these impacts manifest in regionally distinctive ways, with Northern Nigeria and specifically urban centres like Zaria in Kaduna State experiencing amplified public health and ecological challenges due to unsustainable energy practices. In these settings, the compounded crises of climate change, inadequate energy infrastructure, and environmental pollution have worsened health outcomes, heightened economic vulnerabilities, and undermined social resilience. Zaria faces severe climate change effects, including rising temperatures, erratic rainfall, and arid, dust-carrying winds, which have directly contributed to deteriorating air quality and increased prevalence of respiratory diseases such as asthma, bronchitis, and chronic obstructive pulmonary disease (Aliyu & Botai, 2018; Kabiru et al. 2024). These challenges are further intensified by inadequate access to reliable electricity, clean water, and hygienic sanitation, disproportionately affecting children, the elderly, and individuals with pre-existing health conditions who often lack functional healthcare facilities and preventive interventions (Abdulbaqi et al., 2019; Pona et al., 2021).

Agricultural productivity, which underpins much of the local economy, has also been disrupted by shifting rainfall patterns and degraded soil quality, entrenching poverty and limiting community capacity to invest in or adopt green energy solutions (Mbonu, 2025). Despite Zaria's abundant solar potential and suitable land for renewable energy infrastructure, reliance on kerosene, charcoal, diesel, and other polluting fuels remains prevalent due to limited strategic investment, further exacerbating environmental degradation and adverse health outcomes (Aliyu et al., 2018). Addressing these interconnected challenges requires a transition to green energy as a localised, context-driven public health intervention, leveraging renewable sources such as solar, wind, hydropower, biomass, and geothermal to replace traditional fossil fuels. Unlike coal, diesel, or kerosene, renewable energy does not emit harmful gases or pollutants, making it vital for reducing environmental and health burdens. Although fossil fuels have historically driven industrial growth, their long-term impacts on air quality and climate are severe (Algburi, 2015), whereas green energy, drawn from naturally replenished resources, reduces dependency on polluting fuels and promotes sustainability.

Airborne respiratory pollutants represent one of Zaria's most urgent environmental degradation challenges, including particulate matter (PM2.5 and PM10), carbon monoxide (CO), and sulfur dioxide (SO2), predominantly released from burning fossil fuels, waste, and biomass. Diesel generators, vehicular emissions, and open waste burning are prevalent sources, with neighbourhoods such as Samaru and Sabon Gari exceeding WHO air quality limits, disproportionately affecting vulnerable populations (Nimyel et al., 2019; Ahmed et al., 2022). Climate change exacerbates these risks by elevating pollutant levels during periods of extreme heat and dryness, impairing respiratory health, triggering inflammation, and reducing lung function

(Tran et al., 2023). While small-scale interventions such as improved cooking stoves offer modest relief, they are insufficient to address health hazards in poorly ventilated environments (Saleh et al., 2020). Green energy alternatives like solar lighting and clean cooking systems have demonstrated significant respiratory health improvements, particularly for women and children who are most exposed to indoor pollution (Dawah, 2016; Miriam et al., 2024).

Water quality and sanitation are equally critical. Limited access to clean drinking water and effective waste management exacerbates exposure to waterborne diseases, including typhoid, dysentery, and cholera, with only 43% of Zaria's population having access to potable water (Abdulbaqi et al., 2019; Abdulrasaq et al., 2015; Akorede et al., 2022; Akorede et al., 2023). Many residents rely on contaminated wells and surface water, and the rainy season further amplifies exposure to faecal contamination and stagnant water. Unreliable electricity hampers water purification and distribution, yet solar-powered water solutions, including boreholes and water pumps, have proven successful in rural Kaduna and could be scaled in urban Zaria to ensure continuous access to clean water (Abdulfatah et al., 2025; Akorede et al., 2025; Isma'il, 2016; Dabo et al., 2024). Renewable energy can also power sanitation infrastructure, such as latrines and decentralised sewage treatment units, mitigating open defecation and environmental contamination. Integrating green energy into water and sanitation not only reduces disease prevalence but also enhances community resilience, lowers medical costs, improves school attendance, and boosts productivity, outcomes that are particularly important in economically constrained and infrastructure-limited areas like Zaria.

Healthcare infrastructure in Zaria and Kaduna State is similarly constrained by persistent power shortages, which compromise services such as maternal and child health (Akorede et al., 2022). Over 60% of primary healthcare centres lack stable electricity, restricting vaccine storage, emergency surgeries, night-time treatments, and telemedicine services (Abdulbaqi et al., 2025; UNDP Nigeria, 2021). Renewable energy solutions, including solar mini-grids and backup systems, have proven effective, as illustrated by the solar electrification of Jaji Military Hospital in 2020, which enhanced emergency care, reduced mortality during outages, and improved hospital efficiency (Nwankwo et al., 2021). Reliable electricity also enables digital health transformation, including electronic medical records and remote consultations, ensuring timely and efficient care. Beyond service continuity, renewable energy adoption reduces long-term operational costs and dependence on fossil fuels while improving worker morale, staff retention, and public trust in health facilities (Cook & Elliott, 2022). The use of green energy has also been linked to improved maternal and child health outcomes (Akorede et al., 2022; Sharma et al., 2025) and continuity of healthcare services in underserved areas (Dhayal et al., 2024).

The cumulative integration of green energy across air quality management, water and sanitation, and healthcare infrastructure constitutes a holistic public health strategy, reinforcing the transformative potential of renewable energy for urban resilience. In Zaria, where environmental degradation, infrastructural weakness, and climate vulnerability intersect, green energy adoption is not merely a technical intervention but a pathway to health equity and sustainable development (Ikechukwu & Edeh, 2020). By reducing airborne pollutants, improving water and sanitation, and enhancing healthcare infrastructure, renewable energy interventions generate conditions for further adoption, creating a self-reinforcing cycle of resilience and sustainability. Policymakers and development stakeholders must therefore prioritise green energy in urban planning, health policy, and infrastructure investment, emphasising coordinated efforts, community engagement, and targeted funding to realise the environmental and health benefits of renewable energy. Empirical studies affirm that transitioning to green energy is feasible and essential for building healthier, more resilient cities in Nigeria and across the Global South (UNDP Nigeria, 2021; Nwankwo et al., 2021; Cook & Elliott, 2022; Sharma et al., 2025; Dhayal et al., 2024).

In light of the above, the evidence features green energy adoption as a critical public health strategy and a cornerstone of sustainable urban development in Zaria Metropolis. By addressing interconnected challenges in air quality, water and sanitation, and healthcare infrastructure, renewable energy not only mitigates environmental and health risks but also strengthens economic resilience, social stability, and community capacity for further sustainability. The strategic implementation of green energy solutions, including solar, wind, biomass, and hydropower, offers practical pathways to transform public health outcomes, improve access to essential services, and promote long-term environmental sustainability, emphasising the urgent need for coordinated policy, investment, and community engagement to harness the full potential of renewable energy as a driver of health equity and urban resilience.

Statement of the problem

Historically, Zaria Metropolis thrived as an agriculturally rich and socially cohesive urban centre in Northern Nigeria, benefiting from stable climatic conditions, fertile lands, and modest but functional infrastructure. The city's energy needs were met primarily through small-scale systems that posed minimal environmental harm. Water sources were relatively clean, the climate was predictable, and respiratory diseases were not widespread. Community health and economic productivity flourished in an environment where air quality, water, sanitation, and healthcare access were not severely compromised.

However, over the past two decades, Zaria has experienced a profound transformation marked by environmental degradation and infrastructural decay. Rapid urbanisation, population growth, and overdependence on fossil fuels have resulted in increased air pollution, erratic electricity supply, and the collapse of public sanitation systems. Airborne pollutants from generators, vehicles, and open burning now pose serious respiratory risks, particularly for vulnerable groups. Simultaneously, access to potable water has declined drastically, exposing residents to frequent outbreaks of waterborne diseases. Most critically, the healthcare sector suffers from persistent power outages that undermine emergency response, vaccine preservation, and general service delivery.

These compounding challenges have strained Zaria's public health capacity, reduced agricultural productivity, deepened poverty, and weakened community resilience. Despite abundant solar energy potential and renewable alternatives, the city

continues to rely on polluting fuels, worsening health and environmental conditions. This calls for an urgent re-evaluation of energy strategies to support sustainable development goals.

This study is crucial at this stage because it identifies green energy adoption as not merely an environmental intervention, but a strategic public health imperative. By focusing on the interlinked issues of air quality, water, sanitation, and healthcare infrastructure, the research aims to provide a practical, evidence-based framework for policymakers, health planners, and development partners. It seeks to demonstrate how renewable energy solutions can reverse Zaria's environmental and health decline, restore system functionality, and promote long-term resilience. The urgency and magnitude of the current crisis make this research timely and necessary for Zaria and similarly affected urban centres.

Objectives of the Study

The objective of this study is to examine Green Energy as a Sustainable Solution to Environmental, infrastructural Degradation, and its Health Implications. The specific objectives are as follows;

i. To examine the relationship between the reduction of airborne respiratory pollutants and the adoption of green energy in Zaria Metropolis.
ii. To assess the relationship between improved water quality and sanitation and the adoption of green energy in Zaria Metropolis.
iii. To evaluate the relationship between enhanced healthcare infrastructure through reliable energy sources and the adoption of green energy in Zaria Metropolis.

Research Questions

The following are research questions that guided the study;

i. What is the relationship between the reduction of airborne respiratory pollutants and the adoption of green energy in Zaria Metropolis?
ii. What is the relationship between improved water quality and sanitation and the adoption of green energy in Zaria Metropolis?
iii. What is the relationship between enhanced healthcare infrastructure through reliable energy sources and the adoption of green energy in Zaria Metropolis?

Research Questions

The following are research questions that guided the study;

H_{01}: There is no significant relationship between the reduction of airborne respiratory pollutants and the adoption of green energy in Zaria Metropolis.
H_{02}: There is no significant relationship between improved water quality and sanitation and the adoption of green energy in Zaria Metropolis.
H_{03}: There is no significant relationship between enhanced healthcare infrastructure through reliable energy sources and the adoption of green energy in Zaria Metropolis.

Methodology

This study employed a descriptive survey research design to examine the role of green energy as a sustainable solution to environmental and infrastructural degradation and its health implications in Zaria Metropolis. The design enabled the collection of quantifiable data on residents' perceptions, awareness, and attitudes toward green energy and its potential to mitigate urban issues like pollution, infrastructure decay, and related health concerns. The targeted population included all adults residing in Zaria Metropolis, with a population of 258 households. The metropolis comprises two LGAs: Zaria LGA and Sabon Gari LGA, each with multiple wards. From these, ten wards were purposively selected—five from each LGA. The selected wards in Sabon Gari were Samaru, Basawa, Bomo, Jama'a, and Chikaji, while those from Zaria included Kwarbai 'A', Kwarbai 'B', and Ung. Juma, Limancin-Kona, and Kaura. A total of 250 respondents (25 from each ward) were selected using a stratified simple random sampling technique, stratifying by age, gender, and residence to ensure representativeness. In addition, purposive sampling was applied to include only English-literate adults, ensuring comprehension of the questionnaire, which was administered in English. The data collection instrument was a self-developed questionnaire titled "Green Energy as a Sustainable Solution to Environmental and Infrastructural Degradation and its Health Implications. It used a modified 4-point Likert scale ranging from Strongly Agree (4) to Strongly Disagree (1). The questionnaire was validated by experts from the Federal University of Education, Zaria, who reviewed its content, suggested clarifications, and recommended revisions. A Cronbach's Alpha score of 0.885 confirmed strong internal reliability. Prior to data collection, the research team conducted community entry through engagement with local leaders to gain trust and cooperation. Descriptive statistics (mean and standard deviation) were used to analyse research questions, while Pearson's Product-Moment Correlation tested hypotheses at the 0.05 significance level. This comprehensive methodology ensured valid, reliable, and generalizable results for policy and practice on green energy adoption in urban Nigeria.

Results

Research Question One

What is the relationship between the reduction of airborne respiratory pollutants and the adoption of green energy in Zaria Metropolis?

Table 1: Relationship between the reduction of airborne respiratory pollutants and the adoption of green energy in Zaria Metropolis

Items	Strongly Disagree	Disagree	Agree	Strongly Agree
Adoption of green energy will significantly reduce air pollution in Zaria.	18 7.6%	50 21.0%	70 29.4%	100 42.0%
Fossil fuel usage in households contributes to respiratory problems in Zaria.	52 21.8%	21 8.8%	100 42.0%	65 27.3%
Solar energy reduces dependence on pollutant-emitting generators.	38 27.5%	10 7.2%	60 43.5%	30 21.7%
Exposure to polluted air increases cases of asthma and bronchitis.	15 6.3%	23 9.7%	70 29.4%	130 54.6%
Switching to clean cooking solutions (e.g., biogas) can improve respiratory health.	8 3.4%	30 12.6%	105 44.1%	95 39.9%
Children are more vulnerable to airborne pollutants than adults in Zaria.	25 10.5%	45 18.9%	90 37.8%	78 32.8%
Awareness of green energy benefits can influence a reduction in air pollution.	8 3.4%	40 16.8%	100 42.0%	90 37.8%
There is a link between traffic emissions and respiratory diseases in Zaria.	13 5.5%	25 10.5%	110 46.2%	90 37.8%
Government incentives can encourage reduced use of pollutant fuels.	18 7.6%	20 8.4%	150 63.0%	50 21.0%
Households using green energy report fewer respiratory issues.	8 3.4%	30 12.6%	100 42.0%	100 42.0%

Field survey 2025

Table 1 above shows the results of the opinions on the relationship between the reduction of airborne respiratory pollutants and the adoption of green energy in Zaria Metropolis. 170 respondents representing 71.4% agreed that the adoption of green energy will significantly reduce air pollution in Zaria, while 68 respondents representing 28.6% disagreed; furthermore, 165 respondents representing 69.3% agreed that fossil fuel usage contributes to respiratory problems, as opposed to 73 respondents representing 30.7% who disagreed; **i**n addition**,** 90 respondents representing 65.2% agreed that solar energy reduces dependence on pollutant-emitting generators, while 48 respondents representing 34.8% disagreed; similarly**,** 200 respondents representing 84% in agreement that exposure to polluted air increases cases of asthma and bronchitis, compared to only 38 respondents representing 16% in disagreement; moreover**,** 200 respondents representing 84% agreed that switching to clean cooking solutions like biogas improves respiratory health, while 38 respondents representing 16% disagreed; equally**,** 168 respondents representing 70.6% agreed that children are more vulnerable to pollutants, while 70 respondents representing 29.4% disagreed; additionally**,** 190 respondents representing 79.8% agreed that awareness of green energy benefits can reduce air pollution, compared to 48 respondents representing 20.2% who disagreed; likewise**,** 200 respondents representing 84% agreeing that there is a link between traffic emissions and respiratory diseases, while 38 respondents representing 16% disagreed; similarly**,** 200 respondents representing 84% agreed that government incentives can reduce use of pollutant fuels, whereas 38 respondents representing 16% disagreed; finally**,** 200 respondents representing 84% agreed that households using green energy report fewer respiratory issues, while 38 respondents representing 16% disagreed—all of which clearly confirm that a significant majority of respondents across all indicators support the adoption of green energy, thereby establishing it as a sustainable solution to environmental and infrastructural degradation in Zaria Metropolis, with public health serving as the crucial mediating factor for cleaner, healthier urban living.

Research Question Two

What is the relationship between improved water quality and sanitation and the adoption of green energy in Zaria Metropolis?

Table 2: Relationship between improved water quality and sanitation and the adoption of green energy in Zaria Metropolis.

Items	Strongly Disagree	Disagree	Agree	Strongly Agree
Poor energy supply affects the operation of water purification systems.	18 7.6%	50 21.0%	70 29.4%	100 42.0%
Solar energy can power life-saving medical equipment in clinics.	52 21.8%	21 8.8%	100 42.0%	65 27.3%
Lack of electricity affects vaccine preservation in rural hospitals.	38 16.0%	10 4.2%	160 67.2%	30 12.6%
Green energy enhances emergency response in healthcare centres.	15 6.3%	3 1.3%	70 29.4%	150 63.0%
Unreliable power disrupts medical operations and diagnosis.	18 7.6%	30 12.6%	110 46.2%	80 33.6%
The installation of solar systems improves healthcare delivery.	25 10.5%	45 18.9%	78 32.8%	1000 37.8%
Green-powered hospitals are more resilient during power outages.	8 3.2%	40 16.1%	90 36.3%	110 44.4%
Energy supply is critical to maintaining hygiene in hospitals.	25 10.5%	13 5.5%	120 50.4%	80 33.6%
Investing in green energy boosts confidence in healthcare systems.	20 8.4%	18 7.6%	160 67.2%	40 16.8%
Health workers support the use of green energy for better service delivery.	30 12.6%	8 3.4%	120 50.4%	80 33.6%

Table 2 above shows the results of the opinions on the relationship between improved water quality and sanitation and the adoption of green energy in Zaria Metropolis. 170 respondents, representing 71.4%**,** agreed that poor energy supply affects the operation of water purification systems, while 68 respondents, representing 28.6%**,** disagreed; furthermore**,** 165 respondents, representing 69.3%**,** agreed that solar energy can power life-saving medical equipment in clinics, while 73 respondents, representing 30.7%, disagreed; in addition**,** 190 respondents, representing 79.8%, agreed that lack of electricity affects vaccine preservation in rural hospitals, compared to 48 respondents, representing 20.2%**,** who disagreed; similarly**,** 220 respondents, representing 92.4%, agreed that green energy enhances emergency response in healthcare centers, while 18 respondents, representing 7.6%**,** disagreed; moreover**,** 190 respondents, representing 79.8%**,** agreed that unreliable power disrupts medical operations and diagnosis, while 48 respondents, representing 20.2%, disagreed; equally**,** 178 respondents, representing 70.6%, agreed that the installation of solar systems improves healthcare delivery, as opposed to 70 respondents, representing 29.4%, who disagreed; additionally**,** 200 respondents**,** representing 80.7%**,** agreed that green-powered hospitals are more resilient during power outages, while 48 respondents, representing 19.3%**,** disagreed; likewise**,** 200 respondents, representing 84%**,** agreed that energy supply is critical to maintaining hygiene in hospitals, compared to 38 respondents, representing 16%**,** who disagreed; similarly**,** 200 respondents, representing 84%**,** agreed that investing in green energy boosts confidence in healthcare systems, while 38 respondents**,** representing 16%, disagreed; finally**,** 200 respondents, representing 84%, agreed that health workers support the use of green energy for better service delivery, while 38 respondents, representing 16%, disagreed—all of which affirm that the majority of respondents consistently support the role of green energy in strengthening water quality, sanitation, and healthcare infrastructure. This stresses that the adoption of renewable energy not only improves service delivery but also safeguards public health, reinforcing green energy as a sustainable solution to environmental and infrastructural degradation in Zaria Metropolis, with public health acting as the mediating force in achieving long-term resilience and development.

Research Question Three

What is the relationship between enhanced healthcare infrastructure through reliable energy sources and the adoption of green energy in Zaria Metropolis?

Table 3: Relationship between enhanced healthcare infrastructure through reliable energy sources and the adoption of green energy in Zaria Metropolis.

Items	Strongly Disagree	Disagree	Agree	Strongly Agree
Many health facilities in Zaria lack reliable electricity.	18	20	70	100
	8.7%	9.6%	33.7%	48.1%
Solar energy can power life-saving medical equipment in clinics.	52	21	100	65
	21.8%	8.8%	42.0%	27.3%
Lack of electricity affects vaccine preservation in rural hospitals.	38	20	150	30
	16.0%	8.4%	63.0%	12.6%
Green energy enhances emergency response in healthcare centres.	15	13	70	140
	6.3%	5.5%	29.4%	58.8%
Green energy enhances emergency response in healthcare centres.	18	30	100	90
	7.6%	12.6%	42.0%	37.8%
The installation of solar systems improves healthcare delivery.	30	40	78	90
	12.6%	16.8%	32.8%	37.8%
Green-powered hospitals are more resilient during power outages.	30	10	98	110
	12.1%	4.0%	39.5%	44.4%
Energy supply is critical to maintaining hygiene in hospitals.	25	13	110	90
	10.5%	5.5%	46.2%	37.8%
Investing in green energy boosts confidence in healthcare systems.	28	10	150	50
	11.8%	4.2%	63.0%	21.0%
Health workers support the use of green energy for better service delivery.	8	30	155	75
	3.0%	11.2%	57.8%	28.0%

Field survey 2025

Table 3 above shows the results of the opinions on the relationship between improved water quality and sanitation and the adoption of green energy in Zaria Metropolis. 170 respondents representing 81.8% agreed that many health facilities in Zaria lack reliable electricity, while 38 respondents representing 18.3% disagreed; furthermore, 165 respondents representing 69.3% agreed that solar energy can power life-saving medical equipment in clinics, while 73 respondents representing 30.7%; in addition, 180 respondents representing representing 75.6% agreed that lack of electricity affects vaccine preservation in rural hospitals, compared to 58 respondents representing 24.4% who disagreed; similarly, 210 respondents representing 88.2% agreed that green energy enhances emergency response in healthcare centers, while 28 respondents representing 11.8% disagreed; moreover, in another closely related item, 190 respondents representing 79.8% agreed again that green energy enhances emergency healthcare response, while 48 respondents representing 20.2% disagreed—reinforcing the earlier claim; equally, 168 respondents representing 70.6% agreed that the installation of solar systems improves healthcare delivery, as opposed to 70 respondents representing 29.4% who disagreed; additionally, 208 respondents representing 83.9% agreed that green-powered hospitals are more resilient during power outages, while only 40 respondents representing 16.1% disagreed; likewise, 200 respondents representing 84% agreed that energy supply is critical to maintaining hygiene in hospitals, whereas 38 respondents representing 16% disagreed; similarly, 200 respondents representing agreed that investing in green energy boosts confidence in the healthcare system, while 38 respondents representing 16% disagreed; finally, 230 respondents representing 85.8% agreed that health workers support the use of green energy for better service delivery, while 38 respondents representing 14.2% disagreed—all of which strongly indicate that the vast majority of respondents recognize the critical role of green energy in enhancing water, sanitation, and healthcare delivery, thereby confirming that green energy adoption not only addresses infrastructural deficiencies but also promotes a resilient public health system in Zaria Metropolis, making it a sustainable solution to both environmental and infrastructural degradation through the mediating role of public health.

Hypotheses Testing

Hypothesis One

There is no significant relationship between the reduction of airborne respiratory pollutants and the adoption of green energy in Zaria Metropolis.

Table 4: Correlation Analysis between the reduction of airborne respiratory pollutants and the adoption of green energy in Zaria Metropolis.

Variables	N	Mean	SD	r	p-value	Remark
Green Energy	248	3.7581	1.216			
				0.728	0.000	Significant
Reduction of Airborne	248	3.6089	1.507			

Table 4 presents the correlation analysis between the reduction of airborne respiratory pollutants and the adoption of green energy in Zaria Metropolis. Data from 248 respondents revealed mean scores of 3.7581 (SD = 1.216) for green energy adoption and 3.6089 (SD = 1.507) for reduction of airborne pollutants. The Pearson correlation coefficient (r) is 0.728, which indicates a strong positive relationship between the two variables. The p-value of 0.000 is far below the 0.05 level of significance,

confirming that the relationship is statistically significant and unlikely to have occurred by chance. This means that as green energy adoption increases, the reduction of airborne respiratory pollutants improves significantly. Consequently, the null hypothesis, which states that there is no significant relationship between green energy adoption and the reduction of airborne pollutants, is rejected. The result underscores the vital role of renewable energy in mitigating air pollution and improving respiratory health outcomes in Zaria Metropolis.

Hypothesis Two

There is no significant relationship between improved water quality and sanitation and the adoption of green energy in Zaria Metropolis.

Table 5. Correlation Analysis between improved water quality and sanitation and the adoption of green energy in Zaria Metropolis.

Variables	N	Mean	SD	r	p-value	Remark
Green Energy	248	3.7581	1.216			
				0.517	0.001	Significant
Water Quality	248	3.6331	1.416			

Table 5 presents the correlation analysis between improved water quality and sanitation and the adoption of green energy in Zaria Metropolis. A total of 248 respondents were included in the study, with mean scores of 3.7581 (SD = 1.216) for green energy adoption and 3.6331 (SD = 1.416) for improved water quality and sanitation. The Pearson Product-Moment Correlation coefficient (r) between the two variables is 0.517, indicating a moderate positive relationship. The p-value of 0.001 is less than the 0.05 significance level, showing that the relationship is statistically significant. This implies that the observed correlation is unlikely to have occurred by chance. Consequently, the null hypothesis, which states that there is no significant relationship between the adoption of green energy and improvements in water quality and sanitation, is rejected. The result demonstrates that increased adoption of green energy is positively associated with better water supply and sanitation outcomes, highlighting the role of renewable energy in enhancing public health in Zaria.

Hypothesis Three

There is no significant relationship between enhanced healthcare infrastructure through reliable energy sources and the adoption of green energy in Zaria Metropolis.

Table 6: Correlation Analysis between enhanced healthcare infrastructure through reliable energy sources and the adoption of green energy in Zaria Metropolis.

Variables	N	Mean	SD	r	p-value	Remark
Green Energy	248	3.7581	1.216			
				0.771	0.000	Significant
Enhancement of healthcare infrastructure	248	3.6290	1.419			

Table 6 results represent a strong and statistically significant positive correlation between enhanced healthcare infrastructure through reliable energy sources and the adoption of green energy in Zaria Metropolis ($r = 0.771$, $p < 0.001$). The p-value being well below 0.05 indicates that this relationship is highly significant, suggesting that the observed association is not due to chance. Therefore, the null hypothesis, which states that there is no significant relationship between these variables, is rejected. This finding shows that improvements in healthcare infrastructure are closely associated with the adoption of green energy solutions, such as solar power, which ensure a consistent and reliable energy supply. The high correlation demonstrates that as healthcare facilities increasingly utilise renewable energy, their operational efficiency, service delivery, and resilience are significantly enhanced. Thus, reliable green energy plays a crucial role in strengthening healthcare systems in Zaria, emphasising its importance for sustainable and effective healthcare delivery.

Discussion of findings

The findings of this study establish a statistically significant relationship between green energy adoption and public health improvements—specifically in air quality, water and sanitation, and healthcare—in Zaria Metropolis. Table 4 reveals a strong positive correlation ($r = 0.728$, $p < 0.001$) between green energy and the reduction of airborne respiratory pollutants, aligning with Ahmed et al. (2022) and Aliyu & Botai (2018), who highlighted the health risks from fossil fuel emissions. Similarly, Dawah (2016) and Miriam et al. (2024) documented respiratory health improvements in solar-powered communities, with Table 1 showing 70% public agreement that green energy reduces air pollution, especially for children. Table 5 reveals a moderate correlation ($r = 0.517$, $p = 0.010$) between improved water quality and green energy, confirming Isma'il (2016) and Dabo et al. (2024), who reported success using solar-powered boreholes. Only 43% of Zaria residents access potable water (National Bureau of Statistics, 2020), and over 80% of respondents in Table 2 affirmed green energy's role in improving water and sanitation. Sharma et al. (2025) and Dhayal et al. (2024) stressed its hygiene benefits in fragile environments. Table 6 reports the strongest correlation ($r = 0.771$, $p < 0.001$) between green energy and improved healthcare delivery. Nwankwo et al. (2021) and Médecins Sans Frontières (2025) affirmed that solar power enhances emergency care. Over 84% in Table 3 agreed on its transformative health role. However, Okoro and Yusuf (2020) cautioned that without institutional support and energy governance, impacts may not last. Thus, systemic, policy-driven frameworks are essential for sustainable health and urban development outcomes.

Conclusion

This study critically examined the role of green energy as a sustainable solution to environmental and infrastructural

degradation in Zaria Metropolis, with public health serving as the central mediating factor. Across all three research questions and hypotheses, findings revealed strong and statistically significant correlations between green energy adoption and key public health outcomes—namely, the reduction of airborne respiratory pollutants, improved water quality and sanitation, and the enhancement of healthcare infrastructure. Empirical data from survey responses and correlation analyses (Tables 1–6) consistently showed high levels of public agreement, confirming that green energy adoption positively influences air quality, reduces respiratory illnesses, strengthens water systems, and enables resilient healthcare delivery. These findings align with a broad body of literature (e.g., Ahmed et al., 2022; Isma'il, 2016; Nwankwo et al., 2021; Médecins Sans Frontières, 2025) that documents how solar-powered technologies enhance public health outcomes and service efficiency in underserved regions. Although some scholars (e.g., Okoro & Yusuf, 2020) have raised concerns about the long-term sustainability of green energy projects in the absence of maintenance and policy frameworks, this study underscores the transformative potential of renewable energy when embedded within well-supported, policy-driven, and community-backed systems. Ultimately, the study concludes that green energy is not merely an environmental innovation but a vital instrument for public health improvement and infrastructure resilience, making it imperative for policy planners, health authorities, and development stakeholders to prioritise renewable energy integration in urban development strategies to achieve sustainable and inclusive growth in Zaria Metropolis.

Recommendations

1. Government and stakeholders should prioritise investment in renewable energy infrastructure, particularly solar, to address energy gaps in health and sanitation services.
2. Public awareness campaigns on the health benefits of green energy should be intensified to increase community adoption and behavioural change.
3. Integrating energy education into community and school programs can promote long-term sustainability and digital literacy.

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