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Impact of Energy Poverty on Provision of Quality Education: Evidence from Selected Schools in Urban Zambia

Authors

Maona Mukanema [(1)]; Isaac N. Simate [(2)]; Stephen Mbimbi [(3)]

Main author email: maona.mukanema@unza.zm

(1.2.3) University of Zambia, Zambia.

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Abstract

This study investigates how energy poverty impacts the provision of quality education in secondary schools across Lusaka and Kitwe districts of Zambia. A mixed-methods approach was employed, drawing a sample of 850 respondents, including students, teachers, head teachers, parents, and education officials. Results reveal that although 75 per cent of households and 95 per cent of schools are connected to the national grid, electricity supply is highly unreliable, with 54 per cent of households receiving only 0-4 hours of power daily and 77.6 per cent experiencing daily load-shedding. Quantitative analysis showed significant associations between energy access and educational outcomes. Limited electricity hours were associated with lower academic performance ($\chi^2 = 32.47$, $p < 0.001$), whereas grid connectivity strongly influenced night study practices. Frequent load-shedding significantly disrupted homework completion ($\chi^2 = 27.23$, $p < 0.001$), and school-level outages directly impaired lesson continuity ($\chi^2 = 18.57$, $p < 0.001$). Crucially, schools with backup energy sources reported higher teacher ratings of education quality. The findings underscore that unreliable and unaffordable electricity critically undermines study time, ICT integration, and curriculum delivery. This study contributes to policy and scholarship by empirically highlighting that in urban Zambian contexts, energy reliability, not just connection, is a fundamental determinant of educational quality, necessitating integrated energy-education strategies to achieve Sustainable Development Goals 4 (Quality Education) and 7 (Affordable and Clean Energy).

Key terms: Energy poverty, energy reliability, learning outcomes, quality education, Zambia.

INTRODUCTION

Access to reliable and affordable energy is widely acknowledged as a cornerstone of sustainable development and a critical driver of quality education. In Zambia, however, energy poverty remains a pressing challenge, even in urban areas, where schools and households are connected to the national grid but continue to experience frequent load shedding, unstable supply, and rising electricity costs. These energy constraints negatively affect the teaching and learning process by disrupting classroom instruction, limiting the functionality and use of essential learning facilities, and reducing students' capacity to study after school hours. The use of contemporary teaching strategies and digital resources, which are becoming increasingly essential to high-quality education, is also hampered by the energy shortage. If not addressed, many learners risk receiving an education of compromised quality, leaving them inadequately prepared for higher education or meaningful participation in their communities.

Access to quality education is widely recognised as both a fundamental human right and a cornerstone of sustainable development (UNESCO, 2015). Quality education goes beyond access to schooling and focuses on the effectiveness, equity, and relevance of the learning process. UNICEF (2000) defines quality education as one that ensures learners acquire foundational literacy, numeracy, and life skills within supportive and inclusive environments. UNESCO (2017) expands this by emphasising learner-centred approaches, adequate resources, trained teachers, and safe learning conditions as key to achieving meaningful learning outcomes. The quality of education in Zambia remains a concern, with many learners failing to reach the 40 per cent pass mark (UNICEF Zambia, 2025). Although secondary education has been prioritised in Zambia's development agenda and free education has been introduced up to secondary level, the benefits are undermined by persistent infrastructure and energy-related challenges (GRZ, 2023). Transition to secondary school is limited to 63 per cent due to space shortages, and only 46.8 per cent of secondary learners progress to tertiary education (UNICEF Zambia, 2025).

In Zambia, education plays a critical role in advancing national development and human capital formation; however, its effective delivery faces persistent challenges, among them energy poverty, which is increasingly significant. Energy poverty is a worldwide issue that poses a significant challenge to development efforts in both developed and developing countries, negatively affecting the well-being of millions of people, and causing several hundred thousand excess deaths per year worldwide (Guevara et al., 2023). Energy poverty is the inability to access sufficient, reliable, and affordable energy services necessary for basic needs such as cooking and lighting, impacting economic and human development (Simcock, 2020). However, energy poverty in developing countries refers to a lack of access to modern energy sources, which are needed to provide modern energy services (Abdoulaye Sy & Mokaddem, 2022).

In Zambia, energy poverty remains a pressing challenge, with only 53.6 per cent of households nationwide having access to electricity. This problem is most noticeable in rural areas, where electricity rates are only 34 per cent, whereas in urban areas, they have 80.3 per cent. Regional patterns show that Lusaka Province has the highest access rate at 84.8 per cent, followed by the Copperbelt at 81.7 per cent and Central Province at 59.9 per cent, respectively. Northern and Western provinces accounted for the least percentage shares of households with access to electricity at 33.0 and 24.8 per cent, respectively (Zambia Statistics Agency, 2023). This issue must be resolved to promote inclusive growth and ensure that every Zambian child has the chance to achieve academic success. Without power, schools are unable to provide basic amenities such as internet access, lighting, and contemporary teaching aids, all of which are critical in today's educational environment. Additionally, learners from households without electricity have limited study hours since they have to use conventional, inefficient light sources like kerosene lamps or natural light (UNDESA, 2014).

Achieving sustainable development in Zambia requires recognising the critical link between energy poverty and education. Reliable electricity access has the potential to transform learning environments by enabling longer study hours, supporting the integration of digital learning resources, and strengthening school infrastructure (UNESCO, 2017;

UNICEF, 2020). Electrification initiatives, particularly in underserved communities, can play a pivotal role in narrowing educational opportunity gaps. Expanding investments in renewable energy solutions, such as solar mini-grids for schools and households, offers a pathway to equitable and sustainable access (IEA, 2022; World Bank, 2020). Addressing energy poverty not only enhances educational outcomes but also contributes to broader development goals, including poverty reduction, gender equity, and social inclusion (UNDP, 2016; UNICEF Zambia, 2024).

Despite the acknowledged link between energy and education, a critical empirical gap exists in Zambia regarding how energy poverty, specifically unreliable supply in urban areas, directly impacts daily educational processes. This study addresses that gap by investigating the multifaceted effects of energy poverty on quality education in selected secondary schools in Lusaka and Kitwe. Grounded in the Capability Approach and Human Capital Theory, it specifically investigates the relationship between household energy access and students' learning outcomes, the impact of school-level energy access and reliability on the provision of quality education and identifies coping strategies and stakeholder perceptions on how energy poverty affects education.

LITERATURE REVIEW

Conceptualising Energy Poverty and Its Multidimensionality

The concept of energy poverty has evolved from a binary focus on physical access to a multidimensional understanding of affordability, reliability, and health safety (Bouzarovski & Petrova, 2015). In developing contexts, it is often characterised by a reliance on solid biomass fuels and an inability to secure modern energy services necessary for basic well-being (Simcock, 2020). Recent scholarship emphasises that mere grid connection does not equate to energy security, as unreliable supply and unaffordable tariffs can trap households in a state of "connected poverty" (Guevara et al., 2023). In Zambia, while national electrification rates remain low, urban areas exhibit high connection rates juxtaposed with severe reliability deficits, a paradox that underscores the need to measure poverty through the lens of service quality rather than infrastructure presence (Zambia Statistics Agency, 2023). This study adopts this multidimensional conceptualisation, focusing on the unreliability and unaffordability of electricity in connected urban households and schools.

Energy Access and Educational Outcomes: The Established Link

A robust body of literature establishes a positive correlation between electrification and key educational metrics. At the macro level, energy access is linked to national development indicators, including school enrolment and literacy rates (World Bank, 2020). The theoretical link is often explained through Human Capital Theory (Becker, 1964), where education is an investment whose returns depend on complementary inputs, such as energy. Electrification is shown to extend study hours through lighting, enable the use of digital learning tools, and improve school infrastructure (UNESCO, 2017; Banerjee et al., 2021). Furthermore, Sen's Capability Approach (1999) provides a normative framework, positing that reliable energy expands individuals' substantive freedoms and capabilities, such as the ability to study effectively or teach using modern methods. Systematic reviews, such as Katoch et al. (2024), consolidate evidence confirming that energy deprivation consistently constrains access to quality learning opportunities, particularly in Sub-Saharan Africa.

The Urban Reliability Gap in Education

While the rural access deficit is well documented, a significant scholarly gap exists regarding the urban experience of energy poverty. Research often overlooks the challenges in already-connected urban and peri-urban areas, where frequent load shedding and high costs undermine the potential benefits of grid access (IEA, 2022). Studies specific to Zambia, such as Umar et al. (2024) on load-shedding in Kitwe, detail its disruptive impact on household economies and daily routines, hinting at but not explicitly measuring educational consequences. Similarly, research on household energy choices in Lusaka confirms the socioeconomic persistence of charcoal, highlighting affordability as a key barrier to cleaner, more efficient alternatives (Mukanema et al., 2025). This indicates that urban households face a dual burden: they are connected but receive poor service, forcing them into costly coping strategies that compete with educational expenses. The specific translation of this urban energy insecurity into compromised school-level processes such as lesson continuity, ICT integration, and science practicals remains underexplored.

Bridging the Micro-Level Research Gap

The existing literature convincingly establishes a macro-correlation but often lacks granularity into the causal mechanisms at the household and school levels. There is limited empirical research that simultaneously examines how specific dimensions of energy poverty, such as daily supply hours, outage frequency, and cost, directly shape micro-level educational variables such as homework completion, self-study time, teacher instructional efficacy, and student self-rated performance (Sule et al., 2022). Furthermore, while coping strategies are acknowledged, few studies systematically document and analyse the adaptive behaviours of schools and families, nor do they link these strategies to perceived educational quality. This study directly addresses these gaps. It moves beyond the rural/access binary to investigate the urban reliability crisis in Lusaka and Kitwe.

Theoretical Underpinning

This study is theoretically anchored in the Capability Approach and Human Capital Theory, which together provide a causal framework for analysing how energy poverty constrains educational quality. The Capability Approach (Sen, 1999) frames reliable energy access as a fundamental conversion factor that determines individuals' substantive freedoms. It directly informs this study by positing that energy poverty diminishes the capability for extended study time and restricts access to digital resources, thereby shrinking the set of achievable academic functioning (performance). At the institutional level, it conceptualises school quality as dependent on the collective capability to deliver practical and ICT-integrated lessons, a capability contingent on reliable power.

Complementarily, Human Capital Theory (Becker, 1964) treats education as an investment and reliable energy as a critical complementary input in the educational production function. This theory explicitly links energy access to the efficiency of this investment. It interprets inadequate study time as a reduced investment due to higher personal costs, leading directly to lower academic performance, a proxy for accumulated human capital. Furthermore, it frames school quality as institutional productivity, which is systematically degraded by power outages that disrupt core inputs, such as teaching continuity and laboratory use. Synthesised, these theories posit that energy poverty, by constraining capabilities and raising the cost of educational investments, directly undermines human capital formation and perpetuates inequality.

METHODOLOGY

This study employed a parallel convergent mixed-methods design, integrating quantitative and qualitative techniques to both quantify the problem and capture lived experiences. The research was conducted in selected urban and peri-urban secondary schools across the Lusaka and Kitwe districts in Zambia. A representative sample of 850 respondents was drawn from a target population of approximately 1,000 individuals, including 520 students, 100 teachers, 20 head teachers, 200 parents/guardians, and 10 district education officials. Sampling used a two-stage stratified cluster design, with schools stratified by district, location, and energy reliability profile; respondents were then selected through random, purposive, and linked sampling.

Quantitative data were analysed using both descriptive and inferential statistical techniques with the aid of the Statistical Package for the Social Sciences (SPSS) version 26. Descriptive statistics, such as frequencies and percentages, were used to summarise the data. In contrast, inferential statistics, specifically chi-square tests of independence, were employed to examine relationships between categorical variables, such as electricity supply duration and academic performance**.** Qualitative data were analysed thematically using NVivo software to code and identify emerging patterns and themes from interview transcripts and open-ended responses. Thematic analysis was chosen for its suitability in providing rich, contextual insights into stakeholder experiences, perceptions, and coping strategies regarding energy reliability. The University of Zambia granted ethical clearance. Voluntary informed consent and assent (with parental consent for minors) were secured. Confidentiality was strictly maintained, data were stored securely, and participants were free to withdraw without consequence.

FINDINGS AND DISCUSSION

Socio-Demographic profile

The study sample comprised 850 respondents from secondary schools in Lusaka and Kitwe districts. This included 520 students, 100 teachers, 20 head teachers, 200 parents or guardians, and 10 District Education Board (DEBS) officials. Among students, gender distribution was nearly balanced (52% male, 48% female), with the majority aged 15-18 years (84.6%). Teachers were also fairly balanced by gender (55% male, 45% female), with most holding professional qualifications, particularly diplomas (57%) and degrees (38%). At the household level, while 75 per cent of respondents reported being connected to the national grid, supply reliability was poor: 54 per cent had electricity for only 0-4 hours daily, and 77.6 per cent experienced daily load-shedding. These energy challenges were reflected in student outcomes, with only 10 per cent of learners rating their academic performance as excellent, 40 per cent as good, and the majority clustered in the average (35%) and poor (15%) categories. Table 1 presents a summary of the socio-demographic profile.

Table 1: Socio-Demographic profile

Variable	Category	Frequency (n)	Percentage (%)
Gender of Students	Male	270	52.0
	Female	250	48.0
Age of Students (Years)	13-14	80	15.4
	15-16	230	44.2
	17-18	210	40.4
Teachers' Gender	Male	55	55.0
	Female	45	45.0
Highest Teacher Qualification	Certificate	3	3.0
	Diploma	57	57.0
	Degree	38	38.0
	Postgraduate	2	2.0
Household Connection to Grid	Yes	570	75.0
	No	190	25.0
Daily Hours of Electricity	0-4 hrs	410	54.0
	5-8 hrs	230	30.3
	9-12 hrs	90	11.8
	>12 hrs	30	3.9
Load-Shedding Frequency	Daily	590	77.6
	Several times/week	130	17.1
	Once a week	30	3.9
	Rarely/Never	10	1.4
Self-rated Academic Performance	Excellent	52	10.0
	Good	208	40.0
	Average	182	35.0
	Poor	78	15.0

(Source: Field data, 2025)

Household and School Energy Access

Figures 1and 2 show that although 70% of households use grid electricity for lighting, frequent load-shedding compels many to adopt alternatives such as solar (15%) and candles/paraffin (10%), with a small proportion (5%) relying on generators This reliance on a fragmented energy mix, where households juggle grid power with supplementary and often inferior sources, is a classic indicator of energy poverty in settings where supply is unreliable despite physical connectivity (Bouzarovski & Petrova, 2015). This indicates that while connection rates are relatively high, reliability remains a major challenge, limiting students' ability to study at night and forcing households to resort to unsafe or costly coping strategies. These findings align with Sule et al. (2022), who observed that in Sub-Saharan Africa, energy poverty, characterised by unreliable supply rather than a complete lack of access, is a primary driver of educational inequality.

In terms of cooking energy, charcoal remains the dominant fuel, accounting for 66% of household use, followed by LPG (20%), electricity (10%), and firewood (4%). This persistent reliance on biomass in an urban setting aligns with findings by Mukanema et al. (2025), who identified socioeconomic determinants such as household income and size as primary drivers of charcoal dependence in Mtendere, Lusaka. This pattern underscores a dual challenge: the unaffordability and unreliability of grid electricity for thermal needs, coupled with the entrenched accessibility of charcoal. The notable, though still secondary, use of LPG points to a gradual transition toward cleaner fuels among middle-income households. These observations are consistent with broader analyses of urban Zambian energy markets, which attribute the resilience of charcoal to the prohibitive cost and inconsistent supply of modern alternatives (Mulima et al., 2025; Mukanema & Chiguvi, 2025).

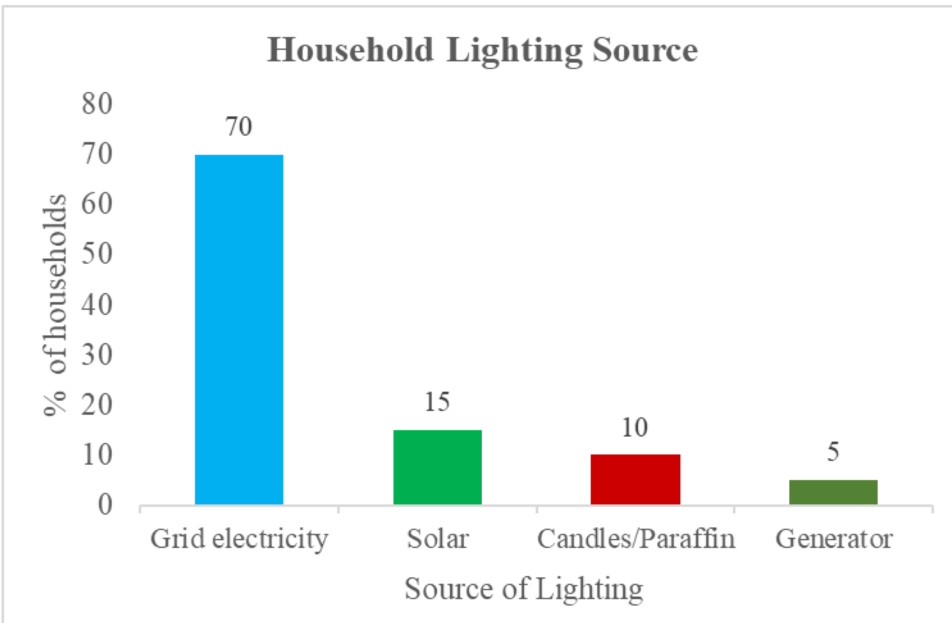

Figure 1: Household Lighting Source

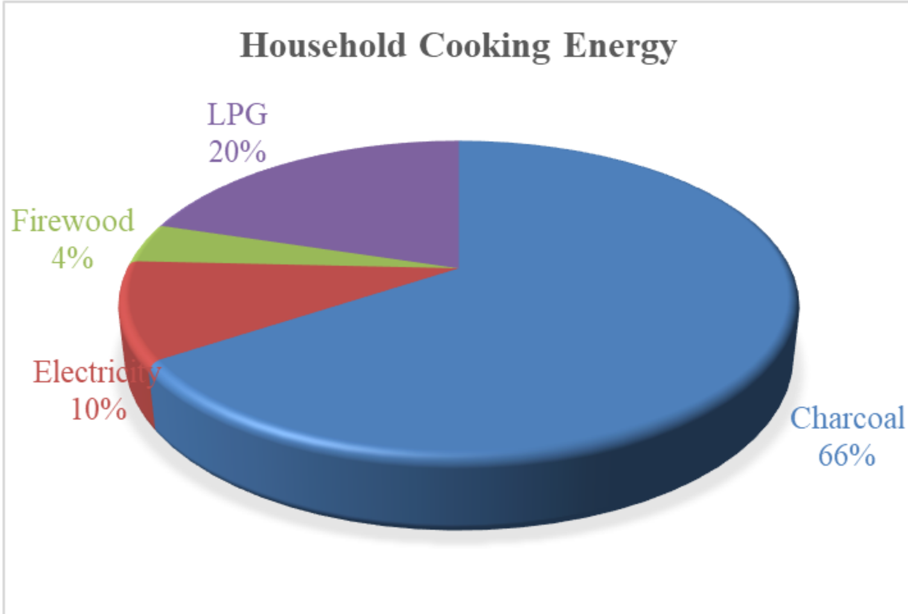

Figure 2: Household Cooking Energy

Figure 3 shows that although 75 per cent of households and 95 per cent of schools in Lusaka and Kitwe are connected to the national grid, access does not translate into reliability: 54 per cent of households report only 0-4 hours of electricity daily, and 78 per cent experience daily load-shedding. Energy costs also exert pressure, with 65 per cent of households reporting that electricity expenses affect their ability to afford essentials such as school fees and books. These findings resonate with Nussbaumer et al. (2012), who highlight how energy affordability forces difficult trade-offs in household budgets, often at the expense of education. At the school level, only 20 per cent have solar or generator backup, leaving the majority vulnerable to frequent outages, 65 per cent of which occur during teaching hours. As a result, 80 per cent of ICT labs, 70 per cent of science labs, 50 per cent of libraries, and 90 per cent of classroom lighting are negatively affected, with 75 per cent of schools reporting disrupted or cancelled lessons. Collectively, these findings show that while grid connection is relatively high, unreliable and unaffordable energy supply severely undermines study time, homework completion, ICT integration, and science learning, thereby diminishing the overall provision of quality education. This critical gap between connectivity and reliable service underscores what Banerjee et al. (2021) identify as a key limitation of development metrics: physical access often masks a deeper crisis of quality and affordability that constrains human capital outcomes.

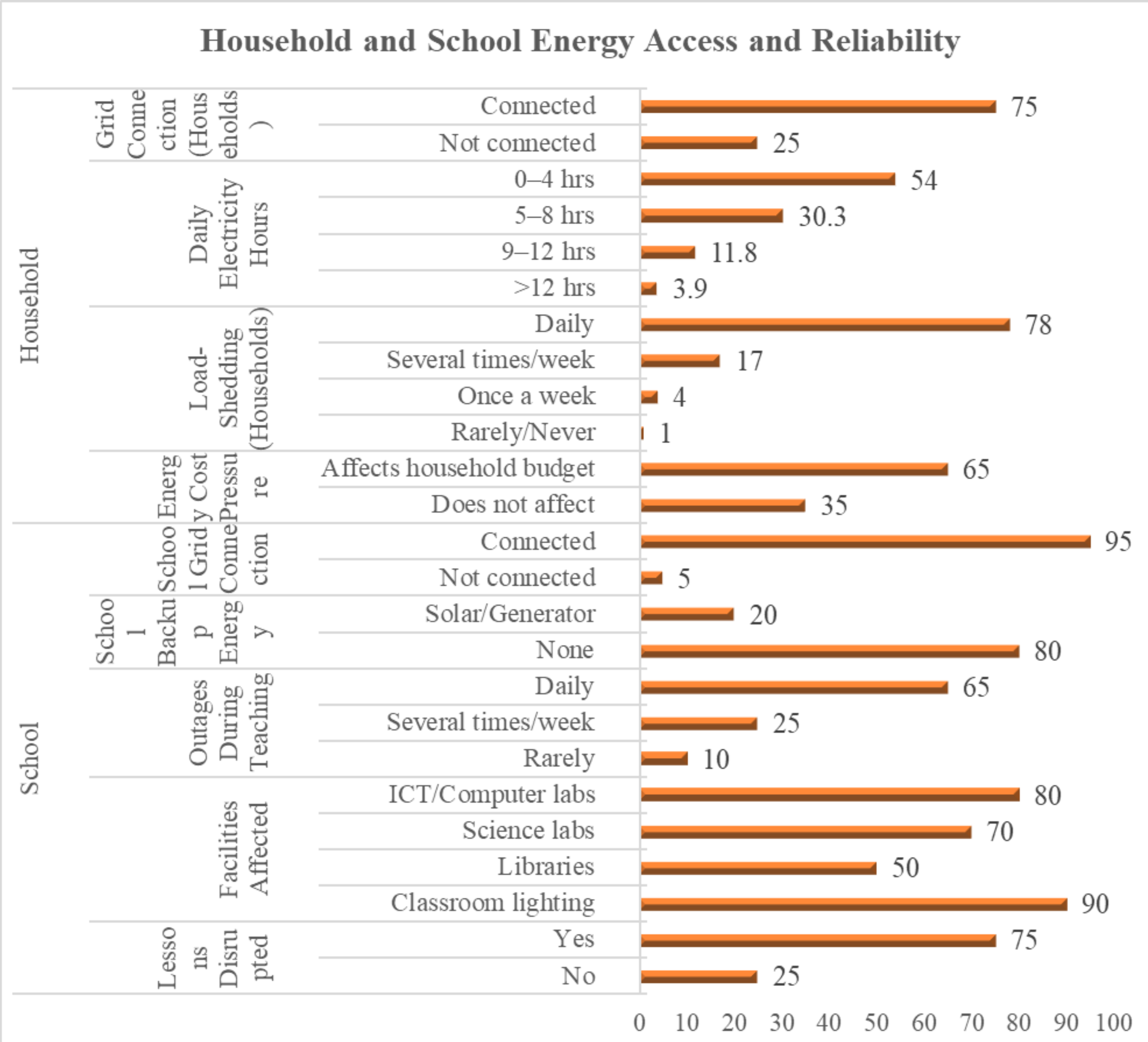

Figure 3: Household and School Energy Access and Reliability

Provision of Quality Education

Figure 4 shows that most students study for limited hours at home, with about 40 per cent studying less than one hour and 35 per cent between one and two hours daily, while only a small minority study more than three hours. Around two-thirds of students reported studying at night, yet their ability to do so depends heavily on energy access: 45 per cent rely on grid electricity, 30 per cent use solar lamps, and 25 per cent use candles or paraffin, which are unsafe and less effective. ICT access remains very low, with nearly 80 per cent of students reporting no computer or tablet at home, reinforcing the digital divide. Homework completion is also negatively affected by energy shortages, with 55 per cent of students sometimes and 35 per cent often experiencing disruptions due to power outages. Consequently, academic performance is modest, with most students rating themselves as average (40%) or good (35%), while only 10% rated themselves excellent, suggesting that energy poverty is a major factor limiting higher achievement.

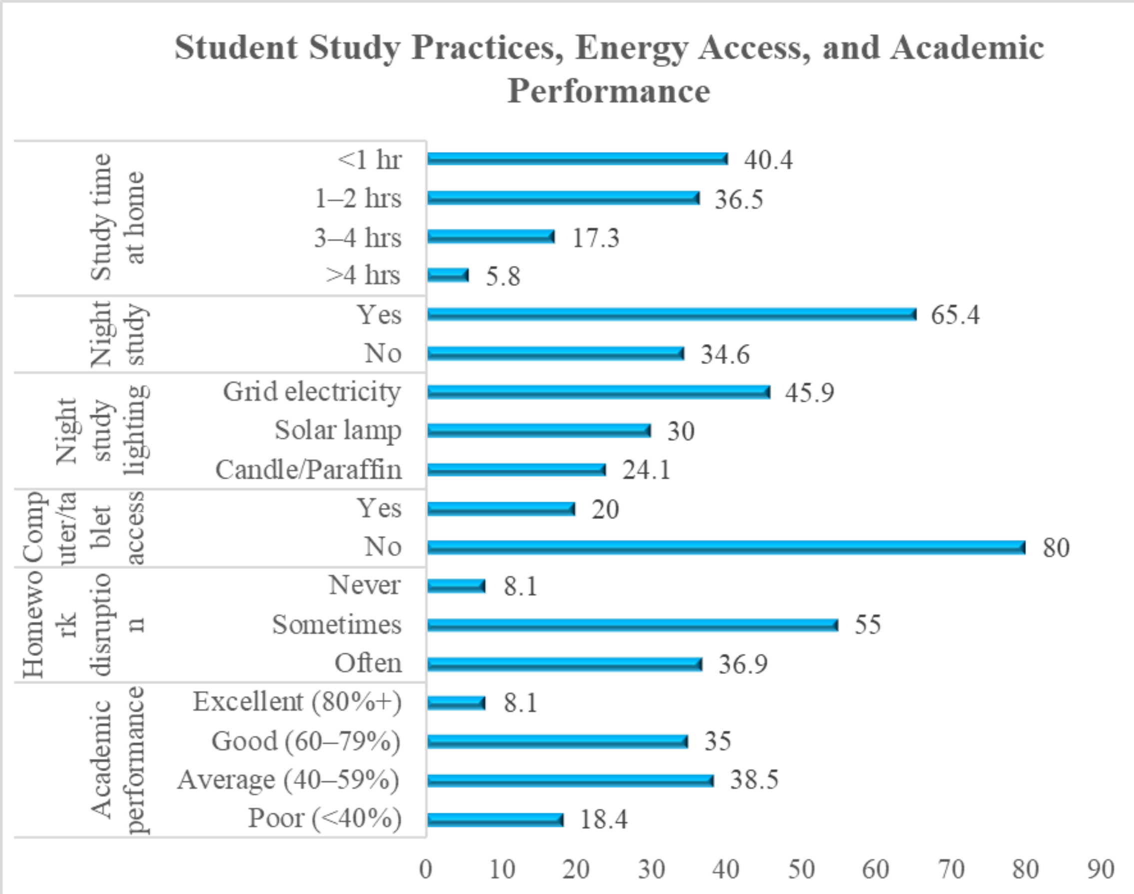

Figure 4: Student Study Practices, Energy Access, and Academic Performance

Association Between Household Electricity Supply Duration and Student Academic Performance

The analysis found a statistically significant relationship between the number of electricity supply hours available to households and students' academic performance ($\chi^2 = 32.47$, $df = 9$, $p < 0.001$). Table 2 shows that students from households with 0-4 hours of daily electricity were predominantly in the poor (29.3%) and average (43.9%) performance categories. This finding is consistent with the empirical evidence from Banerjee et al. (2021), who found that energy poverty significantly constrains educational achievement across countries. In contrast, students with more than 9 hours of daily electricity were more likely to report good (42.2%) or excellent (40%) academic outcomes. This positive gradient aligns with the findings of Khandker et al. (2013), who reported a strong, dose-dependent relationship between the quality of household electricity access and improved educational performance. This pattern suggests that limited electricity availability constrains study time, access to lighting, and ICT use, leading to poorer educational outcomes. Conversely, students with longer supply hours benefit from extended study opportunities and better academic attainment.

Table 2: Household Electricity Supply Duration and Student Academic Performance

Electricity Hours	Poor (<40%)	Average (40-59%)	Good (60-79%)	Excellent (80%+)	Total
0-4 hrs (n=410)	120 (29.3%)	180 (43.9%)	95 (23.2%)	15 (3.6%)	410 (100%)
5-8 hrs (n=230)	40 (17.4%)	90 (39.1%)	80 (34.8%)	20 (8.7%)	230 (100%)
9-12 hrs (n=90)	12 (13.3%)	28 (31.1%)	38 (42.2%)	12 (13.3%)	90 (100%)
>12 hrs (n=30)	2 (6.7%)	7 (23.3%)	9 (30.0%)	12 (40.0%)	30 (100%)
Total (n=760)	174 (22.9%)	305 (40.1%)	222 (29.2%)	59 (7.8%)	760
Chi-Square Test: χ^2 (9) = 32.47, $p < 0.001$					

Relationship Between Household Grid Connectivity and Night Study Practices Among Students

A strong and significant association was found between household grid connection and students' ability to study at night ($\chi^2 = 15.81$, df = 1, $p < 0.001$). As shown in Table 3, 80 per cent of students from grid-connected households reported engaging in night study compared to only 40 per cent from non-connected households. This highlights the critical role of electricity access in enabling consistent study habits. This finding emphasises the critical role of electricity access in enabling consistent study habits. Students without grid access are at a clear disadvantage, as they rely on candles, torches, or solar alternatives, which may not provide adequate lighting or study conditions.

Table 3: Household Grid Connectivity and Night Study Practices Among Students

Grid Connection	Yes (Night Study)	No (Night Study)	Total
Connected (n=570)	456 (80.0%)	114 (20.0%)	570 (100%)
Not connected (n=190)	76 (40.0%)	114 (60.0%)	190 (100%)
Total (n=760)	532 (70.0%)	228 (30.0%)	760
Chi-Square Test: χ^2 (1) = 5.81, $p < 0.001$			

Impact of Load-Shedding Frequency on Homework Completion Among Secondary School Students

The results in Table 4 show a significant association between load-shedding frequency and homework disruption ($\chi^2 = 27.23$, df = 6, $p < 0.001$). Students in households experiencing daily load shedding were most negatively affected, with 60.3% reporting frequent homework disruptions. By contrast, in households where load-shedding occurred rarely or never, 50 per cent of students reported that homework was never disrupted. This localised evidence of load-shedding's disruptive impact on domestic routines aligns with findings by Bwalya Umar et al. (2022), whose study in Kitwe detailed the profound effects of power outages on household stability and daily activities. This demonstrates that frequent power cuts directly undermine students' ability to complete assignments and maintain academic consistency, further reinforcing the link between energy poverty and poor education outcomes.

Table 4: Impact of Load-Shedding Frequency on Homework Completion Among Secondary School Students

Load-Shedding Frequency	Never Disrupted	Sometimes	Often	Total
Daily (n=590)	24 (4.1%)	210 (35.6%)	356 (60.3%)	590 (100%)
Several times/week (n=130)	14 (10.8%)	86 (66.2%)	30 (23.0%)	130 (100%)
Once a week (n=30)	4 (13.3%)	18 (60.0%)	8 (26.7%)	30 (100%)
Rarely/Never (n=10)	5 (50.0%)	5 (50.0%)	0 (0.0%)	10 (100%)
Total (n=760)	47 (6.2%)	319 (42.0%)	394 (51.8%)	760
Chi-Square Test: χ^2 (6) = 27.23, p < 0.001				

Effect of School Power Outages on Lesson Delivery and Continuity

There was also a strong and significant association between the frequency of school power outages and lesson disruption ($\chi^2 = 18.57$, df = 2, $p < 0.001$). Schools experiencing daily outages reported lesson disruption in 92.3 per cent of cases, compared to 60 per cent in schools with weekly outages and none in schools with rare outages. These results corroborate established evidence that energy poverty is a key driver of educational disparity in the region (Sule et al., 2022) and systematically erodes the foundation for quality learning (Katoch et al., 2024). Table 5 shows that electricity shortages at the institutional level impair the delivery of education by forcing teachers to cancel or postpone lessons, particularly those that depend on electricity, such as ICT and science practicals.

Table 5: Effect of School Power Outages on Lesson Delivery and Continuity

Outage Frequency	Lessons Disrupted (Yes)	Not Disrupted (No)	Total
Daily (n=13 schools)	12 (92.3%)	1 (7.7%)	13 (100%)
Weekly (n=5 schools)	3 (60.0%)	2 (40.0%)	5 (100%)
Rarely (n=2 schools)	0 (0.0%)	2 (100.0%)	2 (100%)
Total (n=20)	15 (75.0%)	5 (25.0%)	20
Chi-Square Test: χ^2 (2) = 18.57, p < 0.001			

Influence of Backup Energy Availability on Teacher Perceptions of Education Quality

Table 6 shows that the availability of backup energy (solar/generator) in schools was significantly associated with teacher ratings of education quality ($\chi^2 = 10.92$, df = 3, $p = 0.012$). Schools with backup energy reported a much higher share of good and very good quality ratings (75%) compared to schools without backup (37.5%). This indicates that investment in alternative energy solutions not only cushions schools against unreliable grid supply but also enhances teachers' perceptions of the overall quality of education being provided. This finding resonates with Chanda et al. (2025), who emphasised the transformative potential of grassroots solar energy adoption in Zambia.

Table 6: Influence of Backup Energy Availability on Teacher Perceptions of Education Quality

Backup Energy	Poor/Fair	Good/Very Good	Total
Available (n=4)	1 (25.0%)	3 (75.0%)	4 (100%)
None (n=16)	10 (62.5%)	6 (37.5%)	16 (100%)
Total (n=20)	11 (55.0%)	9 (45.0%)	20
Chi-Square Test: $\chi^2(3) = 10.92$, $p = 0.012$			

Qualitative Analysis

Study Time and Household Energy Access

This theme explored how household electricity availability influenced study hours and homework completion. Many respondents noted that unreliable electricity shortened study time and forced them to rely on candles or solar lamps. Key quotes include:

> *S3: "When power goes, I just sleep early instead of revising."*
> *P2: "We can't afford a generator, so my children use candles when there's load shedding."*
> *S6: "Solar lamps help, but they don't last the whole night."*

These reflections align with quantitative results, where 40.4% of students studied less than 1 hour at home daily, and 55 per cent reported homework was sometimes disrupted by outages. Qualitative insights reveal how energy poverty directly reduces study time, limiting students' learning opportunities and contributing to weaker academic performance.

Impact of School Outages on Teaching and Learning

This theme examined teachers' and administrators' experiences with outages. Most reported cancelled ICT and science lessons, with some shifted to theory. Key quotes include:

> *T2: "We cancel computer classes when there's no electricity; students miss out on practice."*
> *HT1: "Practical subjects suffer the most. Without electricity, we can't demonstrate experiments."*
> *T5: "It is frustrating for teachers and demoralising for learners."*

These accounts confirm quantitative findings, where 75 per cent of schools reported lesson disruptions and 80 per cent noted ICT labs being affected. The qualitative voices emphasise that unreliable electricity undermines effective curriculum delivery, particularly in subjects that require practical or technology-based instruction. This aligns with Banerjee et al. (2021), who found that reliable electricity access has a more substantial effect on educational outcomes than aggregate energy consumption.

Coping Strategies in Schools

This theme highlighted how schools respond to frequent outages. Strategies included rescheduling lessons, switching to theory, or rarely using generators. Key quotes include:

> *T4: "We reschedule science practicals when power returns; otherwise, we just teach theory."*
> *HT3: "Our generator is too expensive to run, so we keep it for emergencies only."*
> *T1: "We adjust timetables, but it means learners lose practical experience."*

Quantitative results showed that 45 per cent of schools rescheduled lessons, 30 per cent shifted to theory, 15 per cent cancelled practicals, and only 10 per cent used generators. These insights illustrate that coping mechanisms reduce lesson quality, especially in science and ICT, further lowering the standard of education delivery.

Household Coping Strategies

This theme explored how families adapt to power shortages. Households relied on candles, solar lamps, and torches, with paraffin nearly phased out. Key quotes include:

> *P4: "Candles are cheapest, but they don't give enough light."*

P6: "Torches need batteries, which we can't always afford."

P7: "Solar lamps help, but they don't last the whole night."

Quantitatively, 46 per cent reported using candles, 33 per cent solar lights, and 18 per cent battery torches. Qualitative narratives reveal the inadequacy of these coping strategies, showing how families are forced to rely on temporary, often unsafe alternatives that compromise learning.

Perceptions of Reliable Energy and Education Quality

This theme captured beliefs about how improved electricity access would change education outcomes. Respondents strongly linked reliable electricity with more study hours, better exam performance, and stronger ICT integration. Key quotes include:

S5: "If power was stable, I would study more at night and improve my results."
T3: "Reliable electricity would allow us to use the computer lab every day."
HT2: "With better power, teachers would deliver lessons more effectively."

This echoes quantitative findings where over 90 per cent of respondents believed reliable electricity would improve teaching and learning. This consensus aligns with the broader educational research context in Zambia. For instance, a study by Chanda T. C. (2023) on poverty and education in Lusaka secondary schools identified resource deprivation, including inadequacies in critical infrastructure, as a primary constraint on quality provision. Qualitative insights provide depth by showing how reliable energy would motivate teachers, extend study hours, and strengthen school performance.

Policy implication

Addressing energy poverty in Zambia's education sector requires prioritising schools in national energy planning to reduce lesson disruptions from load-shedding. Scaling up renewable energy solutions such as solar mini-grids and hybrid systems can ensure sustainable electricity for schools, while targeted subsidies for household solar and clean cooking technologies can improve study conditions for learners. Integrating energy and education policies will better align electrification strategies with learning outcomes and progress toward SDGs 4 and 7. Achieving this vision calls for strong multi-sector collaboration among government, private actors, and development partners.

CONCLUSION AND RECOMMENDATIONS

Conclusion: This study provides robust evidence that energy poverty significantly undermines the provision of quality education in Zambia. Although grid connection rates are high in Lusaka and Kitwe, supply reliability is critically poor, and daily load-shedding disrupts both household study routines and school-based instruction. The statistical analysis confirmed strong associations between electricity availability, night study practices, homework completion, and academic performance. In addition, schools without backup energy reported higher rates of lesson disruption and lower teacher ratings of educational quality. However, the findings also indicate that current coping strategies, both at the household and school levels, are largely reactive and insufficient to mitigate the systemic nature of the problem. To fundamentally enhance educational resilience and quality, energy interventions must transition from focusing solely on connection to guaranteeing a reliable and affordable supply. This requires integrated policy action that prioritises schools in energy planning, scales up sustainable backup power solutions, and alleviates the energy cost burden on low-income households.

Recommendations: Based on the study's empirical findings, the following multi-level recommendations are proposed to mitigate the impact of energy poverty on educational quality in Zambia. These actions target policymakers, school administrators, and communities to create a more reliable and equitable learning ecosystem.

For the government and energy policy, it is recommended to prioritise schools in national energy planning by formally classifying public secondary schools as critical social infrastructure. This would grant them priority status to ensure a stable, uninterrupted daytime electricity supply and shield them from routine load-shedding. Additionally, the government, in partnership with development agencies, should accelerate investment in renewable school infrastructure by launching a targeted fund to equip schools, especially those teaching science and ICT, with sustainable backup power systems, such as solar photovoltaic (PV) mini-grids or hybrid solar-diesel solutions, to ensure the continuity of practical lessons and digital learning. Policy mechanisms should also be introduced to provide targeted energy subsidies for low-income households, including lifeline tariffs or direct voucher schemes, to subsidise the cost of electricity and clean lighting solutions for households with school-going children, thereby alleviating the trade-off between energy costs and educational expenses.

For school administration and management, it is recommended that every school develop and resource school-specific energy resilience plans. This involves creating practical contingency plans for power outages, maintaining backup power sources for core functions, and revising teaching schedules to prioritise practical subjects during confirmed power availability. Furthermore, energy literacy should be integrated into school programs and community meetings, incorporating basic education on energy conservation, the benefits of renewable sources, and the safe use of alternative lighting. This will empower students and parents to make informed choices regarding energy use.

At the community and household level, promoting community-led solutions is essential. Parent-Teacher Associations (PTAs) and local communities should be encouraged and supported to initiate collaborative projects, such as pooled resources for community study halls with reliable lighting or group purchases of solar learning aids. Finally, communities and civil society organisations should advocate for accountability and transparency, demanding clearer communication from energy providers regarding load-shedding schedules and ensuring local authorities are accountable in implementing school electrification and upgrade projects.

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