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Household Adoption of Solar Energy in a Developing Economy: The Challenges and the Prospects in Guyana

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Many developing nations have adopted solar energy as an alternative energy source for the benefit of their citizens and the environment. However, there is a paucity of studies on the acceptance and adoption of solar energy in urban areas in Guyana. Therefore, this study examined the potential for solar power adoption by households in Anna Regina. A mixed-methods approach was adopted for the study. Copies of the questionnaire were administered to households with and without solar photovoltaic (PV) systems. Invoices for solar materials were obtained from three leading wholesalers of solar energy equipment. Interviews were conducted with local electricians and Guyana Power and Light Inc. (GPL) officials. From the findings, solar systems reduced monthly household expenditures by an average of GYD10,233. Households with solar PV systems earned significantly more monthly than those without the systems. Analysis of the invoices of the solar equipment dealers indicated that the average cost of installing solar power was GYD1,182,895. The response from the local electricians revealed that the average labour cost to install a solar PV system was GYD200,000. Before approval could be granted for the installation of a solar PV system, as noted by GPL, applicants must comply with the 2014 National Electric Code (NEC), particularly Articles 690 and 705, as specified by the Guyana Electrical Inspectorate. The barriers to the uptake of solar energy systems are high initial installation costs, maintenance expenses, and inadequate knowledge of the long-term benefits of solar energy. With the significant financial and environmental benefits of renewable energy, the study advocates for policy initiatives and incentives for country-wide adoption of solar energy systems.

Keywords: Solar Energy, Household expenditures, Energy bills, Energy security, Renewable energy, Guyana

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INTRODUCTION

Solar energy is the driver of mankind's evolution, the source of life on Earth, and the hope for humans' survival (Szabó, 2017). As humans continue to develop, energy demand is growing; in 2015 alone, the world consumed 17.4 terawatts (TWh) of energy, over 80% of which came from non-renewable sources (Holechek et al., 2022). The current energy sources, mainly from fossil fuels, have led to some of the greatest challenges of the modern world, such as climate change, pollution, and energy insecurities (Jacobson & Delucchi, 2011; 2024). Combating

these challenges requires cleaner and more efficient sources of energy. Solar radiation is the largest source of clean energy available, easily surpassing human needs (Jaiswal et al., 2022). Domestic solar systems usage has significantly reduced polluting gases and energy costs (Ukoba et al., 2024). For example, 80% savings in domestic solar water heaters have been documented, while the combination of solar water and space heaters saves 40% compared to regular power systems (Ali et al., 2023; Ukoba et al., 2024).

Around the world, the sun's energy has been used to heat spaces through architectural placements (Perlin, 2022). As time passed, solar energy developed into many devices used for heating and steam-powered engines (Perlin, 2022). Perhaps the most essential development of solar energy was the discovery of the photovoltaic effect (Chala & Al Alshaikh, 2023; Sinke, 2019; Szabo, 2017). In 2022, solar energy generated 1,300 TWh of energy, accounting for 4.5% of global electricity (International Energy Agency, 2024). Solar energy development stems from policies to tackle climate change, such as the 2015 Paris Agreement, which aims to reduce the global average temperature to pre-industrial levels. Guyana, as a signatory to the Paris Agreement, aims to produce 90% of its total energy using solar power by 2050 (Inter-American Institute for Cooperation on Agriculture (IICA), 2021). For over a decade, Guyana has been developing its solar energy sector, and the development is further heightened by the recently launched Low Carbon Development Strategy to increase the share of solar PV in isolated grids to an average of 50% by 2027 and 70% by 2030 (Low Carbon Development Strategy, 2022). Through Guyana's Low Carbon Development Strategy, 200 hinterland communities accessed solar energy with 11,540 home systems. Additionally, solar farms are being set up across the country (Papannah, 2022).

The development of solar power in Guyana has been progressing over the years. The government has installed over 13,000 small systems nationwide, focusing mainly on the hinterland regions (International Renewable Energy Agency, 2015). The government has established large solar farms at Mabaruma, Lethem, and Bartica, with Lethem producing some 279.7MWh of electricity (Papannah, 2022). These solar developments have served the communities by reducing electricity costs and allowing some hinterland communities to access electricity for the first time, leading to hinterland/rural development. In Region 2, most of the solar power installations are concentrated in indigenous communities. Private entities also install photovoltaic panels; however, this development is more popular in hinterland regions (Papannah, 2022).

To date, solar photovoltaic (PV) panels have been installed at several prominent institutions in Anna Regina, the central urban hub of Region 2. These locations include the Essequibo Technical Institute, Charity Secondary School, Anna Regina Secondary School, and Cotton Field Secondary School, which serve as examples of renewable energy technology integrated into educational environments. Guyana has made notable national commitments to renewable energy adoption as outlined in the 2015 Paris Agreement and guided by the comprehensive Low Carbon Development Strategy (LCDS) of 2022. Therefore, the country has made considerable progress in adopting solar energy, especially within its rural hinterland communities. This effort has successfully provided electricity access to thousands of homes and initiated the establishment of solar farms. Yet, these advances have not translated into meaningful uptake at the household level in urban towns such as Anna Regina, where private adoption remains low and poorly understood. While rural electrification through solar systems is well documented and widely celebrated, the imbalance in the urban area has created a critical knowledge gap. There is a paucity of literature on factors influencing solar adoption among urban households, who face different socio-economic realities, energy demands, and infrastructural conditions. This is particularly concerning because urban centres, with higher population densities, rising energy demands, and increasing vulnerability to fossil-fuel-driven energy costs, stand to benefit substantially from domestic solar technologies.

The insufficient empirical understanding of urban households' adoption of solar energy has led to an imbalance and a critical knowledge gap that undermines the effectiveness of national renewable energy objectives. Without insight into why adoption remains low, whether due to cost, awareness, cultural preferences, policy gaps,

infrastructural limitations, or trust in the technology, efforts to expand solar energy usage in Guyana risk becoming uneven, rural-centric, and insufficiently aligned with the country's broader sustainability targets. This study is, therefore, necessary to illuminate the socio-economic, technical, institutional, and perceptual factors shaping solar uptake in Anna Regina, to support a more inclusive, balanced, and effective national solar energy transition.

LITERATURE REVIEW

The world relies heavily on fossil fuels as a reliable energy source for development, leading to expensive environmental impacts (Sampaio & González, 2017). One of the most widely accepted strategies to respond to climate change and energy insecurities is renewable energy, especially solar power, as a sustainable and environmentally friendly means of energy generation (Strielkowski et al., 2021). Solar energy has become the go-to solution since it is abundant, clean, and renewable (Dinçer, 2011). Solar energy has many benefits besides reducing greenhouse gas emissions; it can provide energy needs for future generations (Shahsavari & Akbari, 2018). It can help developing nations reduce poverty and eradicate energy insecurities (Shahsavari & Akbari, 2018). Solar energy is a source of electricity that stems from the photovoltaic effect. It is a common consensus among most researchers that the rising population and increasing demand for energy drove the development of solar energy as a sustainable solution (Parida et al., 2011; Sampaio & González, 2017).

Today, solar energy is the most used clean energy in the world (Strielkowski et al., 2021). Advantages of the system include a readily accessible fuel source, no emissions, low maintenance cost and no disturbances (Majeed et al., 2023; Nwagu et al., 2024). Among these advantages, installing a solar system consistently reduces monthly utilities, resulting in lower energy bills or even eliminating them (Majeed et al., 2023). Not only savings, but there is also an opportunity to earn from a solar system; when the system is connected to the grid, the surplus electricity produced can be sold to the grid. Solar system also allows users to have independence from the energy grid; in the event of power outages, electricity can remain on in solar-powered homes through batteries (Glover, 2024). The panels and system also require low maintenance costs since there are no moving parts, and if they are cleaned and in good physical condition, they can last over 25 years (Abdulla et al., 2024; Constellation, 2022).

Currently, Guyanese residents pay a substantial sum to Guyana Power and Light Inc. (GPL) monthly for electricity consumption from the grid. The residents pay a fixed charge of GYD$351.04 along with GYD$43.43 per every KWh used (Guyana Power and Light (GPL), 2021). This equates to high electricity bills per home every month. A study conducted in Bangladesh provided solar home systems to three rural communities without direct access to the grid to compare the costs of kerosene lamps and battery charging. It was found that solar home systems were financially attractive despite the monsoon weather; they were beneficial for small businesses, lighting and entertainment in the villages of Bangladesh (Mondal, 2010). In Germany, the Renewable Energy Act (EEG) offers compensation for solar-powered homes that feed excess electricity into the grid. This has resulted in around 1.3 million solar power systems being connected to the grid. (Korcaj et al., 2015). This allows households to save on electricity bills and gain compensation through their solar systems. In 2017, Stojanovski et al surveyed East African communities tracking the advantages of home solar systems. The systems were found to eliminate the use and cost of kerosene and reduce charging costs for cell phones (Stojanovski et al., 2017).

Also, a book by Ramlow and Nusz (2010) discussed the benefits of using a solar water heater, noting that the system pays for itself in utility bill savings within 11 years (Ramlow & Nusz, 2010). This demonstrates the potential savings offered by solar systems, which can significantly reduce electricity bills or even eliminate the need to pay for electricity. China has been promoting solar energy adaptation through its Rooftop Subsidy Programme and Golden Sun Demonstration Programme; these initiatives offer a subsidy of £1.54/W for excess electricity produced (Gul et al., 2016). These systems allow for savings from electricity bills while earning from the solar system's installation.

A similar programme has been successful in Germany. These studies all proved that solar energy, in some way or another, has resulted in savings for the users, proving that solar energy can save money in all spaces, rural or urban (Rakowska et al., 2022; Rumbayan et al., 2025).

Globally, a common challenge is the cost associated with solar system installation. As technology is advancing, the cost of solar systems has significantly reduced. For example, over the years, the cost of installing solar systems has decreased significantly due to a 90% cost reduction in solar modules since 2000 (Kishore et al., 2025; Piper, 2022). With the decreased costs, solar energy has shifted from one of the most expensive sources of electricity to the cheapest in many countries. However, these costs are still higher compared to conventional energy systems in many countries (Ojo et al., 2023; Pourasl et al., 2025). Although solar energy adoption has increased by 40% annually, making it the fastest-growing energy source, its high cost still renders it inaccessible for many, especially in developing countries (Mahn et al., 2024; Nijsse et al., 2023; Radley & Lehmann-Grube, 2022). Developing nations, especially, struggle to afford these solar systems because of the high initial costs (Mahn et al., 2024; Radley & Lehmann-Grube, 2022).

According to the International Energy Agency (IEA), it was noted that in developing nations, there is less capital to invest in developing solar renewable energy (Grover, 2023). Based on research in northern Nigeria, the viability of solar introduction into the grid system was analysed, indicating that the system is viable; however, in rural locations, the cost of batteries can significantly increase the cost of the system since the grid is not within range (Adaramola, 2014). Malaysia also battles the cost of solar systems, which has resulted in implementation in rural communities not being viable (Maradin, 2021). Solar systems have low maintenance and operational costs; it is the initial investment cost that is significant (Kishore et al., 2025; Sha et al., 2025; Singh & Singh, 2010; Ukoba et al., 2024; Windarta et al., 2022). The high cost of the technology has resulted in solar systems being significantly difficult to adapt (Maradin, 2021).

In addition to the cost of solar systems, several other factors hindered their installation (Korcaj et al., 2015). In most urban centres in the United States of America, peer influence plays a significant role in determining whether people adopt solar energy (Graziano et al., 2019). In Hong Kong, challenges such as long payback periods, incompatible infrastructure, and a lack of awareness and incentives have been obstacles to installation (Lo et al., 2018; Zhang et al., 2012). Meanwhile, in Austria, there is a general lack of awareness and apathy about the advantages of solar energy (Jayaraj et al., 2025). Solar energy systems can be affected by cloud cover, as cloudy conditions or passing clouds reduce the output of solar power. Therefore, as noted by Mahmood et al. (2020), solar power generation may face challenges in cloudy locations or on overcast days. Dust is also a challenge; when dust particles soil the solar reflector/panels, it reduces electricity production by reducing the absorption of solar radiation (Said et al., 2024; Zereg et al., 2021). This results in certain regions of the world finding it incredibly difficult to utilise solar energy.

DESCRIPTION OF STUDY AREA

Guyana, located in the tropical zone of South America, is abundant in solar radiation. The Administrative Region 2 (Pomeroon-Supenaam) is located at the Northern boundary of the country, bordering the Atlantic Ocean (Figure 1). Pomeroon-Supenaam is bordered by the Atlantic Ocean to the north, Essequibo Islands-West Demerara to the eastern section, Cuyuni-Mazaruni region to the south and Barima-Waini to the west. Anna Regina, the administrative headquarters of Region 2, is located on the West Coast of the Essequibo River, developed out of a government land development framework and comprises communities, which include Lima, La Belle Alliance, Bush Lot, Richmond and Henrietta.

Anna Regina, the study area, is the major township in the Region. The settlement was once a colonial sugar

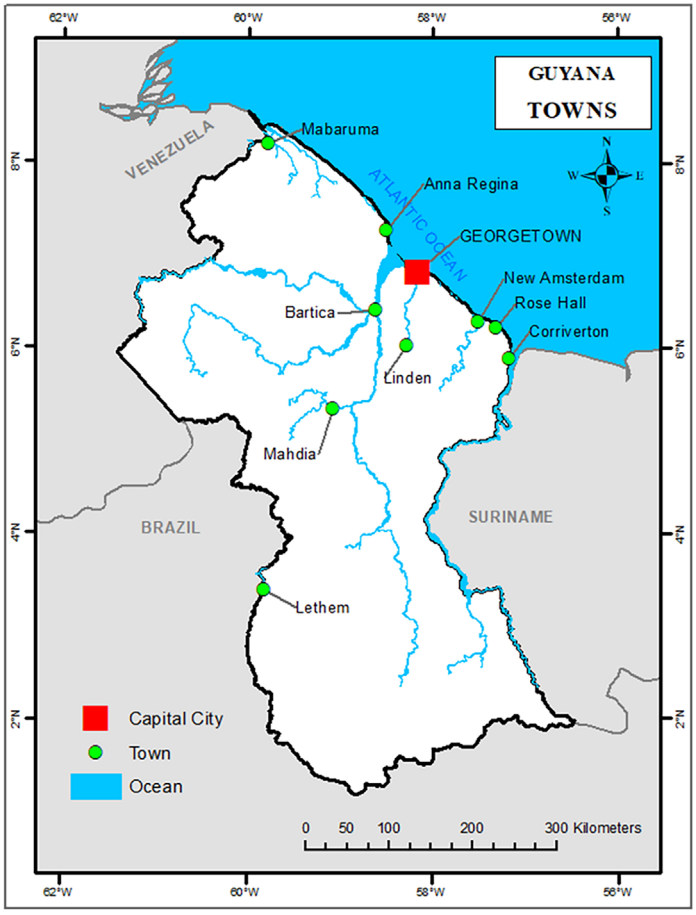

Fig. 1. Anna Regina in the Guyana Context
Source: Department of Geography, University of Guyana.

plantation, but was classified as a town in 1970 with the merging of eighteen (18) villages. The population of the township is projected to be about 16,000 in 2025. The settlement falls within the Af-Tropical rainforest climate and experiences two wet and two dry seasons annually with an average annual temperature of 26°C and annual precipitation of 2499.44mm (Guyana Lands and Surveys Commission, 2013; World Bank Climate Change Knowledge Portal, 2021). The town, like all the settlements in Region 2, is exposed to high average solar radiation with approximately 5 peak hours of sunlight per day, which is suitable for solar power generation (Guyana Lands and Surveys Commission, 2013). The income level of the town could be classified as low, with the main sources of income in the town including the local administration and small-scale farming, especially rice farming. The households' expenditure comprises household goods (food, soap, washing powder, kerosene, toilet paper, wood), clothes, medical care, schooling expenses for children, transportation and electricity.

Methodology

The study utilised an exploratory research design aimed at gaining insight into the factors influencing the adoption of solar energy in Anna Regina. The goal is to gain a preliminary understanding, clarify the nature of the variables, or generate hypotheses for future research. A cross-sectional approach was used for data collection. This research design allows data to be collected from many individuals at a single point in time, and it is fast, inexpensive and requires no follow-up (Hulley et al., 2013). This research relies on primary and secondary data for assessments

and analysis. Primary data was collected by administering questionnaires to households and interviewing relevant stakeholders. The qualitative data collection methods included two interviews. These interviews were used to determine the costs and restrictions of installation. Specifically, the interview of the local electrician examined the installation and maintenance costs of solar systems. The GPL representative interview examined the necessary procedure before installation and understanding of the regional solar adaptation strategy. The secondary quantitative data were collected through quotations from solar power dealers in the study area. Three quotations were acquired from stores across the region for the cost of solar systems. The quotes aided in examining the total cost of solar panels.

The township of Anna Regina consists of 18 communities that share similar characteristics in terms of socio-economic and housing types. However, the preliminary survey indicated that the adoption of solar energy is still low, as most of the 18 communities that make up Anna Regina township did not have solar power installed. There are five communities within the township of Anna Regina with solar energy installed, namely, Reliance, Bush Lot, Anna Regina, Henrietta and Richmond. These communities were selected for the study. The total number of streets in the selected communities is 71, as obtained from Google Earth Imagery and verified by ground-truthing conducted in May 2024. From this total, 80% of the streets, equating to 58, were chosen as the sample size for questionnaire administration, as shown in Table 1.

In the five communities studied, samples were collected using probability sampling to ensure proportional representation of each community's total population. With the assumption that the town is homogeneous in income and appliance usage between the residents with and without solar power installed, a simple random sampling, an unbiased method that selects samples from the entire population and gives every individual an equal chance of being chosen (Sharma, 2017), was employed to identify the respondents. To adhere to the principles of simple random sampling, each house on the selected streets was assigned a number. The "Rand Between" function in Excel was then utilised to randomly select one building on each street from which a household participated in the survey within the targeted communities (Table 1). The method of randomisation is crucial for enhancing the validity of research findings by ensuring that every individual in the study population has an equal chance of selection. This approach significantly reduces selection bias, which can skew results and undermine the credibility of the research while fostering a more comprehensive understanding of the diverse perspectives within the community.

A preliminary door-to-door investigation identified fully/ partially solar-powered houses. Each house with solar panels installed on the roof was identified and recorded within the study area. Eighteen houses were identified and treated as 100% of the solar population. Questionnaires were administered to the 18 houses with solar-power systems installed. Questionnaires were distributed physically and designed to assess the monthly electrical expenses of households and understand the income bracket of persons in the region. The analysis of monthly electricity expenses involved examining electric bills from households that had solar systems installed as well as those that did not. This method enabled the researchers to verify the monthly electricity costs effectively.

Table 1. Number of residential houses in the Anna Regina Township

Communities	Number of Streets in the Communities	Number of Streets selected (80%)	Number of Households Selected
Reliance	11	9	9
Bush Lot	8	6	6
Anna Regina	24	20	20
Henrietta	12	10	10
Richmond	16	13	13
Total	**71**	**58**	**58**

Interviews were also conducted with a local electrician from the study area to determine installation costs for solar and conventional (GPL) sources. An interview was also conducted with a Guyana Power and Light Inc. (GPL) representative, the national electricity provider in the region. This interview was conducted to understand the legalities and necessary actions to be taken before solar photovoltaic installation. This interview also discussed the adaptation factors of the study area. Quotations were also acquired from three regional solar system providers to further assess the costs of solar systems. These providers were selected by considering the range of available items for solar system installation. The three stores with the most or all necessary items were selected, and quotations were acquired. These quotations provided information on the costs and availability of solar systems. The potential for reducing household expenses was assessed through the electrical expenses of homes with and without solar energy. At the same time, the interview provided valuable information on the assessment of solar system installation costs compared to the income bracket, which was gathered through the questionnaire. The regulatory requirements and the challenges to the installation of solar power systems were assessed from the interview with the GPL representative, cost analysis, and the questionnaire.

Following the collection of data from the questionnaires, the information was organised into spreadsheets and thoroughly examined for any missing data or outliers. Upon this preliminary assessment, 55 out of the 58 non-solar households' questionnaires were completed and identified as suitable for analysis. The Statistical Package for Social Sciences (SPSS) was used to analyse the data. The interviews and other quantitative data were analysed through content and narrative analysis. The results of these analyses are presented in tables, graphs, descriptions and narrations.

The study adhered to the ethical principles outlined in the Helsinki Declaration about human subjects. The objectives, methodologies, and intended use of the collected information for the research were communicated to the participants. They were assured of the confidentiality of their responses, the protection of privacy, the voluntary nature of their participation, and their right to withdraw from the study at any time. For example, the rights of a few people who were uncomfortable disclosing their monthly income during the questionnaire distribution were respected, even though this resulted in some missing data during the comparison of the income-installation relationship. The consent form was thoroughly explained to each participant, and their written consent was obtained before the commencement of the data collection. This research response was fully confidential, and no names or identification were recorded.

The principal limitation of this study arises from the scarcity of available data, which results in a foundational analysis predominantly grounded in cost-related factors. While these financial insights have proven invaluable in uncovering critical economic aspects of the subject under examination, this narrow focus risks overlooking other significant dimensions of the issue.

FINDINGS AND RESULTS

From a survey of 55 non-solar-powered and 18 solar-powered houses, combined with two interviews and three quotations, a comprehensive analysis of solar power in Anna Regina is presented. The trends and conclusions were made by comparing the averages of total responses and analysing the responses from interviews. The findings were presented in tables, charts and graphs, which were narratively expressed. Research objectives were all comprehensively and research were answered.

The socioeconomic characteristics of responders

Among the 73 respondents (18 with solar and 55 without solar) surveyed, a significant majority, specifically 60.2%, were aged between 18 and 45 years. This age group represents a vibrant segment of the population that is

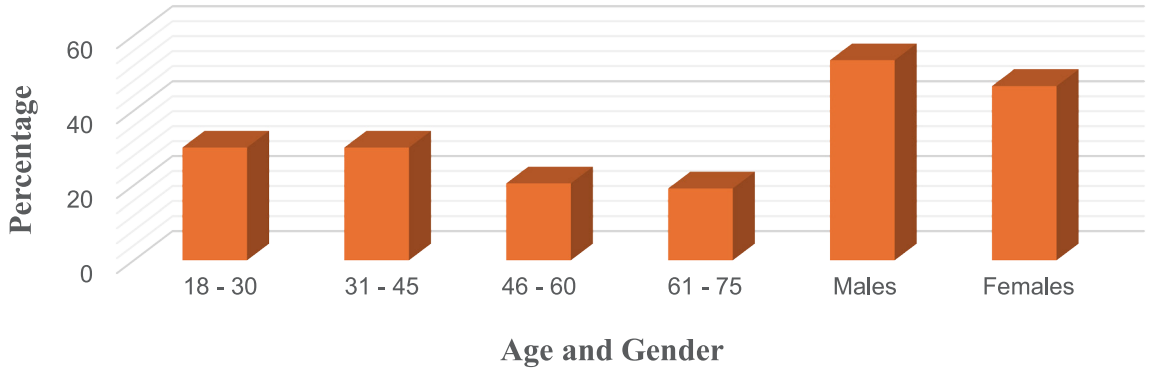

Fig. 2. Age and gender of respondents

often characterised by greater economic productivity and lower dependency on social support systems. In contrast, 20.6% of the respondents fell into the 46 to 60-year age bracket, indicating a smaller yet notable proportion of middle-aged individuals. Meanwhile, 19.2% of the participants were 61 years or older, highlighting a smaller segment of the population potentially facing retirement and related challenges (Figure 2).

These findings suggest that the study area is predominantly composed of a younger to middle-aged demographic, which typically correlates with a lower dependency ratio and the population structure of Guyana. This low ratio implies a substantial number of individuals are actively engaged in the workforce, thus providing ample support for those who may be dependent, such as children or elderly individuals. Overall, the largest portion of the sampled population, comprising individuals aged 18 to 45 years, underlines the area's potential for economic growth and stability, driven by a robust working-age populace.

The demographics of the study's participants indicated that 53.4% were male, while 46.6% were female. This slight imbalance in the sex ratio, reflecting a marginal skew toward males, aligns with trends commonly observed in research studies worldwide. Such disparities in participant gender composition can be attributed to various factors, including recruitment strategies, the nature of the study topic or household structure. This pattern is consistent with findings reported by Ritchie and Roser (2024), suggesting that the gender distribution in research samples often mirrors broader societal demographics, although it raises important questions about the implications for data interpretation and the generalizability of findings across different populations.

The influence of solar energy on Anna Regina's monthly household expenditure

A total of 18 households with solar energy installed reported a combined monthly electricity bill amounting to GYD$114,600. This resulted in an average cost of GYD$6,367 per home, calculated by dividing the total bill by the number of houses (i.e., GYD$114,600 divided by 18). Among these residents, billing patterns varied: seven (7) individuals had payments ranging from GYD$1,000 to GYD$3,000, indicating a significant number of homes benefitting from lower energy costs. Meanwhile, eight (8) households paid between GYD$3,001 and GYD$6,000, one (1) exceeded the GYD$6,000 mark with a bill between GYD$6,001 and GYD$9,000, and two (2) households had higher expenses, each paying over GYD$9,000. It is worth noting that the majority of these solar-powered residences experienced electricity costs of less than GYD$5,000 per month, highlighting the potential savings solar energy can provide, as shown in Figure 3.

In contrast, 55 homes that did not utilise solar energy have a combined monthly electricity bill of GYD$913,000. This leads to a considerably higher average bill of GYD$16,600 per household, arrived at by dividing the total by the number of homes (i.e., GYD$913,000 divided by 55). Within this group, the billing distribution revealed

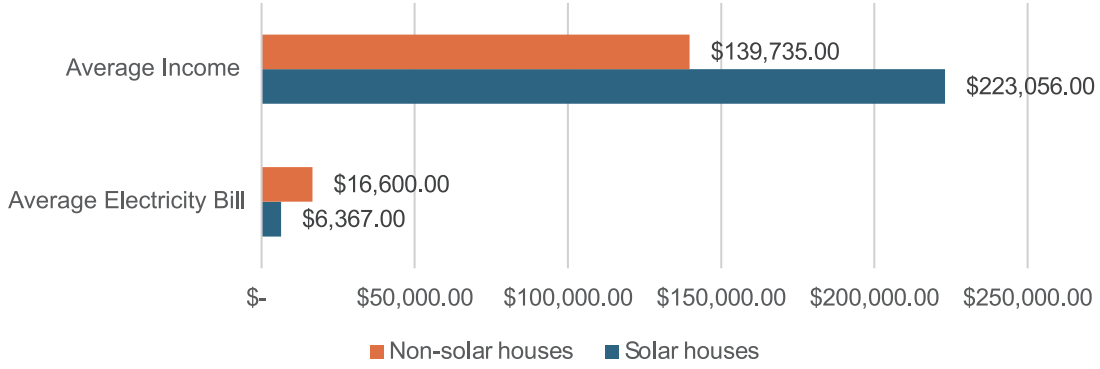

Fig. 3. Average monthly income and electricity bill for solar and non-solar households

greater expenses: 12 residents paid within the GYD$5,000 to GYD$10,000 range, 20 households' bills ranged from GYD$10,001 to GYD$15,000, and nine (9) individuals found their costs between GYD$15,001 and GYD$20,000. Additionally, four (4) households faced expenditures between GYD$20,001 and GYD$25,000, while eight (8) paid between GYD$25,001 and GYD$30,000, and finally, two (2) households incurred bills ranging from GYD$30,001 to GYD$35,000. This comparison demonstrates the financial advantage of solar energy and also illustrates the significant savings potential for households that choose to embrace renewable energy sources.

In the analysis of the income of solar-powered households, a total of 18 such homes collectively earned an impressive monthly income of GYD$4,015,000. This results in an average income of approximately GYD$223,056 per house, calculated by dividing the total income by the number of houses. The income distribution among these solar-powered homes reveals a diverse range of earnings: specifically, two (2) households reported incomes within the range of GYD$100,000 to GYD$150,000; seven (7) households earned between GYD$150,001 and GYD$200,000; six (6) households achieved earnings ranging from GYD$200,001 to GYD$250,000; and three (3) households generated incomes between GYD$250,001 and GYD$300,000. This income distribution not only underscores the potential and incentive for investment in solar energy but also indicates varying levels of energy efficiency installations, as well as potential differences in the sizes or features of the residences (Figure 3).

In comparison, earnings involving 49 respondents from non-solar houses yielded a combined monthly income of GYD$6,847,000, resulting in an average income of GYD$139,735 per house. This figure was derived by dividing the total income reported by the number of households. However, six (6) individuals chose not to disclose their income figures, which may affect the overall average. Among those who did provide information, the earnings differ widely: 11 respondents reported income between GYD$50,000 and GYD$100,000, 20 individuals earned between GYD$100,001 and GYD$150,000, while 18 respondents made between GYD$150,001 and GYD$200,000. This data indicates a considerable gap in income levels and earnings potential between solar-powered and non-solar houses, suggesting that the adoption of solar energy may be a function of income in the community.

This research underscores a significant financial disparity between households that rely exclusively on grid electricity and those that incorporate solar energy into their power systems. On average, households that depend solely on the grid incur monthly electricity expenses of approximately GYD$16,600. This figure is particularly alarming, as it represents a substantial portion of a household's budget, often leading to financial strain for families. In stark contrast, homes equipped with solar energy systems, from observation, use more electrical appliances than households without solar energy, and enjoy lower electricity costs, with an average monthly bill hovering around GYD$6,367. This observation not only highlights the economic benefits of solar energy but also reflects the potential for significant long-term savings. By harnessing the power of the sun, these households effectively reduce their dependency on conventional energy sources, positively impacting their overall financial health.

As a result, the average monthly savings for households utilising solar energy amounts to an impressive GYD$10,233. This value is calculated by subtracting the average monthly expenses of solar-powered homes from those relying on traditional grid electricity (GYD$16,600 for grid users compared to GYD$6,367 for solar users). Such substantial savings can enable families to invest in other essential areas, improve their quality of life, and support sustainable energy practices for a better future. Overall, the adoption of solar energy not only proves to be a financially sound decision but also contributes to a more sustainable and environmentally friendly power grid. In addition to the savings on electricity, a comparison of income levels reveals a notable trend: households without solar energy systems earn an average income of GYD$139,735, while those with solar installations enjoy a considerably higher average income of GYD$223,056. This substantial income gap suggests that households that transition to solar energy could significantly enhance their financial situation, not only by saving on monthly utility costs but also by potentially reallocating resources towards investments or savings.

The impact of solar energy on household expenses is further illustrated in studies conducted in various regions, including Bangladesh and East African communities, where a shift from kerosene and conventional grid electricity to solar power has led to similar reductions in monthly expenditures. These studies, as documented by Ferrer (2017) and Stojanovski et al. (2017), emphasise the transformative potential of solar energy not only in terms of cost savings but also in improving the overall financial well-being of families. The extensive cost reductions associated with solar energy adoption, as depicted in Figure 3, serve as a compelling incentive for households still relying on traditional energy sources. By embracing solar technology, households can achieve substantial monthly savings, thus fostering a path toward greater economic stability and sustainability.

Residents' income and the installation of solar systems

The research focused on the installation of a 1500-watt solar system, which is approximately 6 of 250-watt solar panels and all the necessary items for the proper functioning of the system, which powers approximately 5 LED lights, 1 refrigerator and 1 television set. From the interview with the electrician, it was identified that the labour installation cost for a solar system is GYD$200,000. From consultations with each solar supply store, the necessities for setting up a solar PV system were determined, and a quotation was acquired from each supplier, as shown in Table 2.

The quotation from the first store listed materials at GYD$842,400, and with the additional installation cost of GYD$200,000 from the electrician, the total installation cost comes to GYD$1,042,400. The second store quoted materials at GYD$967,380, and with the same GYD$200,000 installation fee for a total of GYD$1,167,380. The third quotation for materials was GYD$1,738,905, along with the GYD$200,000 installation fee, resulting in a total of GYD$1,938,905 (Tables 2 and 3). Based on the questionnaire responses, the average cost for materials and installation across the 18 responder systems is GYD$1,365,556 (calculated as GYD$24,580,000, the total sum of solar PV installation costs from the questionnaires, divided by 18, the number of responders).

The costs associated with solar energy systems, as reported by 18 households that have adopted this technology, demonstrate significant variation. Estimates for the total expenditures on these systems range widely. Despite this broad spectrum, the majority of responses are concentrated in the GYD$1,000,000 to GYD$2,000,000 range, which appears to represent the predominant segment of the market. Among the submissions, there are a couple of notable outliers that further illustrate the diverse landscape of solar system investments. One household reported a notably low cost of GYD$400,000, which may suggest a smaller system size, basic installation, or limited features. Conversely, another household cited an exceptionally high expenditure of GYD$2.8 million, indicating the potential for extensive custom installations, advanced technology, or comprehensive service packages that include maintenance and monitoring (Figure 4).

The observed differences in pricing likely reflect a range of factors, including the size and complexity of the solar

Table 2. Cost of solar items for the installation of a solar PV system by three suppliers

Supplier	Quantity	Items	Suppliers Cost (GYD$)
Quotation 1	6	250w 30V Solar Panels	$288,000
	1	1000-watt power inverter	$22,500
	1	50-amp Charge controller	$14,000
	1	Earth Rod and Clamp	$2,900
	40 yrd	1×10 Cable	$23,000
	50 yrd	1×1.5 Cable	$12,000
	8	250A 12-volt solar battery	$480,000
		Total	**$842,400.00**
Quotation 2	6	250-watt Solar Panels	$180,000
	1	3000-watt 24V Inverter	$84,000
	1	30-Amp Charge control	$27,000
	40 yrd	Solar wire	$17,600
	1	Earth rod	$1,500
	12 yrd	1×10mm Cable	$8,880
	14	300A Battery Terminal	$3,360
	8	220A Solar Battery	$640,000
	14 yrd	1.5mm Cable	$5,040
		Total	**$967,380.00**
Quotation 3	6	250W, 40V Solar Panels	$295,600
	1	3000W Inverter	$198,000
	1	50Amp MPPT charge control	$162,700
	1	80Amp Double Breaker Solar Disconnect Breaker combination box	$44,825
	60	Solar Rack	$62,400
	4	End Clamp	$1,880
	10	Middle Clamp	$4,400
	12	End Foot	$10,620
	120 ft	Solar Cables	$62,520
	4	MC connectors	$3,100
	1	Earth rod and clamp	$4,500
	34 ft	1×10mm Cables	$8,800
	14	300A Battery Lugs	$14,000
	1	Lightening Arrestor	$35,000
	8	250 AH 12V Gel battery	$830,560
		Total	**$1,738,905.00**

Table 3. Cost of materials and installation costs

	Quotation 1	Quotation 2	Quotation 3
Cost of materials	$842,400.00	$967,380.00	$1,738,905.00
Labour Cost	$200,000.00	$200,000.00	$200,000.00
Total	**$1,042,400.00**	**$1,167,380.00**	**$1,938,905.00**

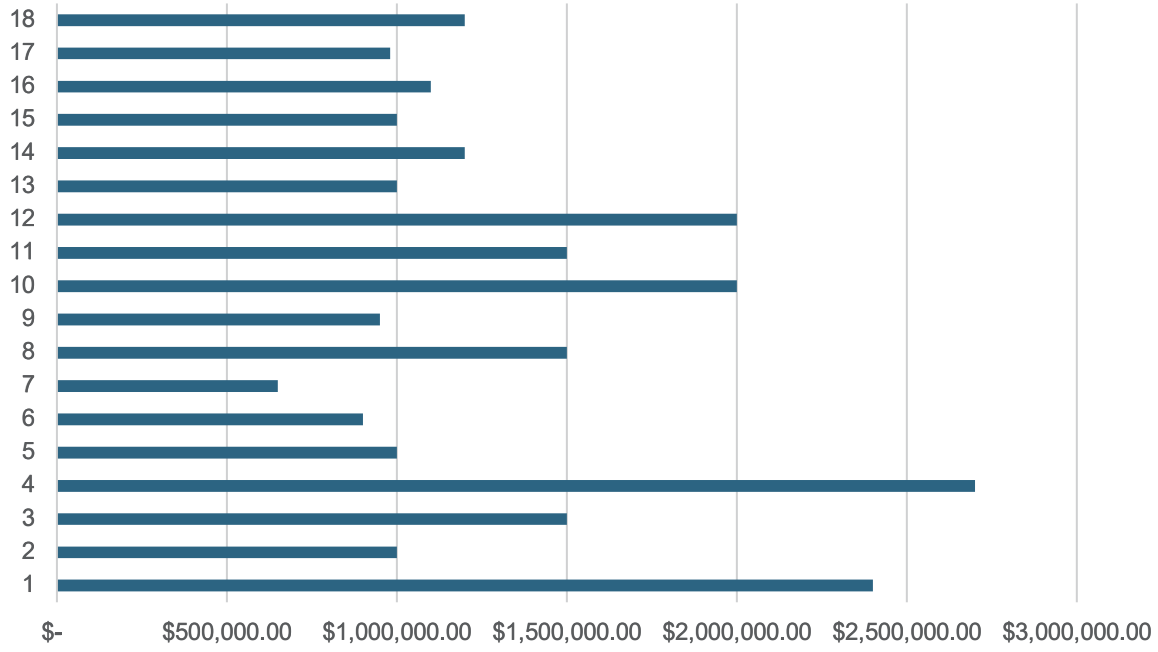

Fig. 4. Cost of installing solar systems from questionnaire responses of occupants with Solar PV installed

Table 4. Average income of occupants with and without solar PV

	Number of houses	Sum of income	Average income (Sum of income ÷ number of houses)	Difference in income
Solar	18	$4,015,000.00	$223,056	$ 83,321
Non-Solar	49	$6,847,000.00	$139,735	

systems, the quality of the components used (such as high-efficiency panels versus standard models), and the breadth of services offered, from installation to ongoing support and energy management solutions. While there is no single standard cost for solar energy systems, the majority of data collected points to a typical investment range of between GYD$1 million and GYD$2 million. This highlights a significant opportunity for homeowners considering solar energy, albeit with important variations based on specific needs and choices.

As illustrated in Table 4, it was determined that households equipped with solar energy systems earn an average of GYD$83,321 more per month compared to those without solar energy. Specifically, households with solar photovoltaic (PV) systems have an average monthly income of GYD$223,056, calculated by dividing the total income of solar-equipped households (GYD$4,015,000) by the number of households (18) with solar energy. In contrast, households without solar energy have an average monthly income of GYD$139,735, derived from dividing their total income (GYD$6,847,000) by the number of non-solar households (49).

The cost of purchasing and installing solar PV systems varies between GYD$1,042,400 and GYD$1,938,905 (Table 2). On average, the combined monthly income of the 67 individuals who shared their earnings amounts to GYD$181,396. This average is derived by summing the incomes of both solar (GYD$223,056) and non-solar occupants (GYD$139,735) and then dividing by two to represent the two groups. If households were to allocate their entire monthly income solely to the solar systems, it would take approximately 5 months and 7 days of income to cover the payment for materials and installation for Quotation 1, 6 months and 4 days for Quotation 2, and 10 months and 7 days for Quotation 3. However, such a long-term financial commitment may be unrealistic for many

Table 5. Necessary time and percentage for the payment for solar PV installation in homes

Quotations		Approximate length of savings for a solar PV system based on a Payment Plan with a monthly income of $139,735 per household	
	Cost for materials and installation	100% of income	10% of income per month ($13,973.5 a month)
Quotation 1	$1,042,400.00	7 months and 6 days	6 years 2 months
Quotation 2	$1,167,380.00	8 months and 4 days	6 years 10 months
Quotation 3	$1,938,905.00	13 months and 9 days	11 years 6 months

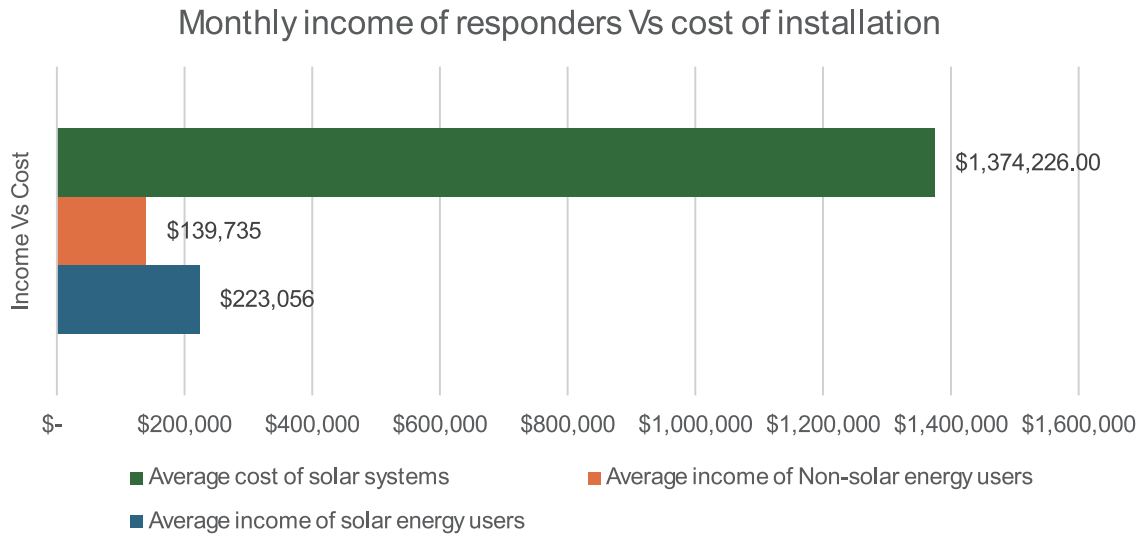

Fig. 5. Monthly income and cost for the installation of solar PV

households. Alternatively, if households dedicate 10% of their monthly income to a solar system, the payback period would range from 4 to 9 years for the installation of solar PV systems, as shown in Table 5.

This indicates that even with a payment plan and saving 10% of household income, it takes a significant period of time before a solar system installation price can be repaid. It should be noted that the income of occupants with solar PV installed is an average of GYD$83,321 per month, more than households without, indicating additional income to facilitate installation of the system (Figure 5). However, the income of the majority of responders will struggle to set up a costly solar electrical system in their homes. The literature also connects with this finding. Northern Nigeria faces significant challenges related to high solar battery costs, largely attributable to the considerable distances from electrical grids (Agbo et al., 2021; Ohunakin et al., 2014). Similarly, in Malaysia, a substantial portion of the population cannot afford the installation expenses (Maradin, 2021), and many other developing nations encounter comparable costs of installation difficulties (Grover, 2023).

The challenges of installing solar systems

A questionnaire was distributed to non-solar-powered households to identify the reasons preventing them from the installation of solar PV systems. The results, as shown in Table 6, revealed that 63.6% of respondents cited cost as the primary barrier, while 29.1% pointed to maintenance expenses, and 7.3% mentioned legal challenges with the GPL as a constraint. The installation cost pertains to the initial monetary investment required for the system. In contrast, maintenance costs involve the upkeep of battery logs, replacing damaged batteries or wiring, and cleaning solar panels, which are typically located on high roofs. Legal struggles refer to the cumbersome process of obtaining

Table 6. Restraining factors of solar power installation

Restraining factors	Respondents	Percentage of responders
Cost	35	63.6
Weather	0	0.0
Unavailability of solar systems	0	0.0
Maintenance	16	29.1
Legal Struggle	4	7.3

the necessary permissions from relevant organisations before installation. However, it was found that weather conditions and the availability of solar materials were not significant factors hindering installation.

The interview with the local electrician also indicated that there are no disadvantages to installation in Anna Regina, stating that the weather and location are feasible for the successful adaptation of solar energy. However, the interview with a representative from Guyana Power and Light Inc. (GPL) revealed that the process for connecting a solar system to the national grid in Guyana can be quite cumbersome, potentially deterring prospective installations. According to the interview, GPL allows individuals to install systems with a capacity of up to 100 kWac, provided they comply with specific regulations. However, any system that exceeds this capacity must receive approval and assessment from the company. To initiate this process, applicants are required to submit their system specifications and a diagram to GPL, along with a certificate from the Government Electrical Inspectorate (GEI). Following this submission, GPL will inspect the system to ensure compliance with the outlined specifications and regulations.

Moreover, all photovoltaic installations must adhere to the National Electric Code 2014 (NEC), specifically Articles 690 and 705. Additionally, the equipment must meet the IEEE 1547 Standard and be certified under the UL 1741 Standard. As emphasised by the GPL representative, these codes mandate that all equipment adhere to national regulations. GPL is responsible for the facilities on its side of the Point of Interconnection (POI), while customers are accountable for their facilities. Consequently, a disconnection device must be readily accessible near the GPL energy meter, solid grounding must be established, systems must account for short-circuit ratings, and they must include mechanisms to detect and cease energy generation to safeguard against overcurrent situations. Voltage regulation is to be managed by GPL, among other codes and regulations outlined in the National Electric Code. The official concluded that while the guidelines established by Guyana Power and Light, as well as the constitution, present challenges, they ultimately serve as safeguards against grid failures and prevent further unfortunate incidents.

DISCUSSION

Over the years, Guyana's solar focus has been centred on hinterland regions. This has resulted in urban locations like Anna Regina not adopting solar energy quickly despite being saddled with a high electricity unit cost of GYD$51.09/kWh and GYD$43.43 for residential with more than 75kWh and less than 75kWh, respectively and a fixed monthly charge of GYD$351 (Guyana Power and Light (GPL), 2021). The citizens have been desirous of cheaper alternatives. For example, households incur high monthly electricity costs on basic household essentials such as refrigerators, lightbulbs, and television sets, which could be lowered using solar energy. The advantages of solar as a cheaper and cleaner energy source have not been adequately utilised, based on some of the challenges identified in this study.

During this investigation, it was found that solar energy systems indeed decrease household expenditure by reducing monthly electrical bills by approximately GYD$10,233. While homes without solar energy pay an average of GYD$16,600 monthly, homes with solar energy pay significantly less at an average of GYD$6,367. Residents pay

GYD$43.43 for every kWh they use, with an additional monthly fixed charge of GYD$351.04 (Guyana Power and Light (GPL), 2021). This was not uncommon in the literature, since many other studies recorded the same results (Korcaj et al., 2015; Mondal, 2010; Stojanovski et al., 2017)

The study identified that the initial costs for the installation of solar systems were expensive for an average Guyanese in Anna Regina. The average income of the respondents was found to be GYD$181,396 monthly, while the average cost of installing these systems is GYD$1,374,226. The cost of installation of a solar system, including materials and labour, is estimated at GYD$1,042,400 for Quotation 1, GYD$1,167,380 for Quotation 2 and GYD$1,938,950 for Quotation 3, while the average cost of solar systems as obtained from the respondents was GYD$1,365,556. The income of households with solar installed averaged GYD$223,056 monthly, while households without solar averaged GYD$139,735 monthly, a GYD$83,321 difference. This means that homes without solar energy will have to dedicate all of their income for seven months to cover the cost of a solar system, which is highly unrealistic. By using a more realistic payment plan of 10% of monthly income dedicated to a solar PV system, it takes 4 years 8 months with quotation 1, 5 years 3 months with quotation 2 and 8 years 8 months with quotation 3, which is an extended period for the installation of a system.

The literature indicates that the costs of solar panels have decreased since 2013 (Kishore et al., 2025; Piper, 2022), yet this is not enough to encourage citizens of the developing world to install solar power (Grover, 2023). In Northern Nigeria, the necessary use of batteries due to the distance from the electrical grid has significantly increased the installation cost of solar systems, rendering it not viable (Adaramola, 2014). Malaysia faces the same battle of the initial cost being so high that installation is not possible (Maradin, 2021). This indicates that it is not just Anna Regina that faces the struggles of the initial cost of solar systems, but many countries around the world.

In Anna Regina, the main restraining factors were found to be the initial cost of solar systems along with maintenance costs, legal struggles and also the lack of awareness. It was already established that the high initial cost of materials makes the adoption of a solar system unviable for most people in Anna Regina. Apart from the high cost, lack of awareness was also noted as a restraint in Austria (Korcaj et al., 2015). In the study area, houses with solar systems installed had a higher knowledge of solar energy as compared to those without. Additionally, the interview with the GPL official indicated a lack of awareness as one of the major restraining factors to the adoption of the solar system. Studies in India, the USA and Australia also confirmed that lack of interest and awareness, including apathy towards solar energy, are some of the major constraints to the adoption of solar energy (Graziano et al., 2019; Jayaraj et al., 2025; Lo et al., 2018; Urpelainen & Yoon, 2015; Zhang et al., 2012). Overcast days with cloudy conditions and high levels of dust particles in the air can result in reduced productivity of solar energy (Zereg et al., 2021). These were not found as issues in Anna Regina, as noted by the electrician. The legal struggle was another factor that discouraged solar adoption. For solar systems to be set up, the National Electric Code 2014 (NEC Article 690 and Article 705, which lists a range of installation and safety regulations necessary) must be adhered to.

Recommendations

- **Availability of Loans to Support Solar Installation:** A significant barrier to the adoption of solar energy has been identified as the high initial costs associated with solar systems. Despite the Government of Guyana's exemption of taxes on imported solar materials (Guyana Revenue Authority, 2017), the overall expenses remain considerable. Introducing loan options, such as bank loans specifically designed for solar installations, could provide a viable solution to mitigate these upfront costs. This approach would enable individuals to lower their electricity bills while repaying the loan over time.
- **Public Awareness, Education and Training:** Another challenge identified is the lack of awareness regarding solar systems and their benefits. By organising seminars and distributing informative materials, the public can be educated, and the citizens can be encouraged to take advantage of the potential savings. It is essential to

conduct extensive outreach. Knowledge-sharing and training initiatives on solar photovoltaic installations to help residents understand the advantages of the systems. The use of dedicated and increased news output on the benefits of the solar system will be of added advantage.

- **Increased Government Engagement in Urban Areas:** Currently, the Government of Guyana has prioritised solar energy initiatives in hinterland regions, where access to electricity is minimal. The implementation of solar panels in these areas not only promotes development but also reduces electricity generation costs. While there have been successful efforts to establish various solar farms in both rural and urban locations, such as Lethem, support for residential solar photovoltaic usage in urban areas has been limited. By providing government subsidies, tax exemption for those who choose to adopt solar systems and fostering programs aimed at encouraging solar energy adoption in urban spaces, Guyana can make significant progress toward its goal of achieving of the increase in the share of solar PV in isolated grids to an average of 50% by 2027 and 70% by 2030. Focused support for regions like Anna Regina could greatly enhance solar production in these locales.

CONCLUSION

Despite national progress and the documented socio-economic benefits of solar energy, there is limited knowledge of what influences household-level solar adoption in urban areas like Anna Regina. This gap may constrain policy planning, slow renewable energy adoption, and limit opportunities for sustainable urban development. This research was designed to enhance the understanding of factors that could influence solar energy within the urban context of Anna Regina. The findings indicate that solar energy can effectively impact household monthly expenditures by providing substantial savings. Specifically, homes equipped with solar energy systems save approximately GYD$10,233.00 each month. This is GYD$122.796 per annum, and the benefit increases cumulatively. Notably, it was found that households lacking solar energy tend to have lower average incomes, which could potentially be improved through the adoption of solar systems. The income levels of residents are also linked to the installation of solar panels. Households without solar energy report an average monthly income of GYD$139,735.00, whereas those with solar photovoltaic (PV) systems earn an average of GYD$223,056.00. Additionally, the cost of solar systems is approximately GYD$1,374,22.00. Higher-income individuals are more likely to install solar systems, as they can afford the significant initial investment, unlike their lower-income counterparts, who often find the costs prohibitive. Other challenges associated with the implementation of solar systems include high periodic maintenance costs, legal constraints, low levels of awareness, instability of electricity and potential interference with grid functionality. The study's recommendations emphasised targeted measures to further lower the installation costs of solar energy systems in urban areas. It also outlined strategies that the government can implement to encourage the widespread adoption and incentivise of solar energy and discussed the long-term effects of increased solar energy utilisation on local economies. In addressing the cost-related limitation of the study and to enhance the robustness and comprehensiveness of the analysis, it is essential to incorporate a broader range of relevant factors, including social dynamics, institutional frameworks, and technical considerations. By expanding the data sources to include these additional elements, future studies could yield a more nuanced understanding of the complexities at play beyond economic considerations, and the analysis will be better positioned to capture the multifaceted nature of the issues at hand, ultimately leading to more informed conclusions and implications. Nonetheless, this research has yielded important insights regarding solar energy in urban areas; however, further research should be undertaken in urban environments to deepen the understanding of solar energy. As the demand for clean energy continues to grow, this research underscores the urgent need for increased adaptation of solar energy technologies, emphasising the necessity for subsidies or policies aimed at reducing the costs associated with the systems to enhance adoption in urban areas of Guyana.

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개발도상국에서의 가구 태양에너지 도입: 도전 과제와 전망

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많은 개발도상국에서는 국민의 삶의 질 향상과 환경 보호를 목적으로 태양에너지를 대체 에너지원으로 도입하고 있다. 그러나 가이아나의 도시 지역을 대상으로 한 태양에너지의 수용 및 도입에 관한 실증 연구는 매우 제한적인 상황이다. 이에 본 연구는 가이아나 안나 레지나(Anna Regina) 지역 가구를 대상으로 태양광 발전 시스템 도입 가능성을 분석하는 것을 목적으로 한다. 연구 방법으로는 혼합연구방법(mixed-methods approach)을 적용하였다. 태양광 발전(PV) 시스템을 설치한 가구와 설치하지 않은 가구를 대상으로 설문조사를 실시하였으며, 태양광 에너지 장비를 취급하는 주요 도매업체 3곳으로부터 태양광 설비 관련 거래 자료(송장)를 수집하였다. 또한 지역 전기 기술자와 가이아나 전력공사(Guyana Power and Light Inc., GPL) 관계자를 대상으로 심층 면담을 실시하였다.

연구 결과, 태양광 발전 시스템을 설치한 가구의 월평균 가계지출은 평균 GYD 10,233 감소한 것으로 나타났다. 또한 태양광 PV 시스템을 보유한 가구는 미보유 가구에 비해 월평균 소득 수준이 통계적으로 유의하게 높은 것으로 분석되었다. 태양광 설비 판매업체의 거래 자료 분석 결과, 태양광 발전 시스템 설치에 소요되는 평균 비용은 GYD 1,182,895로 나타났다. 지역 전기 기술자들의 응답에 따르면, 태양광 PV 시스템 설치를 위한 평균 인건비는 GYD 200,000이었다. GPL에 따르면, 태양광 PV 시스템 설치 승인을 받기 위해서는 가이아나 전기 검사국(Guyana Electrical Inspectorate)이 규정한 2014년 국가전기규정(National Electric Code, NEC), 특히 제690조 및 제705조를 준수해야 한다.

태양광 에너지 시스템 도입의 주요 장애 요인으로는 높은 초기 설치 비용, 유지관리 비용, 그리고 태양에너지의 장기적 경제적·환경적 편익에 대한 인식 부족이 확인되었다. 재생에너지가 제공하는 재정적 및 환경적 효과를 고려할 때, 본 연구는 태양광 에너지 시스템의 전국적 확산을 촉진하기 위한 정책적 지원과 제도적 인센티브의 필요성을 시사한다.

주제어: 태양에너지, 가계지출, 전기요금, 에너지 안보, 재생에너지, 가이아나

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