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Energy Awareness, Energy Use, and Energy-Saving Opportunities in the Caribbean: The Island Curaçao as a Case Study

Richenel R. Bulbaai [1] and Johannes I. M. Halman [1,2,*]

[1] Faculty of Engineering, University of Curaçao, Jan Noorduynweg 111, Willemstad, Curacao; richenel.bulbaai@uoc.cw
[2] Department of Construction Management and Engineering, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands
* Correspondence: j.i.m.halman@utwente.nl

Abstract: Household energy consumption represents a significant share of global energy usage, highlighting the importance of understanding the factors that influence energy use and identifying potential strategies for conservation. The Caribbean region faces unique challenges in energy sustainability, driven by its heavy dependence on fossil fuels and rising energy demand. The primary aim of this study is to evaluate the current levels of energy awareness and energy consumption among households on the tropical Caribbean island of Curaçao and to determine practical energy-saving opportunities that can significantly reduce both energy consumption and costs. This paper is one of the first to evaluate energy awareness, energy use, and energy-saving opportunities among households in the Caribbean. The study included a literature review of key theories, concepts, and energy-saving strategies, along with a telephone survey of 382 households in Curaçao to examine household energy use, the factors shaping energy behavior, and the connections between energy consumption, behavior, and household income. The main findings of this study reveal that energy-efficient appliances are predominantly used in high-income households, with much lower adoption rates in middle- and low-income households. Cost savings, rather than environmental concerns, emerge as the primary motivation behind energy-saving behavior. Notably, the study highlights that most households in Curaçao are largely unaware of the full range of energy-efficient options available to them for reducing energy consumption. Based on the field study results, several recommendations are offered to enhance energy awareness, expand energy-saving opportunities, and ultimately reduce energy usage.

Keywords: energy awareness; energy consumption; energy-saving opportunities; sustainable energy use; energy efficiency; Caribbean SIDS

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1. Introduction

Reducing energy consumption has become a critical global priority in addressing major societal challenges related to sustainability, climate change, and energy security [1,2]. The islands in the Caribbean face unique challenges in reducing energy sustainability due to their limited natural resources and isolated electricity infrastructure, unconnected to the grids of other countries, which leaves them without the option of cross-border agreements to manage intermittency. Instead, to guarantee a reliable electricity supply, expensive backup systems are needed. Electricity production on the Caribbean islands remains heavily reliant on imported fossil fuels to meet their energy needs. This results in high energy costs and significant CO_2 emissions. Raising energy awareness among consumers could significantly reduce energy consumption and encourage the adoption of renewable energy sources, helping to mitigate these vulnerabilities [3].

Since households typically consume a significant portion of around 20–30% of total final energy consumption [4], in this study we focus on energy use by households. We specifically investigate energy awareness, energy use, and the possible energy-saving opportunities for residents of the Caribbean and take the Caribbean island Curaçao as a first case study.

Several studies have been conducted in the last few decades on energy use and behavior among households [5–10]. Unfortunately, there is almost no information available about energy awareness and the adoption of renewable energy sources among households in tropical areas and more in particular in the Caribbean region. Households in tropical areas, e.g., such as the Caribbean, often have one or more air conditioners that are intensively used throughout the whole year. On the other hand, houses in the Caribbean do not need to be equipped with heating systems. This will lead to a varied composition of household appliances, along with different patterns of energy consumption and opportunities for savings. Furthermore, contrary to developed countries, many of the available appliances are often not state-of-the-art, resulting in higher energy consumption for each individual appliance [11,12]. As an initial step to address the identified gap in the literature, this paper presents a survey study involving 382 households, exploring the current state of energy awareness and consumption on the tropical Caribbean island of Curaçao. We also investigate potential differences between high-income, middle-income, and low-income households with respect to energy awareness, energy consumption, and the use of energy-efficient appliances. In addition, we investigate the per-income category, the most important drivers for residents to invest in energy-saving appliances. We further investigate to what extent residents are aware of viable energy-saving opportunities that can be implemented to reduce energy consumption and costs. The study is grounded in the context of Curaçao's unique energy landscape, which is characterized by a reliance on imported fuels, a growing interest in renewable energy sources, and the socio-economic factors influencing energy behavior.

The remainder of this paper is structured as follows: Section 2 offers a review of the literature on energy awareness, energy consumption, and opportunities for energy saving. Section 3 details the research steps taken to conduct the survey study assessing energy awareness and consumption in the residential sector of Curaçao. This is followed by Section 4. The paper concludes with Section 5, addressing the main scientific contributions, policy implications, limitations of the study, and several recommendations for future research.

2. Literature Background

Residential energy use plays a major role in global energy consumption and carbon emissions. Understanding how energy is consumed within households is essential for creating effective strategies to promote energy efficiency and conservation. This section reviews the literature on energy awareness, consumption, and saving options in the residential sector.

Energy awareness is essential for encouraging behavioral changes and fostering a culture of energy conservation within communities [13]. Energy awareness involves understanding and being conscious of energy usage, sources, and the effects of energy consumption on both the environment and the economy. It includes knowledge of energy-efficient practices, awareness of renewable energy sources, and an understanding of the personal and societal impacts of energy use [14]. In the literature, four possible options to enhance energy awareness are distinguished. This can first be done through Education and information campaigns [15], including school programs, public service announcements, and informational websites that educate the community on energy issues. The European Union Energy Efficiency Directive [16] provides measures to improve energy awareness through public awareness campaigns. Second, Feedback Mechanisms, which provide real-time feedback to residents on their energy usage through smart meters and energy dashboards, have been shown to increase energy awareness and help residents understand their consumption

patterns and identify opportunities for energy savings [17,18]. Froehlich discovered that in-home feedback technology can lead to an average reduction in energy consumption by 10–15% when feedback is provided more frequently and with greater data granularity, such as detailed energy usage data for specific appliances. Casals et al. [19] demonstrated that gamification also stimulates energy savings, resulting in an electricity saving of 3.46%. A study by D'Oca et al. [20] showed that the implementation of automated home appliances timely informs users about energy consumption, uses persuasive communication, and personalizes energy-saving prompts, resulting in reducing electricity consumption in homes on average by 18% to 57% [20,21]. Third, Local initiatives and community-based programs encourage collective energy-saving behaviors [22]. Finally, through Technological interventions, the adoption of energy-efficient appliances and renewable energy technologies also contributes to greater energy awareness by making energy savings more visible and tangible [23]. However, factors such as behavioral inertia, information overload, and economic constraints can impede efforts to increase energy awareness and promote energy-saving actions [24].

As population growth and urbanization drive increased energy demand, understanding current energy consumption patterns is vital for sustainable development. Consequently, energy consumption has emerged as one of the key factors in managing development toward sustainability [25]. Residential energy consumption varies significantly across regions, influenced by factors such as climate, building design, socio-economic status, and cultural practices. According to Newell and Raimi [26], residential energy consumption represents about 25–30% of total final energy consumption worldwide. Energy consumption patterns are heavily influenced by climatic conditions, building characteristics (age, size, and insulation quality), and socio-economic factors such as income levels and access to energy-efficient technologies. Higher-income households often have more appliances and larger living spaces, leading to increased energy consumption [27]. There are numerous strategies available for reducing energy consumption in residential areas. In addition to behavioral changes, adopting energy-efficient appliances, home insulation, the integration of renewable energy, and smart home technologies represent viable options for energy saving [28].

To mitigate environmental impacts and enhance energy efficiency in households, the implementation of Energy-saving solutions in households may be considered critical. Numerous energy-saving options are available to residents, ranging from behavioral changes and technological advancements to home improvements and renewable energy integration. This has led to a stream of research showing the many opportunities to cut down on energy use in households. De Almeida et al. [29] concluded that existing technologies and improved behavior can achieve up to 48% in energy savings. Encouraging residents to adopt energy-conscious behaviors can result in significant energy savings. Simple actions, such as turning off lights when they are not in use, lowering thermostat settings, and reducing the use of high-energy appliances, can significantly reduce energy consumption. Studies have shown that behavioral changes alone can lead to energy savings of 5–15% in households [30,31]. Furthermore, adopting energy-efficient appliances and smart home technologies is one of the most effective strategies for reducing household energy consumption. Appliances such as programmable thermostats, smart meters, home energy management systems, and appliances with energy star ratings allow residents to optimize their energy consumption [32]. Improving home insulation in walls, roofs, and floors and sealing leaks and installing energy-efficient windows will decrease the need for heating and cooling, resulting in significant energy savings [33]. Passive solar design, natural ventilation, and using high-performance building materials help reduce energy requirements for heating and cooling [34]. Key additional energy-saving options include installing rooftop solar PV systems and integrating other renewable energy sources, such as solar water heaters. PV solar systems enable residents to generate their own energy, reducing dependence on grid power and lowering energy bills. Meanwhile, solar water heating systems further decrease household energy consumption and greenhouse gas

emissions [35]. A significant body of the literature, such as that by [36–39], emphasizes the importance of retrofitting social housing with energy-efficient technologies to reduce overall consumption. Retrofitting involves upgrading existing buildings with improved insulation, energy-efficient windows, photovoltaics, heat pumps, and other installations. This can be particularly impactful in social households, where residents may lack the financial resources to invest in energy-saving initiatives independently.

There is also a growing recognition of the social factors that affect household energy use. These social factors encompass behaviors, cultural norms, socioeconomic status, and the roles of community and policy in shaping how energy is consumed in a home [40]. Behavioral attitudes toward energy conservation significantly impact household energy use [41]. Research has shown that implicit rules and expectations governing behavior significantly shape energy-related behaviors, such as heating, cooling, and electricity use [42]. For example, the study by Nolan et al. [43] demonstrated that normative messages emphasizing social comparisons (such as those regarding how their energy consumption compares to that of their neighbors) can be more effective in reducing energy consumption than purely informational campaigns. Energy use in households is also deeply embedded in the social interactions and dynamics within households. Family structure, gender roles, and household decision-making processes can all influence how energy is consumed [44]. Socioeconomic status also plays a critical role in shaping household energy use [45]. Lower-income households typically consume less energy overall, often due to financial constraints that restrict their ability to purchase energy-intensive appliances. In contrast, higher-income households are more likely to reside in larger homes that require more energy for heating and cooling, and they are also more inclined to adopt energy-efficient technologies [46]. The social aspects of energy use are also critical for the development and execution of energy policies. Public initiatives that focus on community-based social norms can foster more widespread adoption of energy conservation behaviors across diverse socioeconomic groups [47].

Based on the reviewed literature regarding energy awareness, energy consumption, and energy-saving options, one may conclude that a substantial decrease in household energy consumption can be realized. This is on the condition that knowledge about successful behavioral interventions and the adoption of effective energy-saving options are properly coordinated.

3. Materials and Methods

The objective of this study was to assess the current state of energy awareness and energy consumption among households on the tropical Caribbean island of Curaçao and to identify realizable energy-saving opportunities that can effectively reduce energy consumption and costs. To achieve this, a survey was conducted with the participation of 382 households. The research concept is illustrated in Figure 1.

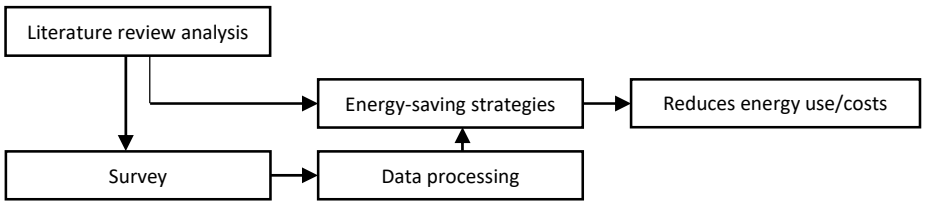

Figure 1. The research concept.

Curaçao, a Caribbean island situated in the southern Caribbean Sea, is located about 65 km north of the Venezuelan coast. It has a population of just over 150,000 residents and approximately 65,225 dwellings spread across an area of 444 km^2 [48]. Curaçao is characterized by a semi-arid to arid climate featuring distinct dry and rainy seasons. The rainy season occurs from October to January, while the dry season lasts from February to June, with July and August acting as transitional months. The island experiences warm

tropical temperatures, peaking in September with an average air temperature of 27.9 °C and an average seawater temperature of 27 °C. [49]. Throughout the year, the wind predominantly blows from east to west. Curaçao experiences relative humidity levels ranging from a minimum of 76% to a maximum of 80% [34].

The Central Bureau of Statistics in Curaçao, CBS, classifies household income in Curaçao into three categories: minimum income, middle income, and maximum income. The minimum income category includes households with a monthly average income of less than USD 1125. The middle-income category encompasses households with a monthly average income between USD 1125 and USD 2808. Finally, households with a monthly average gross income exceeding USD 2808 are categorized as having maximum income.

In the initial phase of this study, a comprehensive literature review was conducted to offer an in-depth overview of the current knowledge regarding energy awareness and consumption, both in general and specifically within the Caribbean context. We focused on essential theories, concepts, and energy-saving strategies. To accomplish this, a variety of journal database search engines, including EBSCO, Emerald, Web of Science, Academia.edu, and Google Scholar, were utilized. This eventually resulted in a selection of about 90 papers for our literature review.

In the second stage, a telephone survey was conducted. Statistics indicate that telephone surveys remain one of the most significant methods of data collection [50]. A telephone survey involving 382 households in Curaçao was conducted to assess household energy consumption, the factors influencing energy behavior, and the connections between energy use, behavior, and household income. Participants were randomly selected to take part in the survey.

A questionnaire featuring eight open-ended questions (see Appendix A) was developed for our survey, which was conducted via telephone over a four-month period. Calls were made during both daytime and evening hours by students from the Faculty of Engineering at the University of Curaçao (UoC). The first author provided these students with the necessary instructions for conducting the interviews. Progress was monitored on a regular basis. The procedure of the telephone survey that was used was as follows:

1. the interviewer introduces himself/herself;
2. a short and clear description of the survey;
3. an explanation of the procedure of the survey;
4. an estimation of the time needed to complete the survey;
5. the respondent is asked to join the survey; and
6. after having completed the survey, the interviewer extends gratitude to the respondent.

A telephone survey has both advantages and disadvantages. The primary benefits noted in this survey included its accessibility, as most households in Curaçao have fixed-line telephones, and the process was quick and straightforward. However, the main drawbacks of a telephone survey are that the interviewer cannot observe the respondents' body language, the questions must be relatively simple, and respondents may be less inclined to participate if contacted at an inconvenient time [50]. In fact, during the survey, the interviewers had to call some respondents back because the initial call was made at an inconvenient time.

After the survey, the data collected from each household were processed. Subsequently, the average electricity usage of the appliances was gathered from various retailers and from Aqualectra, the government-owned provider of water and electricity in Curaçao. It is important to note that a single household may have multiple appliances of the same type.

The annual energy consumption of an appliance is calculated by multiplying the total number of appliances by the appliance's power, the daily usage time, and then multiplying that result by 365, as shown in Equation (1):

$$E = P \times t \times n \times 365 \quad (1)$$

where:

E: is the energy use of the appliance
P: is the power of the appliance in kW
t: is the time used per day
n: is the total number of appliances

Finally, based on the literature and survey results, policy recommendations were developed to reduce household energy use and realize lower household energy costs.

4. Results Findings of the Conducted Household Energy Survey

This section outlines the results and analysis of the telephone survey conducted. Table 1 provides an overview of household sizes based on the number of individuals (p) living in each residence.

Table 1. The number of persons per household (n = 382).

Household Sizes	1p	2p	3p	4p	5p	6p	>6p	Total
Number of households	65	108	88	66	36	11	8	382

In Curaçao, two-person households are the most prevalent, making up approximately 28% of all households. The average household size in Curaçao is around 2.8 individuals, which is comparable to household sizes in Europe. According to [51], the average household size in the European Union (EU) was 2.3 persons in 2022. Among European Member States, this figure ranged from 3.1 persons in Slovakia, 2.9 in Poland, and 2.7 in Croatia to 2.0 persons in Denmark, Germany, Lithuania, and Sweden, with Finland reporting the lowest average at 1.9 persons.

Table 2 summarizes the distribution of households across income categories for both the latest conducted 2011 census by the Curaçao Bureau for Statistics and the survey. As can be seen, approximately 27% of the households in the Curaçao energy survey fall into the low-income category, 38% are classified as middle-income, and 33% are considered high-income.

Table 2. Number of households per income categories.

Income Categories	Percentages and Number of Households	
	Census 2011	**Survey 2023**
Low income < 1125 USD	(30.0%)	115 (27.0%)
Middle income: 1125–2808 USD	(32.0%)	122 (38.0%)
High income > 2808 USD	(33.0%)	126 (33.0%)
Unknown	(5.0%)	19 (3.0%)
Total	(100%)	382 (100%)

Regarding the survey question, "Do you take actions to save energy?", 347 participants (91%) indicated that they do take measures to conserve energy, while 35 respondents reported that they do not. The participants were also asked about their motivations for saving energy. The findings showed that financial concerns were the primary reason for energy-saving actions, followed by environmental considerations (see Table 3). Notably, a higher percentage of middle-income households save energy for environmental reasons, whereas low-income households are more likely to save for financial reasons. These findings align with a study by [52], which indicated that individuals in the low-income category are less inclined to save energy for environmental reasons. Notably, a significant majority of respondents in the low-income group (79%) save energy primarily for financial reasons, compared to 36.1% in the middle-income category and 37.2% in the high-income category. Additionally, consistent with previous research by [53], 89.06% of respondents reported being aware of their household power consumption and expressed a willingness to install a home automation system to lower their electricity bills.

Table 3. Reasons for saving energy based on income categories.

No	Motives to Save Energy	Low-Income Households	Middle-Income Households	High-Income Households	Total Households
1	Financial	79.0%	36.1%	37.2%	50.1%
2	Environment	0.9%	41.5%	15.5%	19.6%
3	Environment and financial	13.1%	11.6%	32.6%	19.4%
4	No motives (do not take action)	7%	10.8%	14.7%	10.9%
5	Total	100%	100%	100%	100%

Table 4 summarizes the energy-saving practices reported in the Curaçao energy survey, along with their frequency of application by income category. When asked if they took measures to save energy, over 92% of participants in the low-income category, 89% in the middle-income category, and 90% in the high-income category responded affirmatively. The survey also inquired about specific actions taken to conserve energy. Hori et al. [54] observed that the initial step many individuals take toward more energy-efficient behavior is turning off lights. As shown in Table 4, the findings from this survey align with [54], revealing that turning off lights and appliances was the most common energy-saving action across all income categories. Despite the majority of respondents indicating they engaged in energy-saving practices, the survey results suggest that they primarily utilized basic methods for energy conservation.

Table 4. Percentage of times energy-saving methods were applied.

No	Energy-Saving Methods	Low-Income Households	Middle-Income Households	High-Income Households	Total Households
1	Turning off lights and appliances when they are not used	94.3%	96.6%	92.2%	94.3%
2	LED Lamps	82.0%	85.0%	82.9%	83.3%
3	Energy-saving air conditioner (AC) Inverter	49.0%	80.3%	89.9%	73.7%
4	LED-TV	74.0%	79.6%	79.8%	77.9%
5	Inverter refrigerator or efficient refrigerator	16.0%	54.4%	64.3%	45.7%
6	Inverter washing machine or efficient washing machine	9.40%	31.3%	50.3%	31.0%
7	Energy-saving lamps	15.1%	30.6%	33.3%	26.6%
8	Candle	0.9%	0.6%	0.7%	0.7%
9	Pool pump timer			0.7%	0.2%

The survey results indicate a positive correlation between household income and the use of energy-efficient appliances. High-income individuals are generally better positioned to purchase these products compared to their low-income counterparts, who, in turn, tend to take more proactive measures, such as turning off appliances and lights when not in use. These findings align with those of [55]. Additionally, as noted by [56], higher-income households typically live in newer and larger homes, equipped with more appliances and energy-efficient features. Conversely, low-income households are less likely to invest in energy-efficient appliances, but they do engage in other energy-saving behaviors. The respondents in this survey appeared unaware of many available energy-efficient options, such as smart power strips, inverter appliances, timers, motion sensors, and insulation. As a result, they primarily relied on basic methods for energy savings. The survey findings indicate that energy-efficient air conditioners and lamps are the most commonly utilized appliances in their homes.

Numerous studies have highlighted awareness as a key factor in promoting energy savings. For example, Hori et al. [54] propose a positive correlation between awareness

and energy conservation. In our survey, we inquired whether respondents believed energy saving should be encouraged in Curaçao and their reasons for this belief. Approximately 76% of those in the low-income category and 65% in the middle-income category responded affirmatively, while about 67% of high-income respondents agreed. The predominant reason given was the need for more information about energy-saving practices. According to [29], energy awareness can be raised through labeling schemes such as the EU Energy label, awareness campaigns on TV and radio, and the expansion of energy labels for different types of products.

This study also revealed that 38% of respondents in the low-income category perceive the prices of energy-efficient appliances as extremely high, with an additional 47% indicating that the prices are high. In the middle-income category, 19% of respondents reported that prices are extremely high, while 51% considered them high. Among high-income respondents, 8% mentioned that prices are extremely high, and 35% considered them high.

Despite the higher price tags associated with energy-efficient appliances, their usage in Curaçao has risen significantly across all three income categories in the past six years [57].

Table 5 presents the types and quantities of appliances found in households in Curaçao categorized by income level, along with the total annual energy consumption of these appliances. The average electricity usage for each appliance type was sourced from various retailers and Aqualectra, the government-owned provider of water and electricity in Curaçao. It is worth mentioning that a single household may own multiple appliances of the same type. The survey results in Table 5 indicate that air conditioners (including both inverter and non-inverter models) are the most energy-intensive appliances in Curaçao's residential sector, followed by electric cooking appliances (which include electric stoves and ovens) and refrigerators with freezers.

Table 5. The quantity of appliances and their total annual energy consumption (n = 385).

No	Type of Appliances	Appliances Low-Income Households	Appliances Middle-Income Households	Appliances High-Income Households	Total Number of Appliances	Energy Use (kWh) per Year
1	Inverter air conditioner	70	224	298	592	1,608,864
2	Refrigerator with freezer	108	145	142	395	462,265
3	Non-inverter air conditioner	27	32	37	96	402,296
4	Electric oven	32	49	65	146	333,360
5	Electric stove	9	27	39	75	298,080
6	Television	158	259	314	731	294,041
7	Small electric boiler	12	54	94	160	201,600
8	Freezer	23	24	51	98	129,005
9	Router	90	127	146	363	94,090
10	TV-Box/Telecommunication company	88	132	122	342	88,646
11	Iron	108	133	133	374	84,823
12	Desktop	15	40	67	122	70,272
13	Fan	195	315	346	856	67,795
14	Indoor light bulb	66	201	242	509	65,966
15	Laptop	40	143	210	393	50,933
16	Electric dryer	8	19	27	54	44,064
17	Indoor led lamp	585	1034	1195	2814	42,548
18	Outdoor led lamp	203	482	716	1401	42,366
19	Outdoor fluorescent lamp	175	198	167	540	39,972
20	Outdoor light bulb	23	45	78	146	37,843
21	TV-box/Android	37	114	175	326	28,166
22	Microwave	60	100	103	263	26,684
23	Electrical boiler for bathing	3	10	10	23	25,308
24	Rice-cooker	75	104	112	291	20,873
25	Semi-automatic washing machine	83	64	45	192	18,931
26	Automatic washing machine	23	83	87	193	18,528
27	Electric kettle	24	74	76	174	6264
28	Indoor fluorescent lamp	67	61	27	155	6407
29	Refrigerator without freezer	2	2	4	8	2400
30	Printer	28	78	93	199	239
31	Non-automatic washing machine	0	0	0	0	0

5. Discussion

5.1. Scientific Contributions

The Caribbean islands are heavily dependent on imported fossil fuels, resulting in high electricity costs, environmental concerns, and energy insecurity. With increasing concerns about energy security and climate change, many Caribbean islands are increasingly exploring renewable energy sources and energy efficiency measures as solutions to these issues. In recent years, a number of studies [57–59] have focused on the drivers and inhibitors to develop and implement renewable energy in the Caribbean region. In addition, the studies of [33,34] have specifically examined the implementation of passive building principles for homes in Curaçao and strategies to reduce standby energy consumption in households on the island.

Our study adds to various portions of the energy efficiency literature. The studies most closely related to our paper are the ones that address energy awareness among households. Hassan et al. [5] convincingly demonstrate that increasing energy awareness through a reward system has a significant impact on reducing energy consumption. Rosak-Szyrocka and Żywiolek [10] provide an extensive literature review on household energy awareness. The results of their study among 1097 respondents in Poland indicate that the respondents possess knowledge about energy and the factors driving its increased consumption, yet they lack awareness of the importance of energy conservation and its implications for the environment. Li et al. [7] conclude, on the basis of a nationwide household survey in China, that awareness alone does not necessarily reduce energy consumption. A household's subjective attitude can greatly influence the decision to purchase more energy-efficient products and promote pro-environmental choices. Bülbül et al. [6] conclude that research on the role of Turkish households in environmental issues remains limited, highlighting the need for media campaigns to raise public awareness about carbon footprints. An interesting observation was made by Gajdzik et al. [60] on the energy behaviors of prosumers in Polish households, and they found that those who generate energy through photovoltaic panels and heat pumps tend to exhibit a general tendency toward pro-ecological behavior. They recommend prioritizing the promotion of prosumers and encouraging the use of environmentally friendly energy in the economy.

This paper is one of the first to evaluate energy awareness, energy consumption, and energy-saving opportunities among households in the Caribbean. Utilizing a survey study with participation from 382 households in Curaçao, we gathered insights into household energy use. Investigating the energy consumption and behavior on the Caribbean islands is crucial for several reasons. First, there are significant differences in device usage compared to other countries. For example, the prevalence of air conditioning per household in the Caribbean is considerably higher than in Europe. Additionally, developed countries tend to have a much greater number of devices compared to those in developing countries. Furthermore, awareness levels regarding energy use are generally higher in developed countries than in developing regions such as the Caribbean islands [12]. One of the key findings of this research is the disparity in the use of energy-efficient appliances between high-income households and those with middle to low incomes. It appears that energy-efficient appliances are predominantly utilized by high-income households, whereas middle- and low-income households tend to use them less frequently. This result highlights a significant socioeconomic aspect of energy use behaviors, where affordability is a crucial factor influencing the adoption of energy-saving technologies.

This research also indicates that financial reasons, and to a much lesser extent, environmental concerns, are the primary motivators for energy conservation. While environmental concerns are often mentioned as reasons for adopting energy-efficient practices, it is clear that in Curaçao, financial considerations are considered more important. This emphasizes the importance of presenting energy-saving projects in ways that focus on economic benefits, especially for households with limited financial resources. Additionally, by informing users about their current consumption habits and suggesting more efficient practices [61]. This research further highlights that despite the potential for substantial energy savings and

cost reductions, most households in Curaçao remain unaware of the various energy-efficient alternatives available to them.

5.2. Policy Implications

The results of this study also have some specific policy implications in terms of public awareness campaigns [15], the adoption of energy-efficient building regulations [34], and financial measures such as tax incentives, subsidies, and regulatory approaches for energy efficiency [62].

Public campaign programs are needed to make households in Curaçao aware of a variety of energy-saving appliances, such as PV panels, intelligent power bars, time switches, and motion sensors. This is in addition to inverter air conditioners, inverter refrigerators, and LED lamps, of which the cost-saving benefits are already better known. The energy-efficiency-promoting campaigns may include the publication and distribution of simple and well-illustrated manuals, promotion campaigns on TV, radio, and in social media, as well as information meetings in community centers.

Significant energy savings can also be achieved by implementing passive building design principles for houses in tropical areas [33,34]. Passive building designs will increase the internal comfort by facilitating natural ventilation through windows and doors and by protecting against direct, bright sunlight. This will also decrease the energy used by air conditioners. From a policy perspective, it is recommended to adapt the existing building regulations in Curaçao by making use of passive building design principles mandatory for all new constructions.

Important barriers to adopting energy-efficient technologies include a lack of capital and insufficient information among residents, as well as households perceiving the upfront costs as too high [62]. House owners may also prioritize factors other than energy efficiency when making decisions, may lack knowledge about energy efficiency, or may be resistant to change. Therefore, policymakers need to create and implement financial measures that encourage the residential sector to become more energy efficient by removing these barriers. Examples of effective policies include import duties and subsidies that significantly enhance the demand for energy-efficient appliances.

Import duties and subsidies that significantly boost the demand for energy-efficient appliances are examples of effective policies [63–65]. Additionally, regulatory approaches such as bans, mandates, or price regulations have also proven effective. For instance, Cao et al. [66] conclude that banning incandescent lamps is one of the most effective policies for promoting the adoption of more energy-efficient lighting technologies.

Implementing these types of energy policies will not only increase energy awareness among residents in Curaçao but may consequently also lead to significant energy savings in households.

5.3. Future Research

The limitations of this study provide several avenues for future research. First, it is advised to extend the conducted survey and the estimation of appliance energy use by conducting field studies in order to derive more accurate and comprehensive methods for measuring appliance consumption and to capture actual usage patterns more effectively.

Given the noted importance of implementing energy policy measures that are focused on increasing energy awareness among energy users, we suggest monitoring the progress in developing and implementing energy policy measures and evaluating the relative effectiveness of these policy measures on a regular basis.

Curaçao's economy can be described as a relatively high-income economy within the Caribbean, featuring a well-developed infrastructure, particularly in the tourism and financial services sectors. Additionally, activities linked to the port of Willemstad, including shipping and international trade, make significant contributions to the economy. To achieve a more comprehensive understanding of energy use, behavior, and efficiency across the Caribbean region, it is advisable to expand this research to include other countries with

lower living standards. It is anticipated that countries such as Cuba, Haiti, and Venezuela will have fewer electrical appliances and less advanced technology. Consequently, households in the Caribbean with lower standards of living may be expected to use less energy and demonstrate a greater willingness to save energy.

6. Conclusions

This paper is one of the first to evaluate energy awareness, consumption, and saving opportunities among households in the Caribbean, using the island of Curaçao as a case study. Following an extensive literature review on energy use, behavior, and efficiency, a survey was conducted in Curaçao to gain insights into local energy practices and efficiency.

This study identified air conditioners, followed by electric cooking appliances and refrigerators, as the highest consumers of electrical energy in households. In a survey involving 382 households, about 91% of respondents reported taking measures to save energy. Cost savings, rather than environmental considerations, seem to be the primary motivation for energy-saving behaviors. The results also indicate that many households in Curaçao are largely unaware of the various energy-efficient options available to them for reducing costs.

The survey results also indicate a positive correlation between household income and the use of energy-efficient appliances. High-income respondents are better positioned to purchase these appliances, whereas low-income participants are more likely to engage in behaviors such as turning off appliances and lights when they are not in use. This study further indicated a clear income-based difference in the perception of energy-efficient appliance prices in Curaçao. A significant majority of low-income respondents view these prices as excessively high, while this perception diminishes notably among middle- and high-income groups.

Despite the higher cost of energy-efficient appliances, their usage in Curaçao has significantly increased over the past six years. Most households depend on familiar energy-saving devices, such as energy-efficient air conditioners and lamps, while remaining unaware of other potential energy-saving options, including smart power strips, inverter appliances, timers, motion sensors, and insulation. This lack of awareness will hinder the broader adoption of energy-saving practices and highlight the urgent need for targeted education and engagement initiatives. Decreasing energy consumption through behavioral changes can also play a role in the solution, but it is crucial to understand the factors that influence energy-saving behaviors.

This study also found that the majority of respondents in all three categories concurred that energy saving should be encouraged in Curaçao.

Based on the findings from the field study, recommendations are provided to enhance energy awareness, expand energy-saving opportunities, and ultimately reduce energy consumption.

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Appendix A Survey Questions Energy Use by Households in Curaçao

1. How many people live in your household?
2. What is the total monthly income of your household?
3. Do you practice energy saving?

4. What motivates you to save energy?
5. What methods do you use to save energy?
6. Which appliances do you utilize?
7. How do you determine the cost of energy-efficient appliances?
8. Are you seeking additional information on energy conservation?

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