An Assessment of Residential Solar Energy Access and Consumption Patterns in Adamawa State

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Abstract

This study conducts a comprehensive assessment of residential solar energy access and consumption patterns in Adamawa State, emphasizing the relationship between Access to Solar Energy Consumption and key independent variables. Through rigorous regression estimation, Solar Energy Awareness, Community-Based Programs, Households Monthly Income, and Primary Use and Consumption of Solar Energy emerge as influential predictors. The model, with an impressive R-squared value of 0.769184, effectively elucidates 76.9% of the variability in Access to Solar Energy Consumption, providing nuanced insights into the strength and direction of these relationships. The assessment sheds light on the intricate dynamics of solar energy dynamics in Adamawa State, offering valuable insights for policymakers, researchers, and stakeholders keen on promoting sustainable energy practices. The study proposes targeted policy recommendations, including the promotion of solar energy awareness, strengthening community-based programs, addressing income disparities for equitable access, encouraging sustainable consumption patterns, supporting research and development for innovation, and emphasizing ongoing monitoring and evaluation of policy impact. These recommendations aim to guide strategic initiatives that foster sustainable energy practices, ensuring informed decision-making and fostering a greener, more equitable energy landscape in Adamawa State.

Keywords: *Solar Energy. Consumption, Access and Residents.*

1.0 Introduction

Africa, and Nigeria in particular, boasts abundant solar energy resources, with the potential to generate vast amounts of clean and sustainable electricity. Harnessing this potential is not only an environmental imperative but also a strategic opportunity to drive economic growth, improve living standards, and achieve the United Nations Sustainable Development Goals.

However, the traditional reliance on fossil fuels for energy production has brought about environmental challenges and concerns about the depletion of finite fossil fuel reserves. This has led to a global imperative for transitioning to sustainable and renewable energy sources to combat climate change (Li et al., 2022). The evolution of the global energy landscape has been marked by a shift from fossil fuels to a diverse array of energy technologies, including nuclear, hydropower, and solar energy. However, this transformation has raised questions about the adequacy of our energy production and consumption (Mohammed et al., 2017).

In this context, it is worth noting the remarkable growth of renewable energy sources on a global scale. Hydropower has emerged as the largest renewable energy source, increasing its capacity from 2,158.85 TWh in 1990 to 4,326.76 TWh in 2022. Simultaneously, solar energy has shown exponential growth, surging from a mere 0.39 TWh in 1990 to a substantial 1,289.27 TWh in 2022. This expansion is driven by growing environmental concerns and concerted efforts by world leaders to combat climate change by harnessing the potential of renewable energy sources, particularly solar energy (Ugwu et al., 2022; WEC, 2020).

In Nigeria, as in many other nations, the challenge lies in providing reliable energy access to its population while promoting the adoption of clean and renewable energy sources. Hydropower generation in Nigeria has increased from 5.60 TWh in 2012 to 8.76 TWh in 2022, while solar power generation has risen from 0.02 TWh to 0.05 TWh during the same period (Ugwu et al., 2022).

Africa, as a continent, boasts abundant solar energy potential, holding 60% of the world's best solar resources according to the International Energy Agency (2023). The World Bank's Global Solar Atlas recognizes Africa's solar potential as a unique opportunity to provide affordable, reliable, and sustainable electricity, particularly in areas with pressing economic and quality of life needs (World Economic Forum, 2023). Remarkably, Africa's solar energy potential is estimated at around 60 million TWh per year, dwarfing Europe's 3 million TWh per year (Ugwu et al., 2022).

Despite this potential, Nigeria faces a significant challenge, with approximately 85 million Nigerians lacking access to grid electricity, representing 43% of the nation's population and making Nigeria the world leader in energy access deficit. This deficit has severe economic implications, resulting in annual losses estimated at $26.2 billion (₦10.1 trillion), equivalent to 2% of GDP. Nigeria also struggles to provide reliable electricity, ranking 171st out of 190 countries in electricity access according to the World Bank Doing Business report (2020). In response, the Rural Electrification Agency (REA) under the Nigerian Electrification Programme (NEP) aims to address this issue by providing off-grid electricity to underserved and unserved areas, including the deployment of solar hybrid power plants in federal tertiary institutions and teaching hospitals (Akinwole, 2022).

The REA's program allocates funding for various aspects, including $213 million for solar hybrid Mini grids, $75 million for stand-alone solar home systems, $250 million for the Energizing Education Programme, $20 million for Energy Efficient Equipment and Productive use of appliances, and $37 million for technical assistance. To date, the agency has deployed over 995,000 solar home systems, connecting more than a million households and businesses. Beyond providing clean and reliable energy, this initiative fosters electricity access for households, micro, small, and medium enterprises (MSMEs), and public education institutions. Understanding energy consumption patterns through behavioural research is essential to optimizing energy use (Akinwole, 2022).

Residential energy consumption is on the rise globally, with the residential sector accounting for a substantial portion of energy demand, especially in developing economies like Nigeria. Approximately 65% of Nigeria's annual energy consumption is attributed to the residential sector. Enhancing energy efficiency in this sector aligns with the United Nations Sustainable Development Goal 7: affordable and clean energy (United Nations, 2015).

Urban areas are major energy consumers, with 70% of global energy supply directed towards cities in 2015, and a projected 90% of global energy growth expected to occur in urban areas (Mallapaty, 2020). Analysing energy demand across various sectors, including electricity, heating, cooling, industry, buildings, and transportation, is crucial for developing future renewable and sustainable energy solutions (IEA, World Energy Outlook 2008; McKinsey, 2022). Understanding energy demand patterns serves as a foundation for energy planning, policy formulation, and the pursuit of the United Nations' Sustainable Development Goals (IEA, World Energy Outlook 2008).

In the pursuit of reduced energy consumption, identifying energy-saving potential in various sectors and implementing effective efficiency strategies is essential. Household characteristics, behavior, appliances, and external factors such as location and climate significantly influence energy consumption patterns. While research on residential energy consumption is growing, there is still a need to focus on efficiency, considering factors such as household income, age, education, housing, and climate that impact household energy efficiency (Mohammed et al., 2022).

1.1 Problem Statement/Justification

Efforts have been made by both government, development partners, and private businesses to transform the solar energy landscape in Nigeria, including Adamawa State. These initiatives have been driven by the recognition of the critical role solar energy plays in addressing the country's energy challenges, reducing greenhouse gas emissions, and fostering sustainable economic development. Despite these efforts, significant obstacles persist, underscoring the need for a comprehensive examination of the state of residential solar energy access and consumption patterns in Adamawa State.

One of the foremost problems that necessitates this research is the enduring energy deficit in Adamawa State. The unreliability of the conventional electricity grid continues to plague households, businesses, and essential services. This deficit not only hampers economic activities but also jeopardizes the quality of life for residents and stymies the region's developmental potential. Consequently, there is a pressing need to investigate the extent and implications of this energy shortfall, particularly in the context of solar energy adoption.

Moreover, the study aims to provide a better understating of the problem of slow pace of residential solar energy adoption in Adamawa State, despite the inherent benefits it offers. Solar energy, as a clean and renewable source, has the potential to provide a dependable and sustainable electricity supply. However, the factors influencing its adoption, whether they are economic, technological, regulatory, or sociocultural, remain insufficiently understood. This knowledge gap calls for a rigorous investigation to discern the barriers that hinder solar energy's wider embrace in the region.

Another critical facet of the problem relates to the economic and environmental dimensions of Adamawa State's energy deficit. The current reliance on non-renewable energy sources engenders substantial economic losses that reverberate throughout the region. These losses encompass direct economic costs and indirect impacts on education, healthcare, and overall productivity. Additionally, the environmental ramifications of relying on fossil fuels contribute to global climate change and local environmental degradation. Evaluating the potential economic and environmental advantages of substantial residential solar energy adoption is vital to inform sound policy decisions and to underline the research problem further.

The primary concern at the core of this research is twofold: firstly, to discern the extent of household access to solar energy within Adamawa State, Nigeria, and secondly, to elucidate the patterns of consumption among these households. Despite various initiatives aimed at expanding solar energy availability, the precise level of access and the dynamics of consumption within households remain insufficiently understood. This is characterized by its multidimensional nature, encompassing not only the barriers to initial adoption but also the utilization patterns that dictate the efficacy and sustainability of solar energy systems. Addressing this issue is paramount, as it informs strategies to enhance solar energy access and encourages optimized utilization, thereby facilitating the transition towards a more sustainable, reliable, and equitable energy landscape in Adamawa State.

1.2 Objectives of the Study

(i) To assess the current level of household access to solar energy infrastructure and technologies in Adamawa State, Nigeria, including the geographical distribution and coverage of solar installations.

(ii) To analyse the socio-economic, technological, and regulatory factors influencing the adoption of residential solar energy systems among households in Adamawa State.

(iii) To investigate the patterns and determinants of solar energy consumption within households, including usage behaviours, energy-saving practices, and the impact of solar energy on daily routines and livelihoods.

To evaluate the economic and environmental implications of household access to and utilization of solar energy in Adamawa State, with a focus on potential cost savings, reduction in greenhouse gas emissions, and contributions to local and regional sustainable development goals.

2.0 Literature Review

The global imperative to achieve carbon neutrality by 2050 has led numerous countries to commit to immediate measures to reduce carbon emissions (Mohammed et al., 2022). One pivotal sector in this transition is the power and energy sector, which is increasingly shifting towards renewable energy sources, with solar and wind power gaining prominence. Solar photovoltaic (PV) technology, in particular, stands out due to its wide availability and ease of installation, making it a practical option for power generation across various scales. Furthermore, when coupled with energy storage systems, solar PV minimizes reliance on traditional grids, making it well-suited for electrifying residential buildings, campuses, hospitals, defense facilities, electric vehicles, and green hydrogen production (Iqbal et al., 2022).

Solar energy can be harnessed directly through photovoltaic panels, where photons from sunlight generate electric currents through the photoelectric effect. Alternatively, an indirect approach involves using solar collectors to focus sunlight for heating water or enclosed spaces, referred to as concentrating solar power (Iqbal et al., 2022; Ozoegwu et al., 2017). Solar energy offers a promising solution to address energy, environmental, and global challenges, particularly in contrast to the detrimental effects of fossil fuel combustion, which consistently leads to energy crises and environmental pollution. The attractiveness of solar energy arises from its renewable nature and wide availability, positioning it as a sustainable alternative to conventional grid power (Iqbal et al., 2022).

Numerous studies have elucidated eight distinct ways in which solar energy can enhance organizational productivity and benefit employees. These advantages include cost reductions in operations, improved return on investment, minimal maintenance requirements, promotion of a clean and eco-friendly environment, boosted employee morale, and enhanced public relations (WEC, 2020; Mohammed et al., 2022). In typical office operations, various electric-powered machines and equipment demand 8-10 hours of electricity supply daily, resulting in substantial monthly electricity bills (Abam et al., 2014; Oyedepo, 2012). The adoption of renewable and sustainable solar power substantially alleviates these costs, freeing up funds for new projects and investments that enhance organizational efficiency.

Fostering a clean and green environment is paramount for employee well-being and overall organizational performance. The absence of greenhouse gas emissions associated with solar energy maintains the office environment free from pollution, fostering improved employee health and energy (Oyedepo, 2012). Motivated and healthy employees tend to exhibit enhanced productivity, a prerequisite for adhering to project schedules and deadlines, ultimately bolstering organizational efficiency.

Energy shortages entail severe consequences, including economic decline, lower living standards, reduced productivity, citizen hardships, and other negative impacts. Conversely, a stable and reliable energy supply is indispensable for a nation's development. A dependable electricity supply plays a pivotal role in economic growth, poverty reduction, industrial expansion, agricultural development, manufacturing, commerce, infrastructure enhancement, employment generation, and security (Ikem et al., 2016; Karatasou et al., 2019; Oseni, 2012; Oyedepo, 2012; Rafindad, 2016; Ayodele and Ogunjuyigbe, 2015; Akuru et al., 2017; Anumaka, 2012). Abundant energy availability is also pivotal for providing fundamental necessities and services such as food, water, housing, healthcare, and education (Anumaka, 2012).

Approximately 1.2 billion individuals still lack access to stable modern energy sources, with nearly half of them residing in sub-Saharan Africa. Nigeria, with its substantial population, accounts for approximately 100 million citizens without access to clean and reliable energy (Mohammed et al., 2022; Chanchangi et al.; Yakubu & Ifeanyi-Nwaoha, 2017). Until recently, renewable energy, excluding hydroelectric power, contributed negligible electricity production, as reported by the World Bank (2017). However, this status quo is undergoing transformation with the aggressive development of solar energy installations. According to the World Energy Council (WEC), Nigeria's leaders grapple with critical uncertainties, including energy poverty, electricity prices, energy subsidies, and energy efficiency, necessitating government attention in 2020.

Empirical studies have underscored the potential of solar and wind resources in Northern Nigeria for sustainable development (Ajayi et al., 2016). Analytical reviews of renewable energy policies in Nigeria have suggested that renewable resources can decentralize energy supply and enhance energy security (Akimbami, 2001). Emphasizing the potential of renewable energy in Nigeria, researchers have suggested the possibility of achieving a 100% renewable energy supply, albeit with substantial financial commitment (Akuru et al., 2017). To address the increasing energy demand driven by population growth, studies have recommended the exploitation of available renewable energy sources to diversify the energy supply (Ohunakin, 2010). Recognizing the limitations of government funding for electricity supply, recommendations have been made to involve private and foreign investors in promoting renewable energy integration and reducing low access to electricity in rural areas (Anumaka, 2012). Moreover, renewable energy has been proposed as a means to combat energy poverty in rural areas, addressing the energy deficit resulting from rapid population growth (Mohammed et al., 2017).

2.1 Research Gap

While the literature provides valuable insights into the benefits of solar energy adoption, particularly in organizational settings, there is a noticeable research gap regarding the specific adoption patterns and challenges faced by households in accessing and utilizing solar energy in Adamawa State, Nigeria. Existing studies have predominantly focused on broader energy policies, economic implications, and organizational contexts. Therefore, this study aims to bridge this gap by conducting a comprehensive analysis of residential solar energy access and consumption patterns in Adamawa State, with a focus on understanding the factors influencing adoption and assessing the impact on household energy costs, environmental well-being, and overall living standards.

2.2 Theoretical Framework

This study is grounded in the framework of endogenous growth theory, also known as the new growth theory. This theory emerged in response to the shortcomings of the neoclassical (exogenous) growth theory. Introduced by Romer in 1986, it fundamentally incorporates knowledge as an input in the production process. The primary objective of this theory is to elucidate long-term growth by internalizing the factors driving productivity growth and technical progress within a given economic unit, such as households.

The central assumptions of this theory encompass increasing returns to scale due to positive externalities, the significance of human capital (comprising knowledge, skills, and training of individuals), and the pivotal role of generating new technologies for sustained growth. Additionally, private investments in research and development are posited as the primary driver of technological progress. The theory also posits that knowledge or technical advancements are non-rival goods.

In the context of the new growth theory, the rate of savings plays a critical role in determining long-term economic growth. Within this framework, higher levels of savings and capital formation enable increased investments in human capital development and research and development. The model predicts that an economy can achieve perpetual growth as long as it continues to generate new ideas and technological advancements. Similar to the exogenous growth theory, the endogenous growth theory advocates the convergence of nations through the diffusion of technology. This entails poorer countries gradually catching up with wealthier nations by imitating technology, as seen in emerging economies like Nigeria. Importantly, technological progress in this theory is intrinsically linked to investment in research and technology, with technology considered an endogenous factor that can be related to energy.

Most technologies available at any given time are reliant on the availability of sufficient energy to operate. This includes machinery, plants, and similar equipment. In the absence of an adequate energy supply, particularly electricity, these technologies become practically unusable. This assertion aligns with the laws of thermodynamics, which stipulate that no production process can function without energy conversion. Energy is not the sole determinant of technology, but it is a crucial prerequisite for its utilization. The conversion of raw energy into a usable form is inherently technology-dependent.

Considering the technology-centric nature of energy production, it is noteworthy that energy production is capital-intensive. The generation of usable energy necessitates substantial machinery and infrastructure. Consequently, substantial capital investments are imperative not only for energy production but also for achieving energy efficiency. To validate the endogenous growth model, this study will incorporate capital, labor, and various energy sources into the model's specifications.

3.0 METHODOLOGY

3.1 Description of Study Area

Adamawa State is located in northeastern Nigeria, situated at approximately 9.3333° N latitude and 12.5833° E longitude. With a population of over 4 million people, it is a state characterized by its diversity and economic activities.

The state's economy is primarily agrarian, with a focus on crops such as maize, millet, yams, rice, and livestock farming. Trade and commerce also play a significant role, contributing to economic development in various urban centers.

In terms of education, Adamawa State hosts a variety of primary, secondary, and tertiary institutions, including universities, colleges, and vocational training centers.

Income levels in the state vary, with some urban areas experiencing higher incomes due to trade and commerce. However, poverty remains a significant challenge, particularly in rural areas, where access to basic services can be limited.

Energy challenges are prevalent in Adamawa State, including inadequate access to reliable electricity. Many households in rural areas rely on traditional energy sources such as firewood and kerosene for cooking and lighting. This situation has spurred interest in alternative energy sources like solar power as a means of addressing energy deficits.

Adamawa State's geographical location provides it with abundant sunlight throughout the year, making it highly conducive for solar energy generation. The state possesses significant untapped solar energy potential, which could be a key solution to improving access to electricity and reducing reliance on less sustainable energy sources.

3.2 Research Design

In this study, a mixed-method research design will be employed. This approach combines both quantitative and qualitative data collection and analysis methods to provide a comprehensive understanding of residential solar energy access and consumption patterns in Adamawa State.

3.3 Sampling Procedure

This study intends to use multistage sampling technique to select the study locations. This will involve selecting sample local government areas, wards and households.

4.0 Results and Discussion

4.1 Demographical Characteristics of the Respondents

The scientific study of population characteristics and the variable's affecting population is known as demography. It is an aspect that focuses on population dynamics and long-term trends, as well as population size, composition, and distribution. Demography is the study of demographic characteristics, including population, age, sex, education, and income.

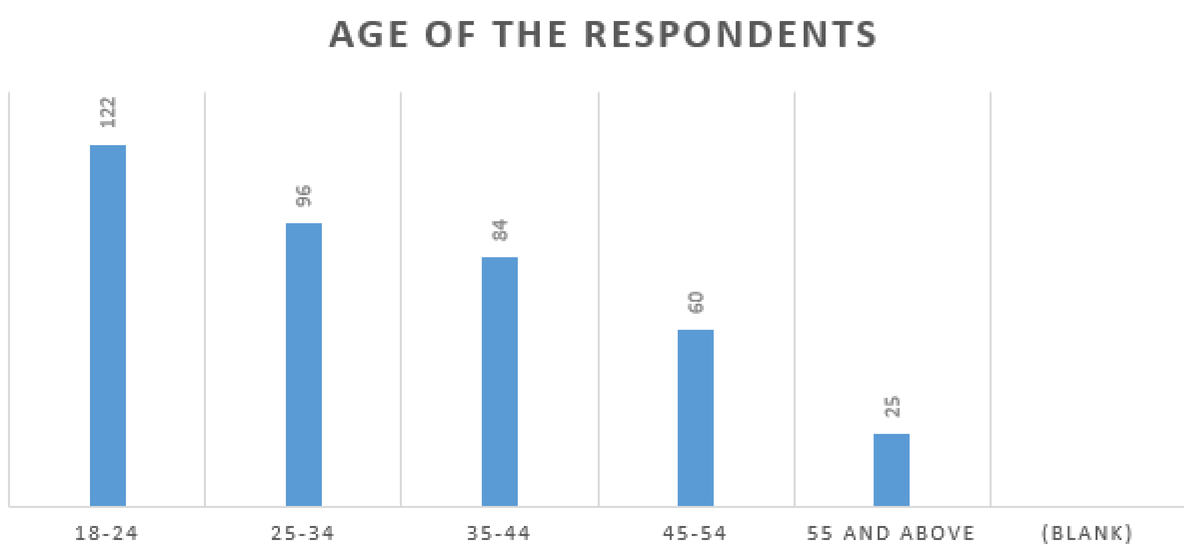

Figure 1. Age Distribution of the Respondents

Based on the depicted information above, a postgraduate diploma (PGD), higher national diploma (HND), or bachelor's degree (BSC) is held by 30 respondents. while 37 possess either a national certificate in education (NCE) or a diploma. no formal education of the population, 47 have never received any formal education. primary school: 119 people have finished their study at the primary school level. secondary school: 113 people have finished their secondary school education. vocational/technical: a total of 41 people has vocational or technical training. (blank): the cell is blank, suggesting that there might be a missing category or piece of information. more information would be required to properly understand this section. all things considered; this table highlights the variety of educational backgrounds by offering a glimpse of the distribution of educational attainment within a particular group.

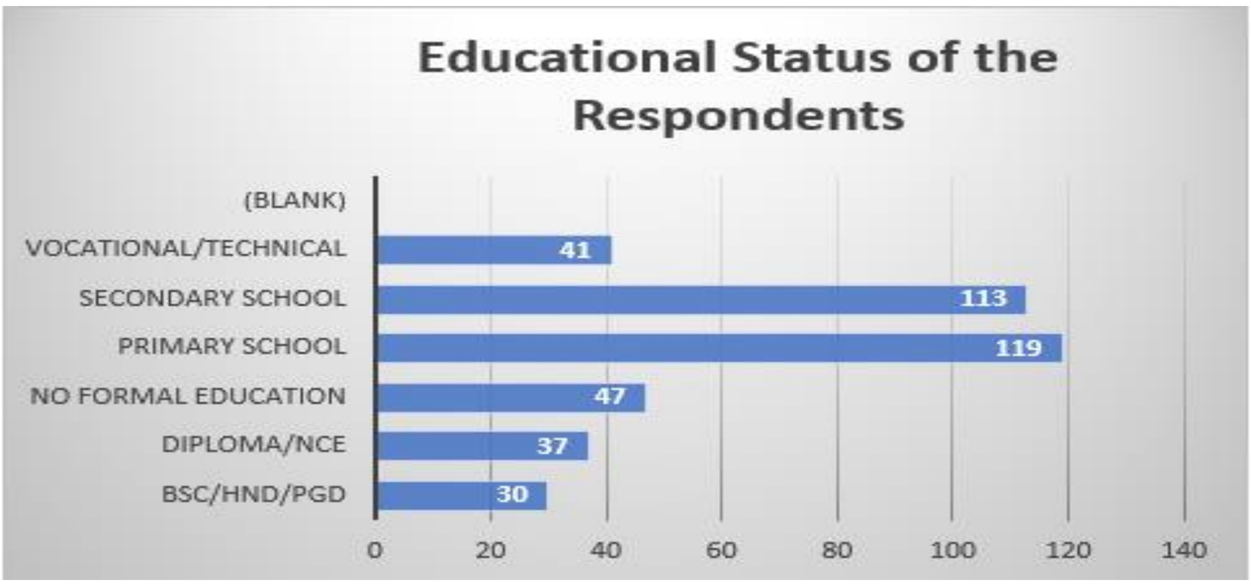

Figure 2. Educational Status of the respondents

Moreover, the age group of 18 to 24 years old has 122 respondents. The age range of 25 to 34 years old has 96 respondents. Similarly, the age range of 35 to 44 years old has 84, age range of 45 to 54 years old comprises 60 respondents. Finaly, twenty-five respondents are 55 years of age.

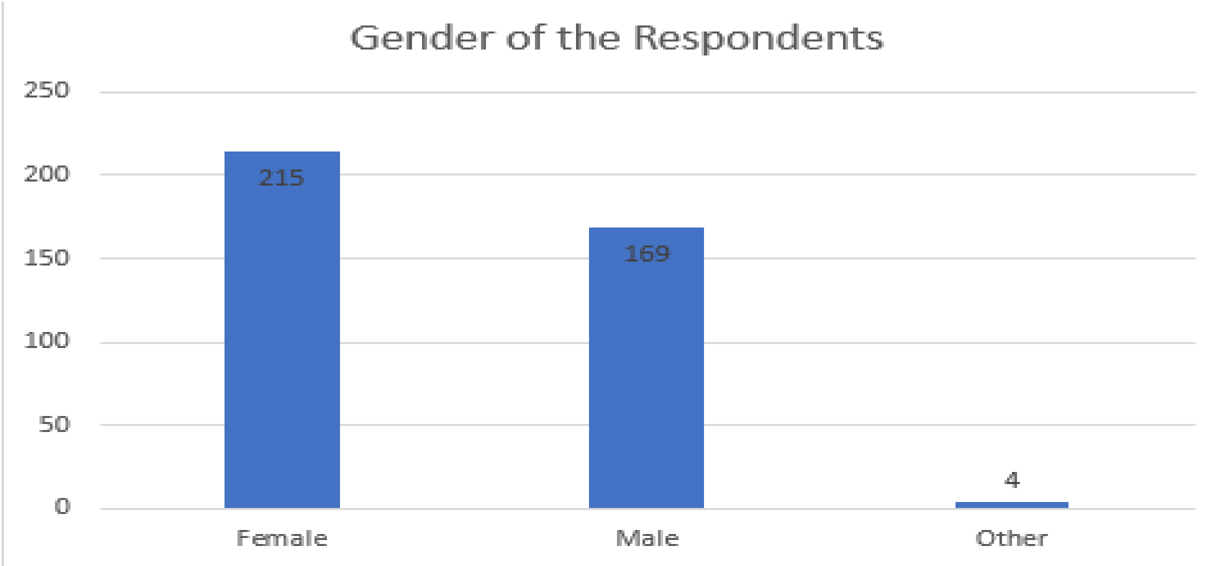

Figure 3. Gender of the respondents

The data from the bar chat categorizes individuals by gender, revealing that 215 individuals are identified as female, 169 as male, and an additional 4 fall into the "Other" category. This inclusive category may encompass individuals who identify as non-binary, genderqueer, or those who do not strictly adhere to conventional male or female identifications.

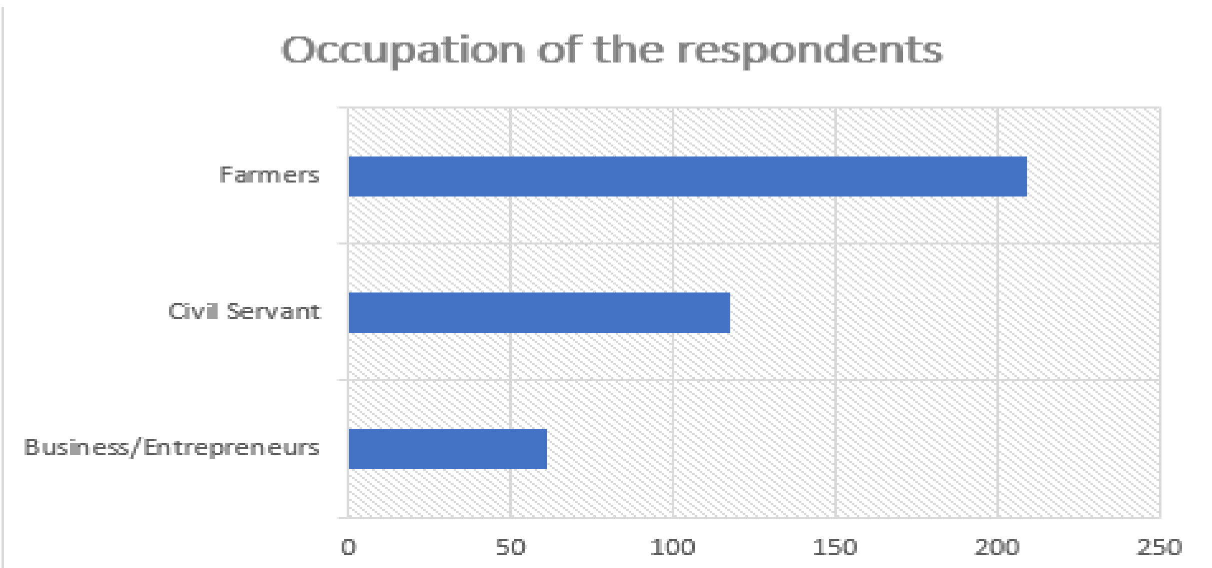

Figure 4. Occupational distribution of the respondents

According to the information above, which breaks down people into different occupational categories, 61 respondents were involved in business or entrepreneurship. 118 people are employed as civil servants, and the bulk of responders (209) are farmers. Consequently, information about the distribution of occupations within a particular group or population that highlights the variety of professions, such as business, public service, and agriculture are well depicted.

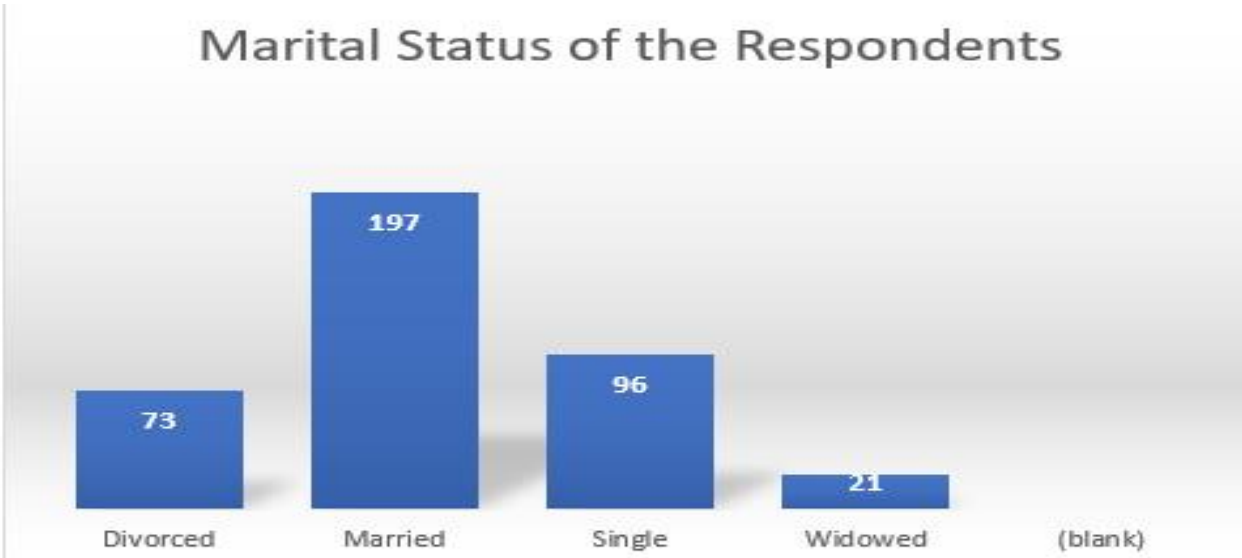

Figure 5. Marital Status of the respondents

Finally, the marital status of the respondents is given in figure 5. 73 of them are divorced. while majority, with 197 respondents, are currently married, and 96 are single, indicating that they are not currently married. lastly, 21 respondents who have been widowed.

4.2 Descriptive Statistics

Variables	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Access to solar Energy Consumption (ACCSP)	388	.768	.4226	-1.275	.124	-.376	.247
Solar Energy Awareness and Government Policies (SEAWN)	388	.469	.4997	.124	.124	-1.995	.247
Community Based Solar Energy Awareness Programmes (CBSEP)	388	.742	.4380	-1.112	.124	-.767	.247

Households Monthly Income (HMIC)	388	.113	.3175	2.448	.124	4.013	.247
Primary Use and Consumption of Solar Energy (PUCSE)	388	.284	.4513	.964	.124	-1.075	.247

The variable "Access to Solar Energy Consumption" has a mean of 0.768, indicating the average level of access in the sample. The standard deviation of 0.4226 reflects the extent of variability in access across the observations. The negative skewness of -1.275 suggests that the distribution is skewed to the left, implying that a majority of observations may have higher levels of access. The kurtosis of -0.376 indicates a relatively flat distribution compared to a normal distribution, with less pronounced tails. For the variable "Solar Energy Awareness and Government Policies," the mean is 0.469, representing the average level of awareness in the sample. The standard deviation of 0.4997 indicates a moderate degree of variability. The skewness of 0.124 suggests a roughly symmetric distribution, while the kurtosis of -1.995 indicates a flatter distribution with thinner tails compared to a normal distribution.

However, **i**n the case of "Community-Based Solar Energy Awareness Programmes," the mean is 0.742, signifying the average level of awareness from community-based programs. The standard deviation of 0.4380 measures the extent of variability in the observations. The negative skewness of -1.112 suggests a leftward skew, indicating that a majority of observations may have higher awareness levels. The kurtosis of -0.767 implies a distribution with flatter tails compared to a normal distribution. The variable "Households Monthly Income" has a mean of 0.113, representing the average income level in the sample. The standard deviation of 0.3175 indicates the variability in monthly income across households. The positive skewness of 2.448 suggests a rightward skew, indicating that a majority of households may have lower income levels. The kurtosis of 4.013 implies a distribution with heavier tails and a sharper peak compared to a normal distribution.

Finally, for "Primary Use and Consumption of Solar Energy," the mean is 0.284, reflecting the average level of primary use and consumption in the sample. The standard deviation of 0.4513 indicates the extent of variability in consumption patterns. The positive skewness of 0.964 suggests a rightward skew, implying that a majority of observations may have higher levels of consumption. The kurtosis of -1.075 indicates a distribution with flatter tails compared to a normal distribution.

4.3 Regression Estimation Result

Dependent Variable: **ACCSP (Access to solar Energy Consumption)**

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SEAWN	0.268276	0.02764	9.702900	0.0000
CBSEP	0.065437	0.34256	8.765433	0.0123
HMIC	0.501244	0.03672	7.978532	0.0034
PUCSE	0.076437	0.14356	6.786432	0.0125
C	-135.8427	17.06820	-7.958822	0.0000

R-squared	0.769184
Durbin-Watson stat	0.841397
F-statistic	564.4667

Regression estimation provides insights into the relationship between the dependent variable "ACCSP" (Access to Solar Energy Consumption) and several independent variables. For instance, SEAWN (Solar Energy Awareness and Government Policies) coefficient is 0.268276, with a standard error of 0.02764. This implies that, holding other variables constant, a one-unit increase in SEAWN is associated with an estimated increase of 0.268276 units in ACCSP. The t-statistic of 9.702900 is highly significant (p-value of 0.0000), indicating that the relationship is likely not due to random chance. Similarly, CBSEP (Community-Based Solar Energy Awareness Programmes) coefficient is 0.065437, with a standard error of 0.34256. A one-unit increase in CBSEP is associated with an estimated increase of 0.065437 units in ACCSP. The t-statistic of 8.765433 is significant at a 0.0123 level.

Moreover, HMIC (Households Monthly Income) has coefficient of 0.501244, with a standard error of 0.03672. A one-unit increase in HMIC is associated with an estimated increase of 0.501244 units in ACCSP. The t-statistic of 7.978532 is highly significant (p-value of 0.0034). Finally, PUCSE (Primary Use and Consumption of Solar Energy) has coefficient of 0.076437, with a standard error of 0.14356. A one-unit increase in PUCSE is associated with an estimated increase of 0.076437 units in ACCSP. The t-statistic of 6.786432 is significant at a 0.0125 level. However, the intercept (C) is -135.8427, with a standard error of 17.06820. The t-statistic of -7.958822 is highly significant (p-value of 0.0000), indicating that the intercept is significantly different from zero. The R-squared value of 0.769184, suggest that approximately 76.9% of the variability in the dependent variable (ACCSP) is explained by the independent variables in the model. The Durbin-Watson statistic is 0.841397. A value close to 2 suggests no significant autocorrelation in the residuals.

Overall, the regression results suggest that Solar Energy Awareness, Community-Based Programs, Households Monthly Income, and Primary Use and Consumption of Solar Energy are all significant predictors of Access to Solar Energy Consumption. The model appears to have a good overall fit, as indicated by the high R-squared value, and the individual coefficients provide insights into the strength and direction of the relationships between the variables.

5.0 Conclusion and Policy Recommendation

In conclusion, this assessment of residential solar energy access and consumption patterns in Adamawa State reveals notable findings regarding the distribution and characteristics of relevant variables. Access to solar energy consumption, as indicated by the mean of 0.768, showcases a considerable average level in the sample. The negative skewness of -1.275 suggests that a majority of observations tend to have higher levels of access, and the kurtosis of -0.376 implies a relatively flat distribution with less pronounced tails. Solar Energy Awareness and Government Policies exhibit a mean of 0.469, indicating the average level of awareness in the sample. The skewness of 0.124 suggests a roughly symmetric distribution, while the kurtosis of -1.995 indicates a flatter distribution with thinner tails compared to a normal distribution.

Community-Based Solar Energy Awareness Programmes, with a mean of 0.742, represent the average level of awareness from these programs. The negative skewness of -1.112 implies a leftward skew, suggesting that a majority of observations may have higher awareness levels. The kurtosis of -0.767 indicates a distribution with flatter tails. Households Monthly Income, with a mean of 0.113, reflects the average income level in the sample. The positive skewness of 2.448 suggests a rightward skew, indicating that a majority of households may have lower income levels. The kurtosis of 4.013 implies a distribution with heavier tails and a sharper peak compared to a normal distribution. Primary Use and Consumption of Solar Energy, with a mean of 0.284, represent the average level of primary use and consumption. The positive skewness of 0.964 suggests a rightward skew, implying that a majority of observations may have higher levels of consumption. The kurtosis of -1.075 indicates a distribution with flatter tails.

The regression estimation further delves into the relationship between Access to Solar Energy Consumption and independent variables. Solar Energy Awareness, Community-Based Programs, Households Monthly Income, and Primary Use and Consumption of Solar Energy emerge as significant predictors. The model, with an R-squared value of 0.769184, demonstrates a good overall fit, explaining approximately 76.9% of the variability in Access to Solar Energy Consumption. The individual coefficients provide insights into the strength and direction of these relationships. Therefore, in summary, this assessment sheds light on the dynamics of residential solar energy access and consumption in Adamawa State, offering valuable insights for policymakers, researchers, and stakeholders interested in promoting sustainable energy practices.

Based on the comprehensive assessment of residential solar energy access and consumption patterns in Adamawa State, the following policy recommendations are proposed:

i. Promote Solar Energy Awareness and Government Policies. For instance, Given the significant positive relationship between Solar Energy Awareness and Access to Solar Energy Consumption, policymakers should focus on initiatives to enhance awareness among residents. Implementing and promoting government policies that support solar energy adoption can further contribute to increased access. Public awareness campaigns, workshops, and educational programs can play a crucial role in informing communities about the benefits of solar energy and available government support.
ii. Strengthen Community-Based Solar Energy Awareness Programs**.** Recognizing the positive impact of Community-Based Solar Energy Awareness Programs on access levels, there is a need to strengthen and expand such initiatives. Local communities should be actively involved in designing and implementing awareness programs tailored to their specific needs and challenges. Collaborations between local authorities, NGOs, and community leaders can effectively drive these programs and ensure their sustainability.
iii. Address Income Disparities for Equitable Access**.** The observed rightward skewness in Households Monthly Income implies that a majority of households may have lower income levels. To ensure equitable access to solar energy, policymakers should focus on income-

based support programs, subsidies, or financing options for low-income households. Implementing targeted financial incentives can help bridge the income gap and make solar energy solutions accessible to a broader segment of the population.

iv. Encourage Sustainable Consumption Patterns**:** The positive skewness in Primary Use and Consumption of Solar Energy suggests that a majority of households have higher levels of consumption. Policymakers should encourage sustainable consumption patterns by promoting energy-efficient practices, technologies, and appliances. Incentives for adopting energy-efficient technologies and incorporating green building standards can contribute to reducing overall energy consumption.

v. Support Research and Development for Innovation. Continuous research and development in the solar energy sector are crucial for innovation and the introduction of more efficient and affordable technologies. Policymakers should allocate resources and create a supportive environment for research initiatives, fostering collaborations between academia, industry, and government agencies. Investing in technology advancements will contribute to the long-term sustainability and affordability of solar energy solutions.

References

Abam F, Nwankwojike B, Ohunakin O & Ojomu S, (2014). Energy resource structure and on-going sustainable development policy in Nigeria: A review. Int Journal of Energy and Env Engr 5(2-3)102.

Ajayi, O. O., Ohijeagbon, O. D., Mercy, O., & Ameh, A. (2016). Potential and econometrics analysis of standalone RE facility for rural community utilization and embedded generation in North-East Nigeria. *Sustainable Cities and Society*, *21*(2016), 66–77.

Akimbami, J. K. (2001). Renewable Energy Resources and Technologies in Nigeria: Pre-sent Situation, Future Prospects, and Policy Framework. *Mitigation and Adaptation Strategies for Global Change*, *6*(2001), 155–181.

Akinwole, I. (2022). The Impact of the Global Energy Transition on Nigeria's Electricity Sector. Available at SSRN 4284681.

Akuru, U. B., Onukwube, E. I., Okoro, I. O., & Obe, E. S. (2017). Towards 100% renewable energy in Nigeria. *Renewable and Sustainable Energy Reviews*, *71*(2017), 943–953.

Anumaka, M. C. (2012). Scenario of Electricity in Nigeria. *International Journal of Engineering and Innovative Technology (IJEIT)*, *1*(6), 2277–3754.

Ayodele, T. R., & Ogunjuyigbe, A. S. O. (2015). Increasing household solar energy penetration through load partitioning based on quality of life: The case study of Nigeria. *Sustainable*

Baurzhan, S., & Jenkins, G. P. (2016). Off-grid solar PV: Is it an affordable or appropriate solution for rural electrification in Sub-Saharan African countries? *Renewable and Sustainable Energy Reviews*, *8*(60), 1405–1141.

Brohmann B, Heinzle S, Rennings K, Schleich J and Wüstenhagen R., (2009). What's Driving Sustainable Energy Consumption? A Survey of the Empirical Literature. Centre for European Economic Research 2009:30p.

Chanchangi, Yusuf. N., Adu, F., Ghosh, A., Sundaram, S., & Mallick, Tapas. K. (2022). Nigeria's energy review: Focusing on solar energy potential and penetration. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-022-02308-4
Cities and Society, *18*(2015), 21–31.

Fu, P., & Rich, P. M. (1999). Design and implementation of the Solar Analyst: an ArcView extension for modeling solar radiation at landscape scales. In Proceedings of the nineteenth annual ESRI user conference (Vol. 1, pp. 1-31). USA: San Diego.

Garg P., (2012) Energy scenario and vision 2020 in India. Journal of Sustainable Energy and Environment 2012:3:7-17.

IEA. World Energy Outlook (2007). International Energy Agency, Paris 007.

IEA. World Energy Outlook 2008; International Energy Agency Bookshop: Paris, France, 2008; pp. 99–116.

Ikem, I. A., Ibeh, A. I., Nyong, O. E., Takim, S. A., & Osim-Asu, D. (2016). Integration of renewable energy sources to the Nigerian national grid—way out of power crisis. *International Journal of Engineering Research*, *5*(8), 694–700.

Iqbal SJ, Mohammad SS. Power management, control and optimization of photovoltaic/battery/fuel cell/stored hydrogen-based microgrid for critical hospital loads. Distrib Gener Altern Energy J 2022; 37(4):1027–54.

Izquierdo S, Montanes C, Dopazo C and Fueyo N., (2010). Roof top solar energy potential under performance-based building energy codes: The case of Spain. Solar Energy 2010:85:208-213.

Kang, SS Kim and D Lee, (2002). Spatial and temporal patterns of solar radiation based on topography and air temperature. Canadian Journal of Forest Research 2002:32 (3):487-497.

Karatasou S and Santamouris M 2019 Socio-economic status and residential energy consumption: A latent variable approach. Energy Build 198 100–105.

Li, Z., Lv, L., & Zhang, Z. (2022). Research on the Characteristics and Influencing Factors of Chinese Urban Households' Electricity Consumption Efficiency. Energies, 15(20), 7748.

Mallapaty, S. (2020) How China could be carbon neutral by mid-century. Nature 2020, 586, 482–484. [CrossRef] [PubMed].

Mckinsey. Preparing for China's Urban Billlion. Mckinsey Global Institute. Available online: https://www.mckinsey.com/featured-insights/urbanization/preparing-for-chinas-urban-billion (accessed on 13 June 2022).

Mohammad SS, Iqbal SJ. Optimization and power management of solar PV-based integrated energy system for distributed green hydrogen production. Distrib Gener Altern Energy J 2022; 37(4):865–98.

Mohammed, Y. S., Mustafa, M. W., Bashir, N., & Ibrahem, I. S. (2017). Existing and recommended renewable and sustainable energy development in Nigeria based on autonomous energy and microgrid technologies. *Renewable and Sustainable Energy Reviews*, *75*(2017), 820–838.

Monyei, C. G., Adewumia, A. O., Obolo, M. O., & Sajou, B. (2017). Nigeria's energy poverty: Insights and implications for smart policies and framework towards a smart Nigeria electricity network. *Renewable and Sustainable Energy Reviews, 81*(2018), 1582–1601.

Nguyen H and J Pearce, (2010). Estimating potential photovoltaic yield with sun and the open-source geographic resources analysis support system. Solar Energy 2010: 345-357.

Ohunakin, O. S., Adaramola, M. S., Oyewola, O. M., & Fagbenle, R. O. (2014). Solar energy applications and development in Nigeria: Drivers and barriers. *Renewable and Sustainable Energy Reviews, 32*(2014), 294–301.

Oseni, M. O. (2012). Households' access to electricity and energy consumption pattern in Nigeria. *Renewable and Sustainable Energy Reviews, 16*(2012), 990–995.

Oyedepo, S. O. (2012). On energy for sustainable development in Nigeria. *Renewable and Sustainable Energy Reviews, 16*(2012), 2583–2598.

Ozoegwu, C. G., Mgbemene, C. A., & Ozor, P. A. (2017). The status of solar energy integration and policy in Nigeria. *Renewable and Sustainable Energy Reviews, 70*(2017), 457–471.

Rafindad, A. A. (2016). Does the need for economic growth influence energy consumption and CO2 emissions in Nigeria/ Evidence from the innovation. Accounting test. *Renewable and Sustainable Energy Reviews, 62*(2016), 1209–1225.

TERI Energy Data Directory and Yearbook. An Overview: The Energy Resource Institute, New Delhi, India 2003. 39.

TERI. TERI Energy Data Directory Yearbook, 2012-13. The Energy and resources Institute, New Delhi, India 2013.

The race to zero emissions, and why the world depends on it. 2022, accessed (09-06-2023) https://news.un.org/en/story/2020/12/1078612.

Ugwu, J., Odo, K. C., Oluka, L. O., & Salami, K. O. (2022). A Systematic Review on Renewable Energy Development, Challenges and Policies in Nigeria with an International Perspective and Public Opinions. Int. J. Renew. Energy Dev, 111, 287-308.

United Nations, 2015. Transforming Our World: The 2030 Agenda for Sustainable Development. Department of Economic and Social Affairs, https://sdgs.un.org/2030agenda.

WEC. (2020). *World Energy: Issues Monitor 2020*. Retrieved from London: https:// www. world energy. org/ assets/ downl oads/ World_ Energy_ Issues_ Monit or_ 2020_-_ Full_ Report. Pdf

Wiginton LK, Nguyen HT and Pearce JM, (2004). Quantifying rooftop solar photovoltaic potential for regional renewable energy policy. Computers, Environment and Urban Systems. 2004: 34:345-357.

World Bank. (2017). Electricity production from renewable sources, excluding hydroelectric (kWh). Retrieved from https:// data. world bank. org/ indic ator/ EG. ELC. RNWX. KH? end=2014& locat ions= NG- GB- NE- DE- ZA- GH& name_ desc= true& start= 1960& view= chart & year= 1990.

Yakubu, A., & Ifeanyi-Nwaoha, C. (2017). Power to the people: solving the 100 million people problem. *EmPower Nigeria*, *16*(1), 1.

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