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Article

Mitigating Zambia's Energy Crisis: Transitioning Beyond Hydropower Reliance

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Abstract: Because hydropower accounts for more than 80% of Zambia's electrical supply, the country's energy sector faces significant obstacles. Droughts and erratic rainfall patterns brought on by climate change have revealed serious weaknesses, leading to frequent power outages. Even though there are many renewable energy sources, such as biomass, wind, and solar, their integration is still somewhat limited. This study uses qualitative analysis of secondary data, including policy reviews and case studies, to examine the viability of diversifying Zambia's energy mix. The results demonstrate the enormous potential of solar energy, when combined with wind and biomass, to stabilize the energy supply and reduce the hazards associated with hydropower. Successful energy diversification requires technology advancement, policy changes, and regional cooperation. The ramifications highlight a path toward sustainable energy security, supporting Zambia's environmental sustainability and economic resilience.

Keywords: Energy Crisis, Zambia, Hydropower, Transition, Diversification

1. Introduction

Hydropower has been the dominant resource in Zambia's energy mix for a long time, buoying approximately 90% of the country's electricity generation. Hydropower, which has been considered for a long time as the cleanest and cheapest source of electricity, has been effectively playing a role in the country's economic development and industrialization. Nonetheless, existing threats by climate change to hydropower development make Zambia prone to energy insecurity in the future. The sector is, therefore, very sensitive to changes in rainfall and water storage in the reservoirs. This poses more risks and uncertainties as to the country's energy supplies, given that weather conditions are shifting, with the effects of periods of drought being longer than before. The available water in the significant hydropower dams has continuously decreased thus causing cyclical power deficits; the crises of 2015 and 2019 are clear examples of the vulnerability of industrial and domestic users to hydropower volatility.

Currently, Zambia relies heavily on hydropower as the main power supply, which has been deemed very risky since power generation heavily depends on the water supply spasmodically affected by drought or irregular rain season, which is now prevalent due to climate change. These challenges demonstrate the necessity for the country to move from the hydropower energy model, which has been its dominant energy source for many years. It remains imperative for the stability and safety of Zambia's electric power supply, especially for the sector's sustainable development and economic growth, that such a shift is vital. To mitigate the risks associated with hydropower dependence, the country must invest in renewable energy sources beyond hydroelectricity. Solar energy, which has vast

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untapped potential in Zambia due to its location in the solar belt of Africa, offers a promising alternative. The widespread availability of sunlight throughout the year makes solar power a key component in the nation's efforts to diversify its energy mix. Similarly, wind and biomass energy have considerable potential, especially in rural areas where agricultural residues could be harnessed to generate electricity.

Firstly, the advent of diversification of energy sources used in Zambia will call to enhancement of investments in energy structures comprising of mechanisms in energy transfer to comprise the renewable energy into the national basket. Also, the use of decentralized energy systems for example off-grid solar systems could assist in meeting the energy demand of the unreached and hard to reach population where electrical grid extension is either difficult or non-feasible. Besides these efforts, the measures that will be necessary in promoting energy efficiency in industrial, commercial and domestic use will be essential in curbing the effects of power shortages.

Regarding this, it is high time Zambia develops an effective long-term energy plan that considers not only the existing power shortages, but also other centralized energy systems that would be made ready to forecast and meet future generations' energy needs. In this paper, various issues affecting the diversification of electricity sources in Zambia are explored, the viability of other renewable electricity sources discussed, and the key issues which include; policy adjustment, technological advancement and regional integration in the quest for a more stable and diversified electricity source considered critically. In so doing, only will Zambia avert dangers inherent in her energy deficit and laid the necessary foundation for a progressive and more hopeful energy future.

Literature Review

Mitigating Zambia's Energy Crisis: Transitioning Beyond Hydropower Reliance

It is not unlikely that Zambia has recently garnered considerable attention as an emblem of a country struggling with chronic power shortages and an over-reliance on hydropower. To date, more than 90% of electricity generation in Zambia relies on hydropower, making the country one of the most hydro-dependent countries countries in Africa. However, climate change has intensified water problems, so energy diversification has become crucial. This paper aims to identify important peer-reviewed literature on Zambia, particularly emphasising the energy challenges and prospects of hydropower diversification. The review also predicts global best practices on upcoming reformed packages and other renewable energy sources that may be considered substitutes for previous sources and outlines the kind of policy environment desirable for successful energy sector reform.

The Dependence on Hydropower in Zambia

Since Zambia has abundant water resources such as Zambezi river and its fellow tributary the use of hydropower comes as a natural choice. Hydro power has remained the main source of electricity in Zambia due to the commissioning of Kariba, Kafue gorge and more recently, the Itehi-Tezi power stations. However, the use of a single source of energy is now most time inefficient due to variability of water influx which is a major source of hydropower.

Some of the adverse consequences relating to the reliance on hydropower in Zambia are described in the following studies. The power outrage of 2015 and 2016 that resulted from the long dry season that reduced water levels at facilities offering hydro power exposed the weakness of the energy sector. At this time there was a lot of load shedding and this affected most sectors in the country including the industrial sector power sector and the agricultural and all sectors of people's lives. This called for change; Zambia being a country that relied mostly on hydropower, policymakers and academics realised that this

source of power was not suitable for a world with changes in power caused by climate change.

Climate Change and Hydropower Vulnerability

Climate change has added to the risks of hydropower generation in Zambia. Indicates that climate risks affect the Southern African region, including Zambia, due to changing patterns of rainfall and rising temperatures. All these changes impact water flow in rivers that supply electricity-generating power stations in Zambia, reducing the energy generated.

A theoretical analysis of the hydrological impacts of climate change revealed that there had been erratic hydropower generation due to changes in climate, specifically frothy and interruptive power plants with significant power plants recording low water inflow due to weather patterns. In the context of Zambia, such climatic shifts are dangerous in the following ways: Energy insecurity, more economic volatility, and displacement of vulnerable livelihoods that would otherwise rely on energy.

Renewable Energy Alternatives

Due to the sensitiveness of hydropower, literature on Zambia's energy sector has centred on the possibility of renewable energy sources. In the same regard, several studies recommend that Zambia pursue a policy of diversification of energy mix through the development of renewable energy sources, which are abundant in Zambia, including solar, wind, and biomass. Of all the renewable energy sources, solar power is regarded as the most promising for solving the energy problems of Zambia.

There has been an increasing focus on renewable energy in the literature since the global concern about the depletion of fossil energy, global warming effects, and energy security. The most promising forms of energy, namely Solar, Wind, hydro, biomass, and geothermal energy sources, are identified as critical in shifting the global energy mix towards a sustainable, low-carbon future. This section reviews the literature on renewable energy options, emphasising technology type, prospects for deployment in the global market, and impediments to RE integration in energy systems.

Solar Energy

Zambia is positioned in the solar belt. Therefore, it is best suited to harness energy from the sun. Several studies have highlighted the country's potential for using solar energy, including, which estimated Zambia's solar energy potential to be over 4000MW, higher than the country's total installed electricity capacity. Argue that solar energy could be vital in complementing hydropower deficiencies, especially in the off-grid and rural regions where physical access to electricity supply is still a challenge. Furthermore, improved technology, solar energy and the cost of photovoltaic systems are some of the reasons why people embrace solar energy.

The potential of solar energy is enormous, and solar resources are available in almost all parts of the world. Global solar power has become one of the most rapidly expanding sources of power generation, with more than 1 GW of solar facilities installed worldwide in 2022, says the IEA. This research intends to address the issues surrounding the implementation of solar energy sources. The energy source has excellent potential to develop significantly, especially in places near the equator where high levels of solar intensity are usually experienced. However, there is great potential in countries within the solar belt of Africa, such as Zambia.

Other research, International Renewable Energy Agency IRENA (2020) projected the average solar intensity in Africa to be 5.5 kWh/m²/day, an ideal position in solar energy.

Solar power resources alone, with the potential to generate more than 50,000 GW in sub-Saharan Africa, are enough to supply electricity demand far over what is currently being consumed in this part of Africa. However, the level of implementation of solar energy in many African countries is still low, the main reasons being high initial costs, lack of infrastructure, and limited access to commercially affordable credit.

Wind Energy

Wind energy is another renewable resource selected to be part of the diversified energy mix in Zambia. Even though Zambia's wind power resource is not regarded as significant as wind power potential in other African countries, there is a map unveile where Wind Potential for Power Generation is marked that some parts of Zambia, mainly in the southern and the western provinces, are potentially viable for wind power electricity generation. The current solar and hydropower systems could be augmented by the development of wind farms, mainly in periods when hydropower production is low, such as during the dry season.

Wind energy is a promising source for electric power generation internationally. The total global wind power capacity as of the end of the calendar year of 2022 is estimated to be 1,019 GW; that is if we will not consider any more use of global resources as seen in the following forecast as the demand for electricity is expected to rise; wind power may be contributing up to 30% of this demand by the year 2050. This growth has been brought about by improvements in technologies that have lowered costs of production, the efficiency of the turbines, and vast areas where wind power is feasible.

The analysis of research featuring the universal potential of wind energy has shown that it can play a significant role in the global energy system. Wind energy resources are not limited to certain areas; they are found in many places globally, both on and off the shore. Different places that have higher wind power can support large wind turbines, including coastal areas and open planes.

However, the success of using wind energy has made it possible by expanding the new opportunities for wind power generation, such as the new physical advance of new offshore wind energy, especially in Europe and some Asia countries. Offshore wind farms are especially beneficial since it is possible to locate wind turbines in regions with a consistently strong gustiness that can rarely be found on the territory. Offshore wind utilization is openly regarded as a promising technological prospect suggesting further expansion of power generation with advancing technological and infrastructural platforms.

Technological Advancements in Wind Energy

Technology has been vital in reducing the cost of wind electricity generation, increasing the competitiveness of wind power needed for electricity generation compared to that needed for fossil-fueled power plants. Developments in the coaxial technology of turbines, high-strength material usage, and the effective control system have extended its efficiency and reduced costs tremendously. Turbines have increased in size and efficiency to produce more electricity within regions containing lower wind levels.

One technological improvement is an increase in the size of the turbines and the length of blades, particularly in the acquisition of wind energy. International Energy Agency (IEA) note that most turbine designs operating in the current industry are above the 4MW mark, with specific designs in the range of 12 MW being used in offshore turbines. These giant turbines, of course, are cheaper because one can produce more electricity with fewer turbines. Furthermore, through advanced prediction and automated control of wind farms, the outcomes of modelling and control systems have also improved the dependability and functionality of wind farms.

Biomass Energy

Another renewable energy source is biomass, which could satisfy this country's energy needs. Biomass resources available in Zambia such as agricultural residues, wood biomass, and waste materials, can effectively produce electricity or biofuels. As pointed out, a study conducted by the authors in 2020 highlighted the use of biomass in rural electrification and large-scale generation. In addition, if appropriately managed, biomass could influence sustainable agriculture and decrease poverty among the rural populace.

Biomass, according to the current studies and estimations, has a huge potential to supply a significant portion of the world's energy needs, especially if it comes from agroforestry residues. In the study carried out, biomass was shown to be capable of contributing up to about a quarter of the global energy demand, which provided the results from the usage of biomass in the power utility and transportation fuel sectors. According to the IEA (2020), current biomass could supply up to 10% of global energy by 2050 with the proper embedding of biomass into national energy plans.

Based on the case of Africa, estimate the potential of biomass resources from agricultural residues, wood, and animal wastes. The utilization of the biomass reserve is more conspicuous in African countries because the area has a large agricultural focus, which generates abundant crop residues such as maize stalks, rice husks, and sugarcane bagasse. Biomass energy in Africa could thus be a useful instrument for decreasing reliance on imported fossil fuels and making adequate power available for the population.

Technological Advancements in Biomass Energy

Importation of biomass energy has improved over the recent past due to enhanced technologies that enable the effective utilization of biomass with minimal impact on the environment. Improved conversion technologies, such as gasification, anaerobic digestion, and biofuel conversion, have enhanced the energy from biomass and reduced emissions from the burning of biomass.

Energy Storage and Grid Integration

While it has been interpreted as a tremendous potential shift to renewal resources incorporation in the electricity supply system, it cannot be by all means considered absolutely problem-free as far as energy storage and incorporation of renewable energy sources in the power system is concerned. This is because most renewable energies, such as solar and wind, are models that only sometimes generate energy. This implies that to balance the existing volatile nature of power generation, there is a need to improve the energy storage systems.

Effected research that investigates energy storage systems, for example, the capacity of battery and pump storage enhances the reliability of renewable power systems. Given the challenges posed by the usage of RE technologies and the unpredictable supply of power from Siemens, energy storage could be considered adequate in Zambia.

Another critical area of change is the level to which the grid in Zambia is connected and integrated. Another challenge is that Zambia's current grid system is inadequate to support some big renewable energy projects, as described, report. Specific upgrading of the grid structures is needed to increase transmission capacity, reduce energy losses, and provide the grid systems with the flexibility to accept various inputs.

Policy and Institutional Framework

This paper examines the policy measures for developing a diversified energy system in Zambia and highlights the critical implications for policy, institution, and investment in energy. Some previous authors have highlighted the need for the government to fulfil its

enabling role to support renewable energy actively. According World Bank (2020), Zambia should have more favorable policies on renewable energy, a clearer signal encouraging private sector participation in utilizing renewable energy, and better legal frameworks for integrating renewable energy into Zambia's national grid.

The government of Zambia has begun to move in this regard through the timing of the Renewable Energy Feed-in-Tariff (REFIT) and the formation of the Renewable Energy Authority. Nonetheless, there is a lack of policy integration at one level and between different governmental organizations, private actors, and local communities. Also, the producing countries of energy within the region can support Zambia in combating some of the challenges facing energy production and distribution. A study points to Zambia's possibility of cooperating more actively with other countries in the Southern African Power Pool, a regional organization set up to promote efficient cooperation in the sphere of energy supply and utilization of the generated electricity.

The shift towards a diversified energy sources in Zambia; a critical must due to continued hydro power reliance and effects of climate change. Solar, wind, and biomass have emerged as the main contenders for this role as the literature discussed in this paper has suggested. Nevertheless, some issues including storage, integration of renewable energy with the grid and many others concerning policies persist. For this reason, Zambia requires a comprehensive vision entailing policy and institutional changes, infrastructure and technological development. Moreover, contributions from neighboring countries and application for international assistance will form key parts of the country's strategy to build a better energy security. The transformation to a diverse system of energy is not only an avenue of tackling the energy problem in Zambia but also a conducive platform for the development of sustainable economic growth.

2. Methodology

This study used secondary data within a qualitative research paradigm to provide insights into Zambia's energy problems and possible reforms. Primary documents included government documents and reports, academic literature, pre-2012 energy policy documents, and previous qualitative data sources, including interviews and focus group transcriptions. Several sources of information were used to get a vivid picture of how Socio-economic and cultural factors and institutions affect the energy situation in Zambia.

Secondary qualitative data enabled the study to analyze views of energy usage, infrastructure stability, and the supply network from different stakeholders. Rich narrative accounts and descriptive analyses revealed the actual social realities and subjectivity of different socio-economic groups, especially the rural and low-income urban populace, regarding the energy sector's reforms and actions.

For instance, policy reports analyzing and presenting the supply-side statistics of electricity were supplemented with data from previous qualitative research that documented the challenges faced by vulnerable groups to gain access to cheap and steady energy. The stories give insights into such barriers as financial constraints and poor quality of service delivery to the affected groups. In the same way, focus group discussion data identified the cultural and social factors that contribute to the public's attitudes towards change from hydropower. The research also unpacked more profound concerns and stood still within specific communities.

The secondary data revealed an intricate and sophisticated picture of how energy deficits influence particular localities, their economic activities, people's daily schedules, and interactions. This approach was the best because it only mapped between high-level

energy policy strategies and user-level considerations. This paper integrated extant qualitative literature to provide a systematic understanding of Zambia's energy demand and the potential obstacles to reform while highlighting the need to ensure that proposed reforms reflect the sociocultural and economic realities of the intended beneficiaries.

Finally, the findings highlighted the importance of energy policies that would suit the local systems, which improves the chances of implementing them. This study helped employ secondary qualitative data to ensure that the findings and recommendations were adequately grounded in the extant literature.

3. Discussion

Zambia's energy problem, mainly occasioned by its dependence on hydropower sources, has revealed that the country has accounted for various shortcomings in its energy sector, not least because of climate change and fluctuating rainfall patterns. Hydropower dominates Zambia's power generation with over 90%, which subjects the electricity supply to natural adversaries such as droughts and water rationing, which have recently culminated in power rationing, the local term for load-sharing. Due to the current energy crisis, it is high time Zambia considered diversifying energy sources and looking for other possible sources.

The one central area for transition is harnessing renewable energy resources – solar, wind and biomass. Another prospective power source is solar because Zambia receives much higher sunshine, especially in the northern and western provinces. The country's reliance on hydropower could be addressed by promoting solar-based industrial plants and household requirements for solar installations. Likewise, wind energy as a source is equally young in Zambia but can also supply a stable power supply if harnessed in places with suitable wind environments. Another easily accessible and renewable energy source is biomass, and besides electricity, it can also be used as a material that helps fight the problem of waste (Chisala, M., & Nkombo, D., 2019).

However, for Zambia to meet the energy demand, the country needs to enhance its energy efficiency and minimize transmission losses since they cause high energy costs and drain. This includes upgrading the existing national grid, incorporating intelligent grid technology, and incorporating energy storage into the system to improve supply and demand. Further, the long-term discovery of nuclear energy as an aspect that is more stable and easier to control to an extent may be of more economic benefit, though risky because of the hazards or effects of the disasters.

It was ascertained that policy reforms and new regulations are premised on encouraging private-sector investment in the energy sector. Private international organizations and the government could help increase the utilization of multiple energy types through PPPs, where the government can offer subsidies for renewable energy. Other energy sources are also crucial; international cooperation concerning the World Bank and the African Development Bank funding and independent collaboration could develop energy structures and technology.

Last, solving the energy crisis in Zambia calls for intervention in both the production or supply and consumer demand sides. Promoting energy saving, using energy-efficient appliances, and keenly sensitizing the public on energy saving would play a central role in minimizing the demand for electricity supply. By changing from depending mainly on hydropower, Zambia would build a more secure and sustainable energy sector with no regular power deficits, high economic development, and sound environmentalism.

4. Results

The energy challenge in Zambia is now alarming, especially considering that 84 per cent of the electricity generated in Zambia is from hydropower. This over-reliance has left Zambia at the mercy of climate change, where occasions of droughts have seen little water available for the production of hydropower, hence being numerous power rationing. In order to overcome these challenges and build a stable and sustainable energy future in Zambia, the country is seeking future development beyond hydro energy sources (Nkombo, D., Chisala, M., & Mwansa, K., 2018).

The first strategic plan to cope with the energy crisis is exploring renewable energy, especially solar energy. Some big solar projects include the 100MW Chisamba solar power plant, a joint venture by ZESCO and private capital. Other solar plants are currently under development in areas such as Choma, Kasama and Kariba. The fruits of these efforts are integral to Zambia's long-term vision to diversify its market away from the dominant hydropower resource.

Thermal power is also being developed during this diversification exercise. For example, the Maamba Collieries thermal power station plans to expand its power generation capacity from 300MW to 600MW (Mweemba, L., & Banda, A., 2020). It offers stable power sources during low rainfall, hence less hydropower production. Seriously, though, this move is interesting because energy diversification is critical to avoid the concentration of risks in terms of climatic shocks.

Besides diversifying and increasing its renewable and thermal power sources capacity, Zambia funds energy storage mechanisms to encourage stable electricity provision. The Battery Energy Storage Systems (BESS) project, under construction with the help of partners in other countries, is in line to improve the different renewable energy inputs into the national grid. This technology shall come in handy in moderating the fluctuation of energy from solar systems, hence guaranteeing an adequate, consistent supply of energy.

Zambia also promotes distributed power generation, especially in the rural market. Under REM, the government is encouraging off-grid renewable electricity systems, including mini hydropower, solar, and biomass. This provides a solution to energy deficits in remote areas while simultaneously taking pressure off the national grid.

The government actions are backed by enabling policy measures, including the recent net metering, which enables consumers to produce and feed excess power into the systems. This is aimed at increasing energy self-sufficiency and promoting the involvement of the private sector in power production.

Thus, Zambia's approach to diversifying the energy and alleviating the energy shortage is based on four primary objectives: renewable energy exploration, further thermal power generation and capacity, energy storage systems investment, and the last direction towards the rural electricity supply. These measures are to achieve a more stable and sustainable energy future for the country and to help together with Zambia's general economic and environmental objectives.

5. Conclusion

In conclusion, addressing the energy challenge in Zambia cannot be achieved solely by focusing on the relevance of electric utilities to the past organizational focus on hydroelectric power. Though hydropower has been regarded to be an essential source of energy, some of the attributes which have sought to threaten her include those to do with climate change and rainfall variations, hence irregular water supply, which has forced Zambians to look for other ways of generating energy. Reducing reliance on hydropower and changing the structure of energy supply – while turning to use solar, wind, and biomass, and considering thermal and nuclear energy sources can be viewed as a way to pursue a more effective and stable energy supply.

There is a significant potential in renewable energies, particularly solar energy, in Zambia, so investing in renewable energy, especially in power-generating infrastructure, is very promising. Green energy is a clean power source with the potential for rural power supply and employment in the green sector. Wind power and biomass also provide realistic options for the energy mix that can further enhance the energy distribution network scenario, especially in the case of less hydropower generation.

Also, enhancing the efficiency of energy consumption and embracing advanced frameworks of the present grid system, including the smart grid and energy storage system, can enhance the present energy system from the angle of reduced energy loss during the transmission and better integration of distributed energy resources. Innovative policies and incentives shall be available to encourage private-sector financing of these sectors to boost investment. At the same time, sustainable regulatory frameworks shall be developed to grow financial commitment and afford energy solutions.

Finally, moving away from the overreliance on hydropower is not only a fix to the energy problems in Zambia but also a chance to develop a stable, diverse new energy future for Zambia. The following are reasons why a diversity of energy sources adopted together with technologies offer Zambia an opportunity to ensure reduced sitting of the country to climate risks, increased ability to meet energy demands and spur economic growth. This change is crucial not only for oil and gas security but also for meeting the African and global sustainability agendas and being integrated into the regional energy transition.

Recommendation

To address Zambia's ongoing energy crisis and reduce its over-reliance on hydropower, the following recommendations are proposed:

1. Diversification of Energy Sources

The use of other sources of energy other kinds of energy Sources of energy Variety of energy Different types of energy Variety of energy resource Energy source Types of energy Source of energy Types of energy Other types of energy

Due to the lucrative nature of hydropower due to climatic changes, it became necessary for Zambia to diversify its energy sources. Renewable energy capitalizes on solar and wind, and biomass must be embraced more than non-renewable energy sources. Notably, solar energy has enormous prospects in Zambia because Zambia is located in the Sun Belt Belt in Africa and can significantly cut down energy shortages, especially in the rural and off-grid regions. Combined with wind energy, which has been researched much less, it offers the potential in some areas as an energy source. At the same time, biomass may be a low-risk energy source for rural communities since agricultural waste and residues can be adapted.

2. Strengthening Energy Storage and Grid Infrastructure

Given the unpredictable nature of solar and wind energy, Zambia must look for energy storage technologies like batteries and pumped hydro storage. This will assist in moderating the volatility of power generation and provide stable power. In addition, significant funding for upgrading the power pylons and substations across the country is required to ensure increased transmission capability, minimize losses, and redesign the grid architecture to incorporate different types of generation.

3. Policy Reform and Regulatory Support

The central energy policy's insistence requires a new policy to support renewable energy in Zambia's energy mix. The government should ensure the formulation of healthier policies that create better conditions for attracting private entities to invest in renewable

energy projects. Another approach is improving existing institutional facilities and coordinating national policies with regional projects, e.g. SASOP.

4. Policy Reform and Regulatory Support

Zambia's electric power generation and distribution problems can be addressed if it allows regional cooperation and membership in Southern African power-sharing, particularly the SAPP. Collaborative investment in energy supply, transmission, and backup capacity can achieve greater local energy security, improved cost-effectiveness, and increased access to cleaner energy technologies. Moreover, Zambia should also seek to borrow funds and technology from other countries to realize renewable energy technologies and structures.

5. Promoting Technological Innovation and Research

Increased spending on research and innovation in renewable electricity technologies can assist Zambia to continue to lead into more progressive global energy change initiatives. The government, academia, and industry should unite to help push innovations to generate renewable energy, store energy, and manage the grid. This will assist Zambia in maximizing the potential of solar, wind, and biomass energy and minimize the due course implications of executing the technologies.

6. Public Awareness and Capacity Building

Consumers embrace structural adjustments in the energy sector, and achieving a diverse portfolio requires societal acceptance and appreciation. More effort should be made to promote the use of renewable energy, especially solar and wind power, and to sensitize local communities about energy conservation. In addition, they are raising awareness of local engineers, technicians, and policymakers in capacity building for implementing and sustaining renewable energy systems.

When these measures are adopted, Zambia has the potential to minimize reliance on hydropower, improve energy security, manage the vulnerability of climate change's effects on its energy sector, and promote sustainable economic growth guided by a more diversified and secure energy mix.

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