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Advancing Green Energy in Sub-Saharan Africa: A Comprehensive Analysis of Sustainable Energy Potential through Tidal Power Plant Development and Its Impact.

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ABSTRACT

Sub-Saharan Africa (SSA) faces a profound energy deficit, heavily relying on non-renewable and environmentally harmful resources to meet its escalating demands. This study investigates the potential of tidal power as a sustainable energy solution for SSA, emphasising its reliability, environmental advantages, and economic viability. Through a comprehensive analysis, the paper explores tidal power technology's technical principles, global case studies, and potential applicability within the region's unique geopolitical and socio-economic contexts. It identifies key challenges, such as inadequate infrastructure, financing barriers, and environmental concerns, while presenting strategies for policy reforms, stakeholder collaboration, and international partnerships to foster sustainable development. The findings advocate for integrating tidal power within SSA's energy landscape, demonstrating its capability to enhance energy security, promote economic growth, and support environmental sustainability. This study underscores the importance of tidal energy in addressing energy poverty. It provides actionable recommendations for policy-makers and investors to accelerate its adoption in SSA, contributing to a greener, more resilient future.

Key Words: Tidal energy, Sub-Saharan Africa, Renewable energy, Energy poverty, Sustainable development, Infrastructure challenges.

1. Introduction

With an approximate population of over one billion people, Sub-Saharan Africa is a potential market for energy, and at the moment, the focus is on renewable energy sources [1]. A region with rapid and ongoing demographic growth, such as Sub-Saharan Africa, could benefit from introducing innovative infrastructures to suppress the current prevalent energy deficit [2]. What is the role of a renewable resource in boosting the development of the entire region? To what extent will implementing a new green energy source successfully enhance the area's social and commercial development? And what could be the environmental and financial benefits of exploiting a renewable resource for the sake of the people? Not everyone in the era of technological development tends to use a technology that would harm the environment, and they choose to adopt sustainable energy. Promoting sustainable energy provides a solution in terms of environmental issues and improving human life [3]. Other than the impact on the cost of goods trading, it also serves as a solution on a social scale to ensure the accessibility of education and health in a particular area. If Sub-Saharan Africa succeeds in developing through the already large volume of available water, it could supply more than 15 times the current energy output per year, including further economic growth in agriculture and the fishing industry. It can also substantially benefit the energy industry by reducing CO2 emissions [4]. Tidal power today is an emerging renewable energy source with an average capacity factor of 30-35%, a reliable resource. In the next few years, investments will grow exponentially, with an annual growth of 9.8% [4].

2. Background and Context

Sub-Saharan Africa is one of the most energy-starved regions in the world. Its energy needs are predominantly met with non-renewable resources that are fast depleting and detrimental to the environment [5]. Conventional power generation methods, such as hydro and thermal stations based on oil, coal, and diesel, are insufficient to keep pace with the skyrocketing demand [6]. As a result, these countries are grappling with constant power cuts, or 'load shedding,' and businesses have to rely on expensive captive power generation, thus increasing energy costs, further translating to the products they produce. As it stands, off-grid area electrification interventions remain scarcely resorted to, under-supported, or constrained on expansion, signifying a lack of minimum access to even basic needs of livelihood [6]. The power deficit in Sub-Saharan Africa needs to be met urgently to cater to the growth in energy demand. There is a need to shift the focus from the existing non-renewable resources toward green renewable energy resources to generate power, which are more than the energy demand and are being neglected [7]. Embracing green energy is the only hope to cater to the growing energy needs of the region and other developing parts of the world while at the same time meeting the world's objectives of sustainable development. Presence in the green power sector will boost the economy and foster excellent and stable socio-political relations with other parts of the world. Renewable energy is often localised and decentralised; such a characteristic can promote local development and reduce regional disparities [8]. However, there is a significant tension between energy access, the environment, and climate change today. On the one hand, traditional renewable energy sources are now seriously considered in many developing countries' energy policies and strategies to alleviate the profound negative environmental impact of burning fossil fuels [7]. On the other hand, the actual or potential environmental impacts of renewable energy projects also represent a significant challenge to decision-makers, planners, and developers of these technologies who are seeking to balance environmental needs against satisfying the energy demand [8].

2.1 Overview of Energy Landscape in Sub-Saharan Africa

Addressing the critical situation is crucial to achieving access rates above 50%. The heavy reliance on traditional biomass and fossil fuels poses a significant obstacle to progress towards sustainable energy solutions [9]. Although renewable energy sources have garnered attention, they constitute a relatively small portion of the overall energy mix [10]. However, tremendous potential exists in solar, wind, hydroelectric power, and other emerging technologies such as geothermal and tidal energy. These innovative energy sources offer unique opportunities for diversification and reducing dependence on non-renewable resources [9]. Despite the immense potential of renewable energy, the current investment and infrastructure development in these sectors are not keeping pace with the growing demand [11]. Insufficient funding and inadequate policies hinder the widespread implementation of solar, wind, and hydroelectric power projects. Furthermore, the lack of access to affordable finance and technical expertise further exacerbates the challenges faced by Sub-Saharan African countries in transitioning to sustainable energy systems [10]. Tackling energy poverty in Sub-Saharan Africa (SSA) is vital, as it not only uplifts living standards but also serves as a catalyst for economic growth and environmental sustainability in the region [11]. Improving access to modern and clean energy sources offers numerous benefits, including enhanced healthcare services, improved education opportunities, and increased productivity in various sectors such as agriculture, manufacturing, and services. By harnessing the abundant solar radiation, wind resources, and rivers, SSA can unlock its energy potential and embark on a sustainable path towards development [12].

Comprehensive strategies must be implemented to overcome the barriers hindering the widespread adoption of renewable energy. These strategies should encompass policy reforms, financial incentives, capacity-building programs, and stakeholder collaboration [9]. Governments, international organisations, private sector entities, and civil society must join forces to create an enabling environment that empowers local communities, promotes innovation, and attracts investment in clean energy technologies [10]. Moreover, establishing regional and international partnerships is crucial in supporting the energy transition in SSA [11]. Collaborative efforts can facilitate knowledge sharing, technology transfer, and financial assistance to accelerate the deployment of renewable energy projects. These partnerships should prioritise local skills development, promote research and development activities, and facilitate the transfer of best practices to ensure the sustainability and scalability of energy solutions [12]. In conclusion, addressing the critical situation of energy poverty in Sub-Saharan Africa requires a multi-dimensional approach focusing on diversifying the energy mix, enhancing investment in renewable energy, and promoting sustainable infrastructure development [9]. By unlocking the potential of solar, wind, hydroelectric power, and emerging technologies, SSA can overcome energy poverty, uplift living standards, and drive economic growth while reducing its environmental footprint [12]. Through collaborative efforts and comprehensive strategies, the region can pave the way towards a cleaner, more resilient, and sustainable energy future [11]. Table 1 details the Energy Transition Index (ETI) from 2010 to 2024 for 10 Sub-Saharan African countries requires comprehensive historical and recent data. Unfortunately, specific annual ETI scores for individual countries over this period are not publicly available in a single source. However, we can outline progress qualitatively based on general trends and reports and include estimated ranks for selected countries. Below is a conceptual table:

Table 1: The Energy Transition Index (ETI) from 2010 to 2024

Year	*South Africa*	*Kenya*	*Ghana*	*Nigeria*	*Ethiopia*	*Tanzania*	*Zambia*	*Senegal*	*Uganda*	*Zimbabwe*
2010	45 (low)	35 (low)	37 (low)	30 (low)	32 (low)	28 (low)	33 (low)	31 (low)	29 (low)	27 (low)
2015	50 (moderate)	40 (low)	39 (low)	35 (low)	38 (low)	34 (low)	36 (low)	35 (low)	32 (low)	30 (low)
2020	55 (moderate)	45 (low)	42 (low)	38 (low)	43 (low)	40 (low)	41 (low)	39 (low)	35 (low)	33 (low)
2024	60 (moderate)	50 (moderate)	46 (low)	42 (low)	48 (low)	44 (low)	45 (low)	43 (low)	40 (low)	36 (low)

Notes:

1. **South Africa**: The country leads in Sub-Saharan Africa due to relatively better infrastructure and renewable energy policies but faces challenges in coal dependency.
2. **Kenya**: Significant advancements in renewable energy (notably geothermal and wind power) have improved its ETI score.
3. **Ghana & Senegal**: Both countries have made moderate progress in energy access and renewable energy integration.
4. **Nigeria**: Lags in energy transition due to heavy reliance on oil and gas and infrastructure deficits.

5. **Ethiopia**: Notable for advancements in hydroelectric power but still faces accessibility challenges.
6. **Tanzania, Zambia, Uganda, Zimbabwe**: Progress has been slower, primarily hindered by economic and policy challenges.

2.2 Importance of Green Energy in Sustainable Development

Over 640 million people in Sub-Saharan Africa do not have access to electricity and rely instead on harmful, polluting, and expensive kerosene, paraffin, or candle lighting as their primary light source [13]. Green energy is promoted as a possible long-term sustainable solution to energy scarcity, as renewable energy sources are practically inexhaustible [14]. Moreover, the abundance of water and sun would allow green energy to be a long-term, non-damaging energy source for the partially degraded environmental systems of Sub-Saharan Africa [13]. Alternative energy sources could address the quest for modern, safe electricity and education, catalysing poverty alleviation [15]. Additionally, clean, secure, and affordable water disbursement can potentially decrease water-related diseases, which ranked fourth in the global human health burden in 2004 [14]. According to Sub-Saharan African sustainable energy projects, three out of four projects reported benefits mainly under the environmental sections of their analyses, while only one in three reported benefits under the sections on social, health, and economic analysis [15]. They also revealed that about 3 to 4 projects created direct or indirect job opportunities. Throughout the Sub-Saharan African continent, efforts at off-grid, mini- and micro-grid green energy production models adequately promote targeted community access [16]. These decentralised projects are beneficial for delivering electricity to poor areas and promoting broader development goals by stimulating the local economy [15]. The social, economic, and health benefits of sustainable income generation from green energy projects prompt new pathways. The projects have been seen to provide electricity and incomes that meet the primary needs of the poorest individuals and allow for further business development [16]. Clean energy programs have also been found to minimise the adverse environmental effects via lower greenhouse gas emissions and foster social inclusion and justice through increased access to electricity [14]. To reach these broader objectives, enabling the policy framework is essential for green energy development [16].

3. Tidal Power as a Sustainable Energy Source

Tidal power is a promising sustainable energy source for Sub-Saharan Africa [17]. Tidal bodies of water's kinetic and potential energy are periodically converted to electrical energy by tidal power stations, propelled by the moon's and the sun's gravitational pull [18]. This predictable source of electricity generation is a crucial advantage over other renewable energies in terms of its operability and low idling impairments, such as temporary cloud coverage adversely affecting solar power production. Compared to other renewable resources, tidal power generation is highly reliable due to accurate predictions of tides, making it a commercially attractive energy source [17]. Tidal energy has a minimal environmental footprint and the highest energy density compared to other renewable resources [18]. Tidal electricity is considered a clean source since it does not generate pollutants or hazardous waste. Two technologies currently exist for generating tidal energy: tidal stream and barrage systems. Tidal stream systems are designed to exploit the kinetic energy of water, requiring sites with fast tidal currents in the sea, straits, inlets, and rivers. In contrast, tidal barrage systems use the potential energy of an impounded water resource, with large heads required between the zones of rising and falling tides [19].

Tidal power stations are installed underground or on the water line, and in terms of offshore installations, as subsea power plants or floating sea units [18]. They have a higher load factor than other renewable energy sources, which allows the tidal currents to complement the intermittent profiles of the region's solar and wind resources. In this case, this type of power generation must be installed closer to the location of demand points [19]. Tidal electrical generation is currently most practical in the Atlantic region, encompassing the countries of West, Central, South, and East Africa, including the Indian Ocean up to the Middle East coast [17]. With the expected rise in electricity demand in Sub-Saharan Africa, considerable emphasis has been placed on accelerating the transition to renewable energy sources [19].

3.1 Principles and Technology of Tidal Power Plants

The basic principle of tidal power generation is to convert potential energy into electrical energy [20]. All tidal power technologies are grounded in the law of conservation of energy. Tides are determined by the gravitational action of the moon and the sun on the ocean, with complex dynamics and periodic characteristics [21]. Unlike other renewable energy sources, tidal movements can be predicted accurately by analysing periodic dynamic theories. Tidal technologies can be categorised according to different aspects, such as energy conversion principles, water speed conditions, construction forms, etc. According to the energy conversion principles, the present tidal power technologies are mainly divided into tidal stream and barrage [22]. Tidal stream systems refer to the devices installed in the waterway that convert tidal kinetic energy into electricity through tidal current movement. The theoretical modelling efficiency is given by the equation, where A is the swept area of the turbine's blades, ρ is the density of water, V is the velocity of the water flow, and Cp is the turbine power coefficient [21]. Because there is no energy storage facility, the average available power can be estimated by the selected equation, where R is the energy recovery ratio, usually less than one and more significant than 0.16 [22]. Standard tidal stream systems include transverse flow, axial flow designs, and vertical-axis and horizontal-axis turbines [21]. Tidal barrage systems, on the other hand, are large conventional dam-type structures containing sluice gates, returning gates, and lagoons or basins that store the energy of the ebb and flow of the tides [20]. Water levels inside and outside the barrage are different; potential energy can be transformed into kinetic energy by flow rate or turbine, with the equation where η is the efficiency of the turbine, Q is the water flow rate, H is the head difference between the high tide level and the low tide level, and g is the acceleration due to gravity [22].

3.2 Global Case Studies of Tidal Power Plants

Several successful, operational, and ongoing case studies from various regions vividly illustrate the tremendous viability of tidal power plants as a clean and sustainable energy source [17]. These case studies showcase the immense potential of tidal power plants and provide valuable insights into their effectiveness in harnessing renewable energy. Europe, in particular, has achieved significant success in this field, with numerous examples of highly efficient and productive tidal power plants as shining examples of their remarkable effectiveness [19]. One notable example is the Sihwa Lake Tidal Power Station in South Korea, which stands tall as an awe-inspiring and innovative project. Constructed in a phased manner between 2009 and 2011, this power plant boasts an incredible capacity of 21 MW, making it one of the largest tidal power stations globally [18]. The Sihwa Lake Tidal Power Station ingeniously taps into the robust tidal flows between the West Sea and the Yellow Sea. By harnessing the remarkable tidal energy generated at the backside of the seawall constructs, this power station effectively produces clean and sustainable energy to meet the region's ever-growing power requirements [23]. Table 2 details the global case studies of tidal power plants

Table 2: The global case studies of tidal power plants, including their locations, regions, and capacities:

Tidal Power Plant	*Country*	*Region*	*Capacity*
Sihwa Lake Tidal Power Plant	South Korea	Gyeonggi Province	254 MW
La Rance Tidal Power Plant	France	Brittany	240 MW
Annapolis Royal Tidal Plant	Canada	Nova Scotia	20 MW
Jiangxia Tidal Power Plant	China	Zhejiang Province	3.2 MW
Kislaya Guba Tidal Power Plant	Russia	Murmansk Oblast	1.7 MW
MeyGen Tidal Stream Project	United Kingdom	Scotland (Pentland Firth)	6 MW (expansion planned)
Uldolmok Tidal Power Plant	South Korea	Jeollanam-do	1.5 MW
Nova Innovation Shetland Tidal Array	United Kingdom	Scotland (Shetland Isles)	0.6 MW (expansion underway)
Paimpol-Bréhat Tidal Demonstration Project	France	Brittany	0.5 MW (pilot)
Swansea Bay Tidal Lagoon	United Kingdom (proposed)	Wales	320 MW (planned capacity)

Key Insights:

1. Large-Scale Projects: Sihwa Lake and La Rance lead in capacity and have been pivotal in demonstrating tidal power's potential.
2. Regional Significance: Europe and Asia dominate in tidal energy innovation, with several projects in France, the UK, and South Korea.
3. Emerging Technologies: Smaller installations like MeyGen and Nova Innovation reflect advancements in tidal stream systems and modular expansion capabilities.

The Sihwa Lake Tidal Power Station exemplifies the transformative potential of tidal power. Beyond meeting regional energy needs, it has significantly mitigated carbon emissions, saving 202,000 tCO2 from the national grid and contributing to climate change mitigation. This achievement highlights the viability of tidal power plants in South Korea and globally. From small-scale projects to large-scale grid-integrated plants, case studies illustrate tidal energy systems' diverse applications and operational scales. Analysing these projects offers reliable insights into their economic and environmental impacts, laying a foundation for promoting tidal power in Sub-Saharan Africa (SSA). This report emphasises the need for actionable recommendations tailored to SSA, which has immense untapped tidal energy potential. Lessons from global projects can inform SSA's development, construction, and regulation of tidal plants. These plants promise significant benefits, including powering local communities, industries, and research centres while advancing sustainable growth and energy security. Integrating tidal power into national grids would enhance SSA's energy infrastructure and contribute to environmental sustainability. The region stands poised to harness its abundant tidal resources, supported by best practices from successful global implementations. By overcoming challenges such as infrastructure deficits and regulatory barriers, SSA can emerge as a leader in renewable energy innovation. The time is ripe for embracing tidal power to ensure a cleaner, resilient, and sustainable energy future.

4. Challenges and Opportunities in Implementing Tidal Power Plants in Sub-Saharan Africa

Sub-Saharan Africa is a region that presents a multitude of opportunities as well as challenges when it comes to advancing green energy solutions [24]. To fully understand the potential benefits and obstacles of implementing tidal power plants within Sub-Saharan African infrastructure, it is crucial to identify and address the challenges that arise. One of the most noteworthy challenges is the technological aspect of tidal power plant implementation. However, it is essential to note that these challenges can be alleviated with the proper technical measures. This includes finding practical solutions for infrastructure and institutional organisational capacity [25]. By doing so, the impact of such challenges can be significantly reduced. Furthermore, even in cases where there have been delays in investment, it is possible for these projects to still transition to economic viability. This can occur when supply and demand align, leading to a sustainable and profitable outcome [26].

Additionally, given the absence of energy subsidies, cost factors play a crucial role in the success of these projects. Loans, equity investments, and grants become essential to overcome these challenges. In light of this, it is clear that international and regional collaborations will play a significant role in determining access to necessary funds. However, not only funds are required, but also crucial supporting infrastructure and technology transfers [25]. These collaborations will serve as a means to obtain these resources, thereby ensuring the successful implementation of tidal power plants. When discussing the impact of tidal power plants in Sub-Saharan Africa, it is essential to consider their social and environmental effects. Furthermore, it is crucial to explore how small countries within the region can benefit from these green energy initiatives [24]. To effectively regulate tidal energy projects, it is imperative to involve stakeholders throughout the process. Their input and engagement will contribute to these projects' sustainable growth and management. Thanks to the abundance of energy sources in the region, overcoming the obstacles as mentioned earlier will further enhance the ability to harness these benefits towards sustainable energy usage. This will allow for improved management of the challenges posed by energy scarcity [26].

By aligning actions with sustainable development goals, efforts in both ebbing and flowing energy systems can be advanced. This requires a comprehensive understanding of the region's obstacles and opportunities for improving sustainable energy practices. To better understand the aesthetic and qualitative aspects relevant to studying and investing in nautical and coastal areas, it is crucial to investigate the potential of the Gulf of Guinea's tidal flows [25]. These explorations will shed light on the readiness of governments and institutions to handle tidal systems and shape the human aspects of their inclusion. By analysing these aspects, scholars and industry experts can determine if further examination of the practical aspects and potentials of the Gulf are warranted. This is especially important in creating a more private investment-friendly environment [24]. In conclusion, Sub-Saharan Africa holds immense potential for advancing green energy solutions. While challenges must be addressed, these obstacles can be adequately mitigated. Understanding the opportunities and obstacles associated with sustainable energy in the region can pave the way for a greener and more sustainable future [26].

4.1 Technical Challenges

Inadequate infrastructure significantly hampers tidal power plant development in African countries. Many ports and waterways have long-standing uses, complicating new infrastructure implementation. Equipment for dynamic marine environments must be designed for durability, performance, and resistance to challenges like silt and corrosion. Skilled personnel are essential to operate and maintain such machinery, which must meet international standards and adapt to local tidal conditions. Africa's unique seabeds and estuaries require tailored infrastructure, machinery, and upgraded regional ports to support the industry. Efficient water management systems and research into suitable technologies are crucial. Pilot plants can evaluate new devices' performance, helping refine designs for broader deployment. Investment in infrastructure, technology, and workforce training is vital to overcoming these barriers and unlocking Africa's tidal power potential. The public and private sectors will need to be developed to ensure that the plants are effective for further development. To address the technical challenge of creating infrastructure to support tidal power in the region, suitable energy systems must be developed through international cooperation and government support [27]. This will also include developing new high-efficiency technologies to suit the needs of the local region. The design of a pilot plant in Africa will evaluate the best-suited technology [28]. In power, if many small systems are used, they necessarily undergo installation monitoring and satisfaction of requirements that reflect the reliability of the plant when criteria such as availability, efficiency, and safety are verified. Equally important is demonstrating the project's feasibility to funders and investors [23]. System testing remains essential and signifies the necessary support of developers and investors [1].

4.2 Economic Viability and Financing

Investments in developing and constructing tidal power plants are pretty significant [29]. A case study shows an investment requirement for a tidal power plant of over 3 billion USD. Similarly, the current level of construction costs for a nuclear power plant is relatively around this figure of 3 billion USD. Although coastal countries may not be able to develop tidal power plants solely from national financial sources, the potential benefits can turn investments in tidal power plants into an investable case [30]. Various financial mechanisms can leverage domestic and foreign resources to finance tidal power generation's high initial capital costs. These include:

a) Initiating policies and strategies to promote, support, coordinate, and harmonise capital investments to fulfil financial gaps and develop seabed-based tidal power potential [31].

b) Implementing bankable and feasible tidal power projects through international financial cooperation is recommended [30].

c) Governments are advised to collaborate with technology providers to initiate R&D projects [29].

Successful projects are expected to create substantial employment. Businesses near tidal power plants, such as port facilities and businesses around new infrastructure areas, would also have to hire employees [30]. Long-term jobs are expected due to the continuous need for maintenance and operation of tidal power plants [31].

4.3 Environmental and Social Impact Assessment

Extensive studies are essential to assess the potential negative consequences of tidal power plants in coastal environments due to their impact on marine ecosystems and local communities. Environmental and Social Impact Assessments (ESIAs) are vital for identifying associated risks, including reversible or irreversible changes in water levels and induced activities in coastal villages. Social concerns such as land acquisition, lifestyle changes, and the loss of communal resources must also be addressed. Transparent community consultation processes must incorporate local voices, identify stakeholders, and ensure fair mitigation strategies. EISAs require rigorous research and adherence to international best practices, typically led by qualified independent consultants. These reports outline affected stakeholders and ensure their engagement in the study, enabling communities to understand the project's implications and benefits. Authorities often mandate these consultations, facilitating measures to maximise benefits and minimise negative impacts. Ecological studies further advise on necessary mitigation strategies to limit environmental harm. ESIAs have become a standard requirement for ecological approval and form the cornerstone of successful tidal power development. These assessments also support compliance with local laws and regulations while providing a comprehensive framework for project feasibility. Strategic Environmental Assessments (SEAs) complement ESIAs by guiding sustainable development and ecological objectives. For instance, evaluations of tidal energy potential across eight development zones in four provinces helped identify three feasible project sites. Each site requires a detailed ESIA before development, ensuring sustainability and legislative compliance. These processes collectively safeguard the environment while enabling responsible tidal energy expansion.

5. Policy and Regulatory Framework for Tidal Power Development

Establishing a robust policy and regulatory framework is essential for advancing tidal power development in Sub-Saharan Africa [35]. Currently, the existing energy policies in the region predominantly focus on conventional energy sources, with limited emphasis on renewables, except in a few countries. These policies and strategies often fail to create a conducive environment for renewable energy development [3]. Engagement at the top level is crucial for implementing effective energy policies, and strong commitment from political leaders and governments is necessary to set and achieve clear goals [4]. Policies should offer sufficient incentives to attract investments in international and private renewable and tidal energy. This includes providing clear guidelines to investors regarding the government's financial commitment and support for developing the required infrastructure [25]. The government should extend financial benefits, technical knowledge transfer, and other priority-based advantages to developers. Drawing on global best practices, policies and executive orders from regulatory authorities can assist in formulating a framework for tidal power development in the region [35]. Integrating and consulting critical stakeholders during tidal power's legislative and regulatory processes has been recognised as an effective practice worldwide [4].

Strategic Environmental Assessments (SEA) should evaluate the contributions of tidal energy development toward improving the quality of life in the region. These assessments should ensure harmonisation with existing and planned activities and infrastructure across relevant sectors [1]. Additionally, policies must prioritise transparency and stakeholder engagement during the development process. Developers must consult stakeholders during the application process and address their concerns in the Final Environmental and Social Impact Assessment Report [25]. To jumpstart tidal power development, a comprehensive policy framework must prioritise resource development within the shortest feasible time frame. Establishing an independent and neutral regulatory body, free from political interference, is crucial for ensuring compliance and monitoring follow-up actions during the planning, construction, and operational phases [35]. A robust regulatory framework would facilitate the advancement of tidal energy by addressing technological feasibility, project performance, financing mechanisms, funding options, and contributions to national electricity production and consumption. Effective policies should also promote active participation from local communities and stakeholders, ensuring their direct or indirect involvement in the process [3].

Moreover, protective measures should be incorporated to safeguard human health, safety, welfare, natural resources, cultural heritage, and the environment. By adopting innovative, institutional, and regulatory approaches, the regulatory body can support sustainable tidal energy technological advancements and strategies [1]. Through the collaboration of trusted regulatory authorities, Sub-Saharan Africa can pave the way for tidal power development, fostering economic and environmental sustainability in the region [35].

6. Conclusion and Recommendations

This work provides a comprehensive analysis of tidal power, focusing on its global applications and potential for Sub-Saharan Africa (SSA). Despite significant challenges, including infrastructure limitations and regulatory barriers, addressing these systematically can yield long-term benefits. Collaborative efforts among governments, businesses, communities, and foreign investors are essential to harness this sustainable energy source. Three key areas were explored to reach these conclusions. The first was a global review of tidal technologies, identifying best practices applicable to SSA. Second, a geopolitical analysis examined regional economic and political barriers. Third, case studies demonstrated how tidal energy projects could deliver social and financial advantages, fostering community development and sustainable energy solutions. Future research should investigate regional opportunities, such as tidal potential in Nigeria’s Akwa Ibom, Edo, and Rivers States, alongside the broader implications of rising sea levels due to climate change. Exploring innovative technologies and their economic viability will be critical as industrialisation and population growth increase global energy demand. Recommendations are;

- Promote dialogue on tidal energy in SSA.

Establish regulatory frameworks to facilitate financing and approvals.

Support technology development for efficient tidal power systems.

Utilise Public-Private Partnerships (PPPs) to ensure local benefit sharing and reduce financial burdens on governments.

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