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Recent Study on Smale-Scale Free Energy Generator, Development and Future Growth in Malaysia

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***Abstract*—This review paper provides a comprehensive overview of the factors influencing the development and future growth of small-scale free energy generators in Malaysia. It highlights the importance of considering renewable energy sources, economic analysis, infrastructure requirements, expertise, public perception, and industrial support factors. The paper also discusses the progress, challenges and potential for renewable energy development in Malaysia, emphasizing the importance of policy frameworks, technological advancements and the exploration of diverse renewable energy sources. The content suggests that Malaysia can achieve a greener and more sustainable energy future by embracing renewable energy technologies and transitioning towards a high renewable net-zero power generation system.**

Keywords*—Renewable energy sources, Economic analysis, Infrastructure requirements, Expertise, Public perception.

I. INTRODUCTION

To develop a small-scale free energy generator in Malaysia, it is crucial to consider the renewable energy landscape and potential in the country. Malaysia has been focusing on sustainable energy development, with various renewable energy sources being explored for electricity generation. One significant aspect is the utilization of small-scale hydro-power, biomass energy, solar energy, wind energy, and other renewable sources for power generation [1, 2]. Studies have shown that small-scale hydro-power systems, with capacities ranging from 5 kW to 500 kW, can be a viable option for renewable energy generation in Malaysia [1]. Additionally, the use of biomass energy from sources like oil palm residues and municipal solid waste has been identified as a potential energy source for power generation in the country [3]. Solar energy, especially large-scale solar PV systems, has been a focal point in Malaysia's renewable energy pathway, with studies analyzing the feasibility of solar energy adoption in different regions like Sabah [4].

Furthermore, wind energy has also been considered as a potential renewable energy source in Malaysia, with studies evaluating the feasibility of wind energy harvesting, including at telecommunication towers and offshore oil and gas platforms [2, 4]. The development of micro-hydropower systems has been highlighted as a way to generate electricity on a small scale, contributing to Malaysia's renewable energy mix [4]. To support the development of renewable energy technologies like fuel cell power generation and solid oxide fuel cells, Malaysia needs to address economic, infrastructure, expertise, public perception, and industrial support factors [5, 6]. Additionally, the establishment of comprehensive national bioenergy policies can catalyze sustainable renewable energy development in the country [7]. The development of a small-scale free energy generator in Malaysia can benefit from leveraging the country's renewable energy potential, including small-scale hydro-power, biomass energy, solar energy, wind energy, and other sources. Addressing economic, infrastructure, and policy challenges while promoting research and development in renewable energy technologies will be crucial for advancing sustainable energy generation in Malaysia.

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II. PREPARE ECONOMIC ANALYSIS OF SMALL-SCALE FREE ENERGY GENERATOR IN MALAYSIA

For an economic analysis of a small-scale free energy generator in Malaysia, it is essential to consider various factors such as the cost-effectiveness, financial viability, and environmental benefits of renewable energy systems. Several studies provide insights into the economic aspects of renewable energy technologies in Malaysia, which can be valuable for analyzing the feasibility of small-scale free energy generators in the country. One study by Manaf *et al.* [8], focuses on the economic and environmental sustainability of low-carbon power generation technologies in Malaysia, which can provide a framework for evaluating the economic viability of renewable energy systems. Additionally, the work by Malek *et al.* [9] delves into the economic, energy, and environmental analysis of a biomass gasification-based power generation system in Malaysia, shedding light on the economic factors influencing such projects.

Furthermore, the study by Mokhtar *et al.* [10] on decision-making for renewable energy penetration in Malaysia through SWOT-PESTLE analysis can offer insights into the economic considerations for integrating renewable energy technologies like hydrogen fuel cells and solar photovoltaic systems. Additionally, the research by Yong *et al.* [11] on sustainable waste-to-energy development in Malaysia provides a perspective on the economic and environmental aspects related to energy recovery from municipal solid waste, which can be relevant for economic analyses of renewable energy projects. Moreover, the economic analysis of large-scale renewable energy systems, such as farm biogas power generation and solar photovoltaic (PV) systems [1], conducted in studies by Zhang *et al.* [12] and Laajimi *et al.* [13], respectively, can offer valuable methodologies and insights for assessing the economic feasibility of small-scale free energy generators in Malaysia. These studies highlight the importance of considering economic indicators such as the levelized cost of energy (LCOE), net present value (NPV), and internal rate of return (IRR) in evaluating renewable energy projects. Conducting an economic analysis of a small-scale free energy generator in Malaysia would involve assessing the costs, benefits, and financial viability of renewable energy technologies in the local context. Drawing on existing research on the economic aspects of renewable energy systems in Malaysia can provide valuable guidance for evaluating the economic feasibility and sustainability of small-scale free energy generators in the country.

III. INFRASTRUCTURE ANALYSIS OF SMALL-SCALE FREE ENERGY GENERATOR IN MALAYSIA

To conduct an infrastructure analysis of a small-scale free energy generator in Malaysia, it is crucial to consider various factors related to the development and deployment of renewable energy technologies. Several studies provide insights into infrastructure considerations for renewable energy projects, which can be valuable for analyzing the infrastructure requirements of small-scale free energy generators in Malaysia.

The study by Terrapon *et al.* [14] on the social impacts of large-scale solar thermal power plants highlights the importance of infrastructure development in renewable energy projects. The positive reception of infrastructure development in the context of solar power plants can provide insights into the potential acceptance and impact of infrastructure associated with small-scale free energy generators. Additionally, the work by Taminiau *et al.* [15] emphasizes the significance of infrastructure-scale sustainable energy planning in urban settings. Understanding the economies of scale and integrated deployment of interventions can be crucial for optimizing infrastructure for small-scale free energy generators in urban areas of Malaysia. Moreover, the economic feasibility and development potential of solar irrigation systems in sub-Saharan Africa, as discussed by Falchetta *et al.* [16], shed light on the financial aspects of deploying distributed small-scale infrastructure. This insight can be valuable for assessing the economic implications of infrastructure development for small-scale free energy generators in Malaysia.

Furthermore, the study by Jalil *et al.* [17] on smart energy transition in South Korea underscores the importance of advanced metering infrastructures, energy storage systems, and intelligent energy management systems in optimizing energy use. Such advanced infrastructure components can be relevant for enhancing the efficiency and effectiveness of small-scale free energy generators in Malaysia. Conducting an infrastructure analysis of a small-scale free energy generator in Malaysia would involve considering factors such as social impacts, sustainable energy planning, economic feasibility, and advanced energy management systems. Drawing on existing research on infrastructure development for renewable energy projects can provide valuable insights for optimizing the infrastructure requirements of small-scale free energy generators in Malaysia.

IV. EXPERTISE ANALYSIS OF SMALL-SCALE FREE ENERGY GENERATOR IN MALAYSIA

In this country, there has been a concerted effort to promote renewable energy sources, such as small-scale free energy generators. Initiatives like the Small Renewable Energy Power (SREP) program, the Biogen Full Scale Model Demonstration project, and the Malaysia Building Integrated Photovoltaic

(MBIPV) project have been pivotal in stimulating domestic renewable energy production [17]. Micro hydro systems, capable of generating electricity ranging from 5 kW to 500 kW, have been identified as a viable option for adoption in Malaysia [1]. Additionally, the Small Renewable Energy Program (SREP) launched in 2001 aimed to have renewable energy sources contribute to 5% of electricity generation in Malaysia [18].

The country has recognized the potential of various renewable energy resources, including biomass, biogas, municipal waste, solar photovoltaic, and small hydropower, as part of its Five Fuel Diversification Strategy under the Eighth Malaysia Plan [7]. Malaysia aims to achieve 20% of its energy generation through nonconventional sources, as stated by the Malaysian Photovoltaic Industry Association [19]. The government has set ambitious targets, such as aiming to achieve 20% renewable energy generation by 2025 [20]. Research has delved into factors influencing innovation in renewable energy technology in Malaysia, highlighting the importance of policy and regulatory frameworks in accelerating the deployment of distributed energy resources [1, 21]. Malaysia is actively pursuing the development and utilization of renewable energy sources, including small-scale free energy generators, to diversify its energy mix, reduce greenhouse gas emissions, and achieve sustainable energy security.

V. CURRENT FREE ENERGY GENERATOR IN MALAYSIA

To establish a free energy generator in Malaysia, it is crucial to consider various factors that influence the innovation and deployment of renewable energy technologies in the country. Policy and regulatory frameworks play a significant role in accelerating the adoption of distributed energy resources, as highlighted in research focusing on factors influencing innovation in renewable energy technology in Malaysia [22]. This research emphasizes the importance of understanding socio-political and community acceptance of renewable energy innovations, which is vital for the successful realization of specific projects [23]. Moreover, transitioning to a sustainable development framework for bioenergy, particularly utilizing palm oil mill residues, has been suggested as a strategy to catalyze the utilization of renewable energy sources in Malaysia [7]. The country has aggressively moved towards a higher penetration of renewable energy in its energy mix, aiming for 20% by 2025, with a particular focus on solar photovoltaic energy [24]. Additionally, the potential of palm oil biomass to replace coal in power generation for decarbonization purposes presents a significant opportunity for renewable energy utilization in Malaysia [19].

While Malaysia has made progress in renewable energy development, challenges such as regulatory barriers and the need for a comprehensive policy framework for sustainable oil palm biomass electricity generation persist [25]. Understanding the legal frameworks and comparative studies on renewable energy laws between Malaysia and other countries, such as Canada and India, can provide insights into enhancing renewable energy initiatives in Malaysia [26, 27]. Establishing a free energy generator in Malaysia requires a holistic approach that considers policy frameworks, community acceptance, sustainable bioenergy utilization, solar energy penetration, and overcoming regulatory barriers. By leveraging the research findings and recommendations from studies on renewable energy innovation and development in Malaysia, the country can further advance its renewable energy goals and contribute to a more sustainable energy landscape.

VI. MALAYSIA PUBLIC PERCEPTION

Public perception of small-scale free energy generators in Malaysia is influenced by various factors related to renewable energy sources and sustainability. Studies on bioenergy policies [7] (Salleh et al., 2020), the design of energy storage systems for solar PV [13], and the impact of optimized electricity tariffs on renewable energy growth [28] in Malaysia indicate a growing interest in renewable energy technologies in the country. Additionally, research on the potential of wind energy in reducing greenhouse gas emissions [29] and the acceptance of renewables through location-related factors [30] emphasize the positive impact of renewable energy on environmental sustainability. Studies on rural public acceptance of wind and solar energy in Malaysia [31] and the use of Instagram to understand public perceptions of renewable energy infrastructures [32] shed light on the importance of social acceptance and cognitive factors in shaping attitudes towards renewable energy technologies. While the focus of some studies may not directly address small-scale free energy generators, the broader context of renewable energy perceptions in Malaysia provides valuable insights. Understanding public perceptions and acceptance of renewable energy sources is crucial for the successful integration of small-scale free energy generators into the Malaysian energy landscape. By considering factors such as sustainability, environmental impact, and public acceptance, stakeholders can work towards promoting the adoption of small-scale free energy generators in Malaysia.

VII. MALAYSIAN INDUSTRIAL SUPPORT FACTORS ON SMALL SCALE FREE ENERGY GENERATOR

To explore Malaysian industrial support factors for small-scale free energy generators, it is essential to consider relevant references that focus on renewable energy, sustainability, and industrial applications. Salleh *et al.* [7] discusses the influencing factors that shape renewable energy growth in Malaysia, providing insights into the transition to a sustainable development framework for bioenergy. This study can offer valuable policy suggestions to catalyze the utilization of renewable energy sources, which can be applicable to small-scale free energy generators in the industrial sector. Additionally, Chagas *et al.* [33]

reviews small wind turbine applications, highlighting the potential boost in the small wind turbine environment. Understanding the lessons learned from the US to Brazil in small wind turbine applications can provide valuable insights into the factors that contribute to the successful deployment of small-scale renewable energy technologies in industrial settings.

Moreover, Cornejo *et al.* [34] focuses on small-scale solar-powered desalination plants, offering a sustainable alternative for water-energy nexus challenges. While the study pertains to desalination, the concept of small-scale renewable energy technology for sustainable solutions aligns with the potential applications of small-scale free energy generators in industrial contexts. By synthesizing insights from these references, it can be inferred that Malaysian industrial support factors for small-scale free energy generators may include policy frameworks for renewable energy growth, lessons from small wind turbine applications, and sustainable solutions such as solar-powered technologies for industrial processes. These factors can contribute to the successful integration of small-scale free energy generators in the Malaysian industrial sector, promoting sustainability and energy efficiency.

VIII. RECENT DEVELOPMENT OF FREE ENERGY GENERATOR IN MALAYSIA

In Malaysia, there has been a significant shift towards renewable energy development in recent years. The country has set ambitious targets to reduce its dependency on fossil fuels and increase the share of renewable energy sources in its energy mix. Initiatives such as the establishment of comprehensive national bioenergy policies, transitioning to a high renewable net-zero power generation system, and developing peer-to-peer energy trading models reflect Malaysia's commitment to sustainable energy practices [7, 35, 36].

The Malaysian government aims to achieve 20% energy generation through nonconventional sources by 2025, as stated by the Malaysian Photovoltaic Industry Association [19]. This transition is further supported by the aggressive move towards a higher penetration of renewable energy, particularly solar PV energy, in the country [24]. Additionally, efforts are being made to enhance energy efficiency and reduce carbon emissions through policies that promote sustainable development [37, 38]. Various renewable energy sources are being explored in Malaysia, including wind energy, hydropower, wave energy, and bioenergy. Studies have shown the potential for significant energy generation from these sources, with Malaysia having the ability to generate substantial power from wind and wave energy [1, 39, 40]. Furthermore, the utilization of marine current energy devices and fuel cells is being considered to meet the country's energy needs sustainably [41, 42]. Despite the progress in renewable energy development, challenges remain, including the impact of the COVID-19 pandemic on the renewable energy sector and the need to address environmental and financial issues related to waste-to-energy projects [11, 43]. However, with a focus on transitioning towards sustainable energy practices, Malaysia is poised to continue its journey towards a greener and more energy-efficient future.

IX. THE FUTURE OF FREE ENERGY GENERATOR IN MALAYSIA

The future of renewable energy development in Malaysia holds significant promise and potential for sustainable energy growth. As Malaysia faces the challenge of fossil fuel depletion due to increasing energy demand [6], there is a pressing need to transition towards renewable energy sources. Establishing a comprehensive national bioenergy policy can pave the way for sustainable renewable energy development in Malaysia [24]. This policy framework can catalyze the utilization of various renewable energy sources, including small-scale free energy generators, to meet the country's energy needs. Technological advancements, such as energy storage systems for large-scale solar [13] and the selection of fuel cell power generation [5], can further enhance the integration of free energy generators into Malaysia's energy landscape. The potential of micro hydropower systems in reducing energy costs and boosting social development [44] highlights the importance of exploring diverse renewable energy options for sustainable energy generation.

Moreover, the review of available hybrid renewable energy systems [45] and the transition to a high renewable net-zero power generation system [46] underscore the importance of diversifying Malaysia's energy mix. By leveraging solar, hydro, biomass, and other renewable technologies, Malaysia can work towards achieving a high renewable net-zero power generation system, aligning with global sustainability goals. The utilization of waste-to-renewable energy transitions, such as biogas generation [47], and the exploration of distributed generation technologies [48] can further contribute to Malaysia's renewable energy portfolio. Additionally, advancements in peer-to-peer energy trading models [36] and fuel cell technologies for residential applications [42] can enhance energy efficiency and decentralize energy production in the country.

As Malaysia aims to reduce greenhouse gas emissions and enhance energy security, evaluating potential renewable energy resources through multi-criteria decision analysis [1] and focusing on biomethane production [48] can drive sustainable energy transitions. The stability analysis of floating buoys for wave energy harvesting [49] and the energy output from barrages in East Malaysia [50] demonstrate innovative approaches to harnessing renewable energy sources in coastal areas.

In conclusion, the future of renewable energy development in Malaysia is intertwined with the country's commitment to sustainable energy growth, policy frameworks supporting renewable energy development, technological advancements in energy storage and generation, and the exploration of diverse

renewable energy sources. By embracing renewable energy technologies and transitioning towards a high renewable net-zero power generation system, Malaysia can pave the way for a greener and more sustainable energy future.

X. CONCLUSION

This paper discusses the development and future growth of small-scale free energy generators in Malaysia, focusing on various aspects such as economic analysis, infrastructure requirements, expertise, public perception, industrial support factors, current status, recent developments, and the future of free energy generators in the country. It emphasizes the importance of considering renewable energy sources like small-scale hydro-power, biomass energy, solar energy, and wind energy for power generation. Economic analysis is crucial for evaluating the cost-effectiveness, financial viability, and environmental benefits of renewable energy systems, and several studies provide insights into economic aspects, including the economic and environmental sustainability of low-carbon power generation technologies, biomass gasification-based power generation systems, and decision-making for renewable energy penetration. Infrastructure analysis is essential and encompasses understanding sociopolitical and community acceptance, sustainable energy planning, and advanced energy management systems. The document also delves into the expertise, public perception, and industrial support factors for small-scale free energy generators in Malaysia, highlighting the country's efforts to promote renewable energy sources and achieve sustainable energy security. Furthermore, it discusses the current status, recent developments, and the future of free energy generators in Malaysia, emphasizing the need for a comprehensive national bioenergy policy, technological advancements, and the exploration of diverse renewable energy sources to achieve a greener and more energy-efficient future.

In conclusion, this review paper provides a comprehensive overview of the recent factors influencing the development and future growth of small-scale free energy generators in Malaysia. It underscores the significance of considering renewable energy sources, economic analysis, infrastructure requirements, expertise, public perception, and industrial support factors to achieve sustainable energy generation in the country. Additionally, it highlights the progress, challenges, and potential for renewable energy development in Malaysia, emphasizing the importance of policy frameworks, technological advancements, and the exploration of diverse renewable energy sources to pave the way for a greener and more sustainable energy future.

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