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A Review of Renewable Energy Mini-Grid Systems in the Non-Interconnected Rural Areas: A Case Study

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Abstract: More than 100,000 people scattered in rural areas or outer islands are still using non-interconnected power generation systems such as thermal power. The ecological balance is reduced because the electricity costs are too high due to dependence on fossil fuels. However, the energy transition (ET) in island/rural areas is faster in terms of a low carbon economy because the potential for renewable energy is very large there. This presents a renewable mini hybrid grid system that can connect rural areas/outer islands. The research paper deals with a comparative analysis across remote island/rural areas based on the previous literature. The application of the business systems identified in this work is undertaken to encourage the introduction of renewable energy (RE) and promote HRE-MG utilization in island/rural areas. The targets for achieving advanced success of ET are specifically discussed in this work. The ET development can involve the government and the private sector to support the achievement of these targets. In addition, funding sources must be sought for certain areas as an alternative to assistance, and foreign investors are needed. Cooperation at the international and government levels must be established so that effective policies can support capacity building at the local level. The application of HRE-MG in island/rural areas is suitable for companies to invest in renewable energy services because the renewable technology costs and the value of tax incentives are lower in these areas.

Keywords: Hybrid Renewable Energy (HRE) System, Mini-grids (MG), Electricity Access, Rural areas, non-interconnected.

非互联农村地区可再生能源微型电网系统研究：一个案例研究

摘要：散布在农村地区或外岛的十万多人仍在使用非互连的发电系统，例如火力发电。由于对化石燃料的依赖导致电力成本过高，从而降低了生态平衡。但是，就低碳经济而言，岛屿/农村地区的能源转换（ET）更快，因为那里的可再生能源潜力很大。这提出了一种可再生的微型混合电网系统，可以连接农村地区/外岛。该研究论文根据以前的文献对偏远岛屿/农村地区进行了比较分析。进行这项工作中确定的业务系统的应用是为了鼓励引入可再生能源（回覆），并促进在岛/农村地区使用 HRE-名爵。在这项工作中具体讨论了使 ET 取得成功的目标。ET 的发展可以使政府和私营部门参与，以支持实现这些目标。此外，必须寻求某些领域的资金来源以替代援助，

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并且需要外国投资者。必须建立国际和政府一级的合作，以便有效的政策可以支持地方一级的能力建设。HRE-名爵在岛屿/农村地区的应用适合公司投资可再生能源服务，因为这些地区的可再生技术成本和税收优惠价值较低。。

关键词：混合可再生能源（HRE）系统，微型电网（名爵），电力接入，农村地区，非互连。

1. Introduction

Although the millennium development goals do not include renewable energy [1]. However, for sustainable development in 2030, the role of energy is important for all development processes. Access to modern energy is the key to reducing poverty, meeting people's needs, saving human lives, and improving health conditions [2]. Systems for converting energy production and consumption to reduce poverty and promote sustainable development are discussed. A paradigm shift towards a green economy is needed, particularly in markets and developing countries [3]. To accelerate the transition process into a modern energy system, a series of high-impact opportunities must be identified in advance so that the goal is to achieve synergy between actors. Besides, the industrial sector can advance towards universal energy access [4]. The link between renewable mini-hydro networks and existing resources in a sustainable manner can be used as a tool to be included in the government's national and international targets. Different definitions of business models can provide the knowledge to create and facilitate access to finance, both public and private [3]. Communities and institutions are key to an energy transition towards innovative financing mechanisms, seeking private investment, a global economy, and an ownership structure [5].

The mini-hybrid grid system from RE sources is a more feasible alternative way to be applied in rural areas, remote areas, or islands in increasing their energy access. As a result, the use of diesel fuel is reduced, costs are lower, and the quality of electricity services improves. Also, conditions for uncertain climate change in the last few years can be minimized [6]. The HRE-MG network system as a whole includes social and economic benefits in rural areas and local businesses. Also, it can increase agricultural production; new jobs are available, income increases, and health and education can be achieved [7]. This system also offers diversification opportunities as well as provides competitiveness against power generation companies [8]. In the last few decades, the global HRE-MG network has increased as conventional energy continues to decrease. In 2017 the mini-hydro grid and photovoltaic solar energy (PV) produced electricity capacities of 509 MW and 308 MW [9]. The HRE-MG network has connected 9 million people in 2016 [10]. The potential for the HRE-MG network systems sector in the future is enormous. As many as 1.06 billion people currently do not have access to electricity or 14% of the global population [11]. The International Energy Agency (IEA) predicts that in the 2017-2030 period, as many as 485 million people or 60% more of the current population can enjoy electricity through a decentralized power system. Meanwhile, the energy needs of 185 million people can be protected by the electricity grid. The mini-hybrid network can be implemented, requiring an investment of USD 188 [11]. However, the mini-hybrid technology network system can provide a target for large energy access [12]. However, the energy-saving system from HRE-MH for electricity supply is the most appropriate choice. Studies on energy hybridization in the average cost reduction of up to 0.3% to 8% when market conditions are evident. Even if the public sector's investment could finance the project, the reduction in generation costs could be reduced by up to 16% from 12% [13]. Globally diesel capacity can be blended with renewable energy at rates varying from 50 GW to 250 GW [6], where 15 GW are in islands/remote areas based on the existing population [14]. It is estimated that households without electricity access in island/rural areas are more than 70% [15]. Meanwhile, solar and wind energy potential that can be hybridized with diesel generators is 2.95 MW and 4.97 MW [14]. The sustainable development of HRE-MG must analyze several variables (geography, environment, socio-economy, and regulations that exist in each region). Thus, the natural area context can influence the success and failure rates of various business models for renewable energy [16].

Good and diverse management of resources and ecosystems is the main role for reducing environmental problems, and the future community livelihoods can be ranked [17]. Global climate change is a vulnerability to island/rural areas, so that actions to reduce greenhouse gas (GHG) emissions must be taken immediately, especially those related to the use of fossil fuels [18]. Islands/rural areas globally have off-grid grid systems such as thermal power plants. This can affect the cost of electricity, and the level of reliability to the safety of the electricity supply is not guaranteed [19]. However, the energy transmission system can be accelerated due to abundant RE resources [20]. The full use of RE is a general goal of the region towards sustainable development [21]. About 7% more of the earth's surface is covered by 87,000 islands worldwide [22]. While the global population of islands is approximately 740 million people, as many as 20 million people (3%) are located in 1785 islands with a total population of more than 100,000. The highest energy potential is predicted to be 15 GW from solar and wind energy, which can be hybridized with diesel built-in islands/rural areas [5]. Thus, 7.5 GWp of solar energy and 14 GW of wind energy can be combined with a 5.82 GWh battery capacity. So that as much as 7.8 billion liters of diesel consumption per year and 20 million tons of GHG emissions can be reduced.

Savings in fuel costs of USD 10 billion with an average of 3.3% per year can be deducted from the gross domestic product (PBD) found in islands/rural areas. This number does look small, but in reality, islands/rural areas can generate 20% to 30% of their total GDP for fuel use [23]. Even up to 90% of electricity production uses imported oil, as reported by [24]. Thus, there was a reduction of 1.5% of GDP with an increase in the price of imported oil by USD 10/barrel. The volatility of current volatility in oil prices can affect transportation, communication, and electricity costs. Also, it can affect poverty and real income for the community in general [25]. Island/rural development is more susceptible to various external influences. This is due to the disadvantages of limitations to achieving economies of scale, limited land availability, remoteness, high disaster vulnerability, population distribution, vulnerable environmental conditions, and dependence on foreign countries [26]. The HRE-MG network system in archipelagic/rural areas is the right choice in increasing RE penetration of the electric energy mix, especially in areas without land interconnection. However, islands/rural areas have a significant contribution to reducing GHG emissions globally. However, this area can show independence to the world not to depend on fossil fuels in the future [3]. Several islands/rural areas in developed countries can generate electricity up to 100% from renewable sources. The electrical energy is generated from a diesel generator, a backup from El Hierro, Kodiak, and Graciosa. The planned acceleration of energy transmission is a constraint for each island/rural area, so that economic incentives must be considered at the planning stage [27]. There are several causes such as institutional, financial, social, environmental, and technical conditions. Strong energy policy is a top priority in linking objectives locally and nationally as in the 2030 agenda. International commitment to setting regulatory frameworks is a valuable mainstay [28].

The review of this research presents an overview of the various conditions of power plants with energy technology (ET) systems based on mini-hydro networks in islands/rural areas that are not connected. This investigation comparatively analyzes islands/rural areas globally by considering the two regions as one region. Configuration systems with renewable energy technologies that vary from one region to another with the level of difficulty and challenges in their application and different business models to support HRE-MG application are presented in this paper. The purpose of this study specifically investigates the application of a business model for hybridization of thermal power plants in islands/rural areas that are not connected using the definition of rural electrification. Apart from that, the technical, political, social, financial, and environmental conditions associated with RE penetration are also the objectives of this study. The findings generated in this study can be useful for future RE project development, especially for stakeholders and policymakers.

2. Research Methodology

Renovating Globally there are 1785 islands with a population range of more than 100,000 [30]. The identification of islands in this study uses a geographic information system (GIS). The small islands are located in the Pacific Ocean, Atlantic Ocean, Indian Ocean, Caribbean Sea, and the Mediterranean as many as 890, 380, 319, 103, and 93, respectively. Meanwhile, the number of islands in Indonesia in 2019 was 17.491, where most of the islands do not have access to electricity [83]. Every year the total electricity consumption required reaches 50.000 GWh, so the need and demand for fossil fuels have increased [29]. In 2019, Indonesia's electricity consumption reached 1,084 kWh/capita with a target amount of 1,200 kWh/capita. Meanwhile, the electricity consumption target in 2020 is 1,142 kWh/capita. In general, all of the islands had no direct connection to the mainland. This is because the cost of submarine cable connections is quite high. Thus, the supply of electricity in island/rural areas far from the mainland is reduced and unstable [20]. The problem of lack of electrical energy in the outermost islands/villages can be overcome by building a mini-hybrid network which is also the objective of this review. Hybridization of diesel power plants with abundant RE potential such as wind and solar power can be implemented to overcome energy shortages [22]. Investigations regarding economic and technical studies found in pensioners / rural areas differ according to their location. This difference, for example, is the highest GDP/capita found in developed countries and the lowest GDP. The Levelized Cost of Electricity (LCOE) in the Pacific is the highest at 45 USc/kWh. This is because the transportation costs for the most remote areas are quite high. Meanwhile, the highest wind power projects are in the Atlantic and Pacific Oceans, estimated to be 6.44 GW and 2.95 GWp, respectively. Meanwhile, the potential for power plants with a hybridization system in the islands is estimated to be around 10% -97%.

Based on these research results, the analysis carried out in this paper is an island/rural area to determine the main factors to drive the development of the HRE-MG network system. For this goal to be achieved, the first thing to do is to create a classification matrix so that descriptive information found in islands/rural areas can be collected. Information needed such as geographic location, vulnerability factors, RE resources and availability, policies, and economic activities intending to promote RE, business models, and financial mechanisms used. Besides, to combine thermal systems and identification of RE applications and their storage grid systems. Furthermore, the data-related matrix is the most interesting thing in this work. For example, total population, total area, GDP/capita/year, installed electricity capacity, percentage of RE for the power plant mix, electricity consumption/year/capita, and peak demand. These indicators can strengthen the characterization carried out in this study. Also, the details of several previous studies that selected four basic criteria, including (one island in a region, a population of more than 100,000, islands / rural areas that have no direct connection to the mainland, and islands/rural areas that have hybridized mini-networks. Hybrid with ET as shown in Table 1 [30]. The development carried out in this paper is based on some literature related to the development of mini-hybrid networks with ET sources in remote areas that have no direct connection to the mainland. Besides, documents, information, and data from the government, statistics, surveys, and official websites are complementary to convey the purpose of this work. Several examples were taken to analyze comparatively and descriptively to describe the situation of a particular area.

Table 1 Small Islands in global scale

Location of Ocean	Island	Population	Areas (km^2)	Name of archipelago
Atlantic	Tuvalu	10,782	26	4 coral reefs and 5 atolls
Caribbean	Necker	60	0.18	The British Virgin Islands
Atlantic	Tokelau	1411	12	3 atolls
Indian	Seychelles	93,400	455	115 islands
Atlantic	Galapagos	29,658	8.01	19 major islands and 200 islets
Indian (Tasmania-Bass Strait)	King Island	1938	1109.8	Island

3. Definitions of HRE Mini-Grids

3.1. Hybrid Renewable Energy Mini-Grids

The utilization of electric energy generation from renewable sources combined with HRE-MG such as wind power, PV, hydropower, diesel, and storage systems is very suitable for islands/rural areas because the network system has more than one client. The HRE-MG network system currently in use has become widespread so that the exploitation of renewable resources can be helped. Thus, the reliability, safety, and quality of the HRE-MG network system are further guaranteed [36]. Besides, this system can also provide many socio-economic and environmental benefits [36]. This network system is the best choice for off-grid locations in remote island areas. Network integration systems like this are generally used to address battery requirements [36]. In island/rural areas, efficiency and economic problems are the main challenges. Frequency and voltage stability control of the mini-grid network with HRE-MG can ensure optimal economic operation [37]. Both systems can be operated as a network in islands/villages. HRE-MG and mini-hybrid network systems in remote islands/rural areas can be connected directly to the mainland. The HRE-MG network system can centrally address power demand, especially electrical energy, in interconnected islands.

3.2. System Mini-Grids

One renewable energy source used for mini-grids can connect many clients [36]. Two types increase the price of electricity compared to when using a mini-hybrid network. First, a 100% RE power system requires batteries to store more electrical energy so that electrical service can always be guaranteed. The renewable system capacity installed is higher than that of diesel or hybrid systems in generating electricity. Thus, the hybrid network system can reduce the battery life, which is more constant and high usage. Second, a fuel power system as much as 100% can be delivered but impacts the environment. Meanwhile, the investment in diesel generator sets is lower than the investment in renewable energy power. However, the operating and maintenance costs of a diesel system are more expensive than renewable energy. This is because the cost of fossil fuels for diesel generators is more expensive [12].

3.3. Business Models for Implementing Systems HE-MG

The development of off-grid business depends on existing regulations and political conditions, and local conditions in the region [12]. The regulation of the HRE-MG network system with its difficulty level is very relevant. To ensure the operating system against the opportunities and constraints, it can use this framework [12]. At the same time, a better and stronger governance system is a prerequisite for the needs of suppliers, consumers, and owners so that risks for stakeholders can be further reduced. To ensure funding in the long term, the installation and HRE-MG can use a more varied business model. The main determining factors can classify different business model systems [12]. The model adjustment must be adapted to the system requirements in the location area. The owner defined in this study is an entity that acts as the person in charge of funding this project. Intended entities such as international organizations and donors who invest their funding. However, ownership must be clear in determining responsibility for this project [12]. Meanwhile, donors at the traditional level are leaders in seed financing, especially in developing countries.

4. Classification of Studies Reported: RE Engines and Inhibitors

In island/rural areas, it is the most common control, such as shortages of natural resources, small domestic markets, and unfavorable environmental conditions [38]. However, not all islands/rural areas are the same, such as the availability of RE resources in islands with their size, economic welfare, and socio-economic conditions. Enabling and inhibiting factors for the development and implementation of HRE-MG are discussed in this section.

4.1. RE Potential

A sustainable development system, especially in remote island/rural areas, plays a very important role in determining whether an area is progressing or not. Expanded energy access to replace fossil fuels aims to decarbonize the electricity sector so that climate change mitigation and RE introduction targets can be achieved [35]. The island's techno-economic ET capacities, such as wind and solar, are 14 GW and 7.5 GWp, respectively [11]. However, the fairly high transaction costs and potential ignorance can slow down RE development [30]. Meanwhile, wind and solar power potential in the Atlantic and Arctic islands reaches 6.44 GW and 1.94 GWp. Meanwhile, El Hierro islands are best, with wind speeds reaching 8-10 m/s. Besides, solar radiation in one of the Canary Islands, especially in the upstream and northern parts of the mountains, is 7 kWh/m2 and 6 kWh/m2. Thus, the PV technology is very compatible with the potential of the sun is quite large. The potential availability of wind and solar power in the Pacific is 4.97 GW and 2.95 GWp with a storage rate of 2.27 GWh [30]. This potential is spread across Tuvalu at 5.5 kWh/m2/day, while the maximum wind speed is 5.79 m/s at an altitude of 30 m. Meanwhile, at Funafuti, the amount is 20-50 kW and allows for the installation of small-scale turbines [12]. The availability of this energy source has the potential to produce quite large biomass and biofuel because of coconut trees that grow a lot in the archipelago for 1.600 ha [23]. The utilization of solar energy sources, biofuels, and storage systems provides electricity availability up to 150% of production as in Tokelau. However, in Tokelau and Tuvalu, biomass production is higher because it meets labor and transportation costs [24]. The most suitable PV and solar thermal technology installation was developed in the Galapagos Islands located in Ecuador. Biomass resources in the area are not obtained, but the generation of biofuels using RE is an alternative since biofuel from castor oil shows the most expensive cost. This is because jatropha planting is done on land. The cost for jatropha oil production is 66.94 USc/kWh and the cost of biofuel production reaches 24.50 USc/kWh. As an archipelago with a long coastline, Indonesia has great wind energy potential. In 2018 the potential for wind energy in several islands in Indonesia reached 100 MW. Areas with considerable wind potential include Sukabumi (170 MW), Garut (150 MW), Lebak, and Pandeglang (150 MW each), and Lombok (100 MW). Meanwhile, Indonesia's potential for solar energy reaches 3.41-4.47 kWh/m²/day, spread across 8 regions [39].

The installed wind and solar energy capacities in the Mediterranean islands are 894 MW and 972 MWp, respectively [30]. In the ASEAN region in Ikaria, the average wind speed ranges from 7-9 m/s. The potential for solar power in the summer reaches 5 kWh/m2/day, supporting electricity needs, especially in the tourism sector. Also, biomass and geothermal energy sources are found in several islands/rural areas [40]. Wind and solar energy capacities of 1.25 GW and 905 MWp are found in the Caribbean islands. Wind speed in the region, especially the eastern Caribbean region, reaches 8-9 m/sec during the dry season, and the rainy season is around 6-7 m/sec. Meanwhile, the RE potential of wind and solar power of 319 MW and 704 MWp, respectively, are found in the Indian Ocean islands [30]. RE's potential is generated from wind power, solar power, biomass, hydropower, energy waste of 16 MW, 40 MWp, 5 MW, 2 MW, and 7 MW in Seychelles can be utilized until 2030 [40]. Freshwater power in some areas appears to be scanty but can use an energy source from the abundant seawater that can be pumped and supplied for electricity generation. However, this can only be done at high elevations to be installed as a power plant using hydropower. This includes seawater and freshwater sources found in several islands such as Seychelles, El Hierro, Kodiak, and the Galapagos. Meanwhile, regional islands such as Tokelau and Tuvuan are very unlikely to obtain water energy sources because these areas are relatively high [23]. Thus, islands like this are not suitable for energy development from water, but energy generation suitable in this area is like solar PV. Renewable energy technology solutions sourced from biomass are the most appropriate choice in the region. This is because the production cost is relatively low, especially for islands/rural areas with large territories. The achievement of integration of renewable technologies depends on the availability of renewable resources in the area. The process of RE integration has been very slow, but the efforts made to introduce ET into the RE generation lacked a strong boost. To accelerate the promotion of RE against RE, it must be recognized concerning environmental areas, geography, measures that can limit the integration of RE into RE generation.

4.2. Scale, Insularity, and Remoteness

Small size and dependence on external markets, and limited natural resources often become obstacles to islands/rural areas. Thus, dependence on imports and foreign exchange results in considerable losses, especially GDP [41]. Limited capabilities and markets severely affect import systems and economic achievements, limiting their internal prices [41]. For the most part, in remote islands/rural areas, the infrastructure system is not developed. Apart from that, the condition of existing human, financial, and natural resources is also very limited [41]. Transportation costs, uncertain security, and insecure supplies are major constraints [41]. These problems, in general, can affect the price of electricity, especially in islands/rural areas that have no connection to the mainland. It is estimated that in the next 20 years, the thermal generation cost is the highest in the region at 45.1 USc/kWh [30]. Thus, the review in this study finds that the most vulnerable islands in the area are some of the countries with remote islands around the world. The cost of generating electricity in Tokelau in 2002 was around USD 1.02/kWh. Meanwhile, in Fakaofo and Nukunonu, it was USD 1.30/kWh and USD 1.82/kWh, respectively. Furthermore, the price rates for electricity subsidies received are 50, 35, and 30 USc/kWh, respectively [145]. Fuel distributed from Samoa is stored at Fakaofo and transported by Cargo Ship [23]. Meanwhile, subsidized power plants such as in the Galapagos Islands are only intended for thermal power, and the price is around 12.32 USc/kWh [146]. Delivering diesel fuel costs 49 USc/liter, so the price for the final customer reaches 51 USc/liter. The total price includes the cost of weighing, transportation, taxes, commercialization, and time of storage. Meanwhile, the region's housing sector consumes an average electricity tariff of 9.8 USc/kWh; the cost of electricity consumption is around 500 kWh. The RE integration system to drive the energy transition in every remote island/rural area is a must. The resulting energy system is low-carbon, and the conditions are more durable [42].

4.3. Factors of Environmental

Population growth that continues to increase is a threat to island/rural ecosystems in a region [41]. This increase in population increases the number of imports and local resources for better provision and services. Also, vulnerabilities such as natural disasters in island/rural areas directly affect economic growth so that provision and services can be disrupted [41]. Developments such as housing, agriculture, tourism, and animal husbandry from land exploitation of natural resources can harm the regional ecosystem. Thus, balancing social, environmental, and economic needs is very important for maintaining the existing ecosystem. The different benefits given to several islands/rural areas are due to the system of preserving nature reserves and biodiversity so that sustainable economic growth can be encouraged. For example, The Biosphere Serves the famous El Hierro and Graciosa regions and a World Heritage Site designated the Galapagos archipelago. Whereas much is 58% more land surface is protected in the El Hierro islands [43]. Meanwhile, as much as 3% of the island's total surface and the national parks in the Galapagos Islands are also protected. Thus, energy scarcity due to the protected area land must be a factor to consider so that energy planning can be in line with climate impacts. It is like the need for land to install solar power plants the day after tomorrow. However, permits to obtain a protected area used as a power plant location appear to be very difficult to obtain, especially from local utilities. Besides, the location of the power system must be able to avoid the effects of existing biodiversity.

Disasters that frequently hit islands/villages, such as hurricanes, extreme weather events, etc., have a major impact on people, the environment, socio-economics, and finances. In general, these islands/rural areas are located in areas prone to natural disasters due to geology and hydrology [41]. This includes the major islands in the Pacific Kodiak Islands. In 1788 and 1964, tsunamis hit the islands and destroyed settlements on the Old Harbor. A strong earthquake caused the tsunami that occurred in 1964. The disaster destroyed public and private facilities at a replacement cost of USD 22 million [44]. Meanwhile, an earthquake erupted from a volcano in Novarupta in 1912, almost covering the islands, destroying their local fishing industries. The cost of settlements resulting from the disaster is greater than on land [41]. For example, the cost of damage caused by earthquakes and hurricanes from 2004 to 2013 in Seychelles was USD 39 million. Thus, the perspective on available energy security must be able primarily to provide electricity services sustainably. Also, it is important to avoid predicting more severe hazards associated with natural disasters. The introduction of RE technology with a more reliable infrastructure can further assist in sustainable configuring energy systems [45]. For example, a nuclear disaster occurred in Japan in 2011. The private and public sectors have implemented a mini-grid system with the HRE-MG system there so that the price of nuclear power can be reduced and the sustainable energy plan in Japan can be increased.

4.4. Factor Economy

Energy consumption and GDP have a very strong relationship [46]. The GDP increase of 0.85% is in line with the 1% increase in capital, closely related to energy consumption. The fundamental factor of various economic activities is a system for calculating renewable energy in islands/rural areas, which are considered better [46]. Detailed analysis of economic data for several islands is shown in Table 2.

Table 2 Economic activities and GDP globally

Location of the ocean	Island	Economic Activities	GDP (USD)	GDP (USD/capita)
Indian Ocean	Seychelles (Mahe, Praslin and La Digue)	Services industry and agriculture (including tourism)	484, 71 and 14	6223, 9346 and 5451
Atlantic	Graciosa	Most of the Agriculture, forestry, fisheries, and a growing tourism sector	96	19,331
Caribbean	Necker	Tourism and Services of Finance	-	-
Mediterranean	Ikaria	Tourist destination, forestry, utilities (transportation, health, and education)	239	34,794
Pacific	Galapagos (Santa Cruz, San Cristobal and Isabela)	Tourism, forestry, and research	122, 66 and 32	7993, 8702 and 13,843
Pacific	Kodiak	Most of the Services and Fisheries	445	31,900
Pacific	Tokelau	Public policy and trade	10	7087
Pacific	Tuvalu	Public policy and trade	40	3710
Indian Ocean	King Island	Agriculture, forestry, fisheries, and a growing tourism sector	10	5160
Atlantic	El Hierro	Most of the Tourism	371	24,985

A GDP of USD 31,400/year is the highest value found in islands in the Atlantic, Caribbean, Pacific, and Indian regions. [30]. The highest electricity demand per capita in islands/rural areas, especially in some developed countries, is caused by high tourist activity. However, not all homeland/rural areas follow such a pattern as with islands/rural areas such as the Pacific and Kodiak regions with GDP values of USD 15,900 and USD 31,900, respectively. Meanwhile, electricity consumption in the two regions is 6,976 kWh/capita. The island is home to the largest Coast Guard Base in the United States and the country's most productive fishing port. Besides, the seafood industry and economy in Alaska in 2015-2016 amounted to USD 262 million. Meanwhile, Africa's highest income is for the service sector at 81% of GDP, used for electricity consumption of 324 GWh/year 55% mainly for tourism. The demand for electricity in this archipelago of 3472 kWh/capita/year is almost comparable to that of the El Hierro Islands, amounting to 3233 kWh/capita/year from desalination power plants. The fastest economic growth globally was recorded in the Galapagos Islands during 2005-2009, with 10% mainly generated from the tourism sector [43]. This sector's growth rate has decreased due to the reduced public service system and resources [43]. The number of tourists in 2014 reached 215,691; this number is seven times the islands' population. The tourism sector, which increases every year in the island/rural areas, also increases its economic growth.

Finally, the economic level in the Tuvalu Islands is the most vulnerable. This is because the poverty index is the third highest compared to other developing countries as included in the members of the Asian Development Bank (ADB). Developing countries included in the ADB contribute more than 10% of island/rural funds, including high poverty rates. A distinctive feature in archipelagic/rural areas is the high level of external financial dependence. This is because of the system for sending migrant money through Official Development Assistance (ODA) [41]. Meanwhile, the financing system, market, and governance have shown progress. The Tuvalu Islands have received funding of USD 373 million and USD 2,368 from 1997-2017. This number is more than double that of the previous 1997. The amount of outside aid received in an archipelago/rural area makes a difference in the increase in each island/rural area. Apart from that, the limited availability of local and economic resources in the region is also a major factor.

5. Regulations for Promoting RE

The price volatility caused by dependence on fossil fuels impacts climate change, especially the public interest in remote island/rural areas. Ambitious goals in islands/rural areas to switch to a sustainable renewable energy system are shown in Table 3. Energy supply and supply to the community, especially in island/rural areas, must be more secure. This can be done in various safe, reliable, and affordable ways, especially on the price side. RE potential in some islands/rural areas has high availability, especially renewable energy sources. The broader and measures for the development of RE for the energy-efficient need to get support from various parties [23]. Energy-efficient also must consider the synergy between power systems, heating, transportation, and cooling [47]. The RE relationship for efficient energy can be used as a strategy for current and future energy planning. However, in this case, the target that is achieved and is successful is only the island/rural areas in developed countries that are successful.

Table 3 Policies of Island in Globally

Inland	**Target**	**Action of policy**
Ikaria	A national strategy to hit 20% of renewables by 2020 and 40% by 2040.	N/A
Graciosa	To make 100 % use of renewable energy.	N/A
Seychelles	To achieve 100 % renewable energy: 5% by 2020 and 15% by 2030.	In the long term, the energy matrix can diversify.
Tuvalu	Gaining 100 % RE by 2020. To improve Funafuti's energy efficiency by 30 %.	Make 100 % RE by 2020. To improve Funafuti's energy efficiency by 30 %
Necker	Around 100% of renewable energy output.	Richard Branson initiative (island owner)
Kodiak	Via the Pillar Mountain Project: producing 95% of its energy from renewable sources and reducing reliance on diesel and the cost of generating electricity.	Alaska plans to generate 50 % of RE by 2025
Galapagos	To reach 100% of RE generation (without a year in which to achieve it).	Zero Fossil Fuel Project at Galapagos Islands.
El Hierro	Providing renewable energy sources. Around 100% of RE output	The White Document and the EU Course of Action. El Hierro Island Management Strategy
King Island	Reduce reliance on gasoline, provide reliable and efficient electricity supplies, and a long-term subsidy for the Community Service Obligation.	Australia plans to hit 20 % of the production of renewables by 2020. By 2022 King Island Renewable Energy Integration Project (KIREIP), the state of Tasmania, aims to achieve a 100 % renewable energy share.
Tokelau	Taking advantage of the islands' energy resources to slash fuel imports for power production. Increasing energy efficiency and incorporating RE into the energy blends. Around 100% of RE output.	Global Energy Policy and Regional Action Plan in Tokelau (NEPSAP) 2004. Tokelau 2010-2015 National Development Plan. Tokelau RE (TREP) plant.

Consideration of conditions, socio-economic, and geographic, especially in less developed islands/rural areas, must be supported by several reliable and realistic policies [48]. Electricity demand and per capita RE market share, which shows greater heterogeneity, is shown in Fig. 1.

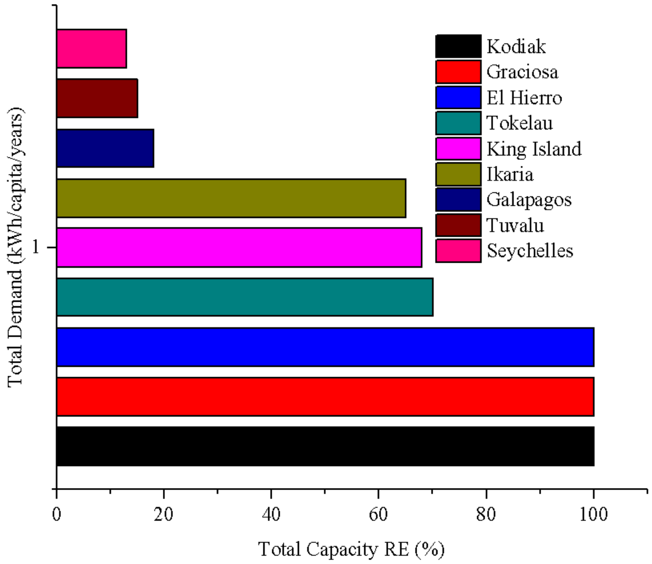


Fig. 1 Penetration of RE compared to per capita demand

The main objectives of island/rural areas, especially those in developed and developing countries, were to improve energy efficiency since 2008 through a bottom-up strategy for climate change in 2020. These strategies imply increasing RE penetration, reducing GHG emissions, and increasing energy efficiency. Besides, there are two other initiatives to strengthen energy availability, such as the Smart Island Initiative and Clean Energy for Islands/Rural Areas. The islands/rural areas of Graciosa and El Hierro are the most efficient for electricity consumption compared to other islands/rural areas. Both islands/rural areas have reached 100% penetration of ET. The International Renewable Energy Agency (IRENA) since 2011 has provided its support, especially for the RE transition through the Lighthouse Initiative. However, islands/rural areas have yet to meet the targets that have been set. This is due to insufficient funding so that residents are more likely to increase their respective electricity consumption [23]. The share of RE reaching 70% is only found in the Tokelau Islands because electricity consumption is lower than the others. However, plant-based electricity generation to support solar PV cannot be supported by the government itself [23]. The energy consumption in the islands/rural areas of Tuvalu is the highest compared to the cases in the group amounting to USD 3710 US/cap. Thus, achieving a high share of ET is difficult to achieve. The main constraints for ET share include financial, institutional, and social issues [23]. Policy on efficient energy must be intensified so that awareness of efficient energy use and RE policies can be created. Also, a radical system and consideration of local conditions can be implemented.

Besides, the main objective of energy policy is to conserve nature both on land and in the oceans so that oil spills in these islands can be better preserved. In 1989 and 2001, there were spills of fossil fuels in the Kodiak and Galapagos Islands of 41.6 million and 681.3 thousand liters, respectively. The entire archipelago was contaminated by the spilled oil spreading throughout their seas and beaches. Besides, access to electricity by 99%, 83%, and 99.83% is the highest level in the Indian Ocean, especially in Tuvalu, Galapagos, and Seychelles. [23]. The competitiveness between access to electricity and RE targets is showing and appears constantly. Government subsidies to clients can connect directly to the grid, however, not rural electricity. Access to energy in 2030 is a must, especially when it comes to many people. Access to electricity is an implicit right and attribute, especially non-discrimination or a sustainable development system. Policies regarding access to electricity in several countries have been included and made on their agenda [49]. Where is the HRE-MG with a centralized system as previously defined in section three? As it is known, the public demand for Solar Home Systems (SHS) cannot be fulfilled because it is the largest. This is due to its innovative nature, making it possible to increase access to electricity in the islands. Reforms to governments such as the Pacific region and Seychelles are urgently needed to overcome unrealistic adhesive targets. Also, private investment and limited capacity mean that long-standing barriers can be resolved quickly. On the other hand, energy policies on other islands show better and more rigid towards higher RE gains as the private sector's support in their institutions is more stable in developing a strong energy program.

6. Hybrid RE Configurations for Mini-Grid System

Development in the RE sector has been very well supported by more mature technology globally. The hybridization process for thermal power generation in the islands using renewable energy has started in the last decade. The installed capacity of RE, diesel, and storage systems and indicators such as RE penetration in each island are shown in Table 4. Also, peak demand and energy consumption are discussed in Table 4 and the previous section. The capacity of renewable energy such as wind and solar potential as a whole represents a fraction of some case studies, which are estimated globally at 0.3% and 0.08% [30].

Table 4 Hybrid mini-grid setup

Island	PV (MWp)	Biodiesel (MW)	Diesel (MW)	Hydro-electric (MW)	Wind (MW)	Batteries	RE (%)	Total Power	MWh/year	kWh per year	Demand (MW)
King Island	0.1	-	6	-	2.4	Pb 3MW or 1.5 MWh and Flywheels 2MVA	65	8.55	12,000	6191.75	2.5
Graciosa	1	-	4.61	-	4.5	4 MW/3.2 MWh	70-100	10.11	14,000	2819.17	3
Kodiak	-	-	33	11,5	9	3 MW or 0.75 MWh	100	53.5	94,800	6976.46	27
Tuvalu	2.065	-	2345, 0.26 and 0.13–0.201	-	-	-	8.2	4.87	6400	593.58	0.936
Ikaria	1.04	-	12.16	4.15	2.7	-	60-70	23.05	29,000	4221.87	9
Tokelau	0.365, 0.3 and 0.265	-	-	-	-	Pb 3.37, Pb 2.76, and Pb 2.45 MWh	70	1	255.1, 201.8 and 219.4	479.80	0.0512, 0.038 and 0.0367
Necker	0.3	-	0.96	-	0.9	0.5 MWh	80	2.16	-	-	0.4
Galapagos	1.567, 0.952 and 0.21	0,138	8.2, 13.9, 2.3 and 0.15	-	2.4 and 2.25	Pb 4, Li 0.268, Li 0.66, 0.33 and Pb 0.096 MWh	8.2, 20 and 57	10.7, 17.71, 3.25 and 0.31	14,400, 27,850, 4540 and 197	1475.19	3.37, 9.28, 1 and 0.076
El Hierro	-	-	11.36	11.3	11.5	-	70-100	34.16	48,000	3232.54	7.6
Seychelles	-	-	71 and 13	-	6	-	8	77 and 13	324,300	3472.16	50 and 7

High technology sophistication in remote islands/rural areas has made it possible to identify common technologies for hybridizing MG, especially wind and PV, by utilizing electromechanical batteries. In the last decade, wind and solar power generation showed an increase in the penetration of the power system because the costs are lower [50]. The largest renewable energy capacity on the island is wind energy. This is due to the availability of renewable energy resources for their electricity generation. The economic competitiveness of renewable power plants is better than when utilizing traditional diesel technology. The availability of PV for the development of power plants in their islands is greater than the availability of hydroelectric plants with an altitude of 1000 m to 1500 m. the installation of ET technology, control systems, and multiple storage systems have helped the HRE-MG to compensate for RE and seasonality intermittency. Also, the imbalance of supply and demand can be helped by the existence of ET. The three built-in islands/rural areas can increase RE penetration that is 60% -100% higher. The thermal hybridization system is a type of technology that depends on the geographical and geological conditions of various renewable sources, especially in the region. However, hydropower generation does not suffice with this prerequisite because of the pumped storage system. This is related to investment, capacity, and research in the technology sector, which a very large number at the local level has compared to other cases in the region. Dependence on technology from production results from international state aid is also experienced by islands such as the Galapagos. Some of the cases that can serve as examples are described below.

A total of five hybrid system wind turbines of 2.3 MW each are installed at El Hierro. Additionally, the hydroelectric power plant consists of four Pelton turbines of 2.8 MW each, a 6 MW desalination water pump station, and an 11.36 MW thermal power plant, making the backup system [43]. The storage pump system serves to assist the power system in achieving higher wind power penetration [50]. About a thousand hours or 100% RE that can be generated from a hybrid system (48 GWh/year) which can represent every hour can save about 1,765 liters of diesel, and as much as 3 tons of CO_2 emissions to the atmosphere can be reduced. The increase in RE in recent years was due to improvements in control strategies regulating frequency deviation [32]. The pumping system cost can be as high as USD 3230/kW, mainly for wind power, hydropower, and control systems, as shown in Table 4. The relatively smaller system may reflect that the project does not have to use public and private financing and encouragement from the Archipelago Institute of Technology. The current maintenance costs for wind hydropower systems are four times less than for diesel power plants [31]. It is important to mention and specify the desalination work carried out by the island/rural government in the last 50 years. The main human consumption is water, besides being used for electricity production and agriculture. There are four desalination plants on the island of El Hierro, which have a total demand and electricity consumption of 9% [50]. Meanwhile, the consumption and demand for electricity in the San Cristobal islands have a hydro potential of 140 m3/year. However, the technical feasibility of the storage system cannot yet be assessed by the national government. This is due to insufficient funding, making it difficult to make agreements with institutions locally. At the same time, the wind power plant located in San Cristobal costs USD 4200/kW more expensive than El Hierro by 14%, as shown in Table 4. Also, there is no control system with stronger storage, so that the result of RE penetration much lower at 8.2%.

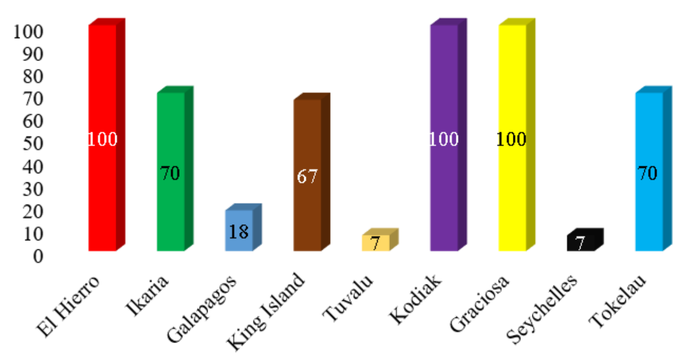
The system power capacity costs per unit such as battery pumped, lead-acid, flywheel and lithium-ion are USD 583/kWh, USD 326/kWh, USD 526/kWh, and USD 430/kWh, respectively, as reported by. While the storage cost is USD 77/kWh from the output pumped, lithium-ion USD 903/kWh, and lead-acid USD 702kWh. However, the costs for the battery and flywheel storage systems have decreased at a rate close to that of the storage system from pumping. Pumped storage systems are a USD 136/MWh cheaper option than others [45]. Installing a storage pump system in the archipelago is not possible. Hence, a battery storage system is an alternative option because it has lower costs, as was the case in Tobelau and Tuvalu. Based on the findings of several studies, it is concluded that CO_2 and LCOE emission from the energy power system utilizes RE sources and batteries rather than follows a diesel generator scenario. Utilizing a battery storage system can reduce costs substantially, especially in islands with high irradiation potential [22]. The HRE-MG system utilizing PV technology can open up storage systems for greater electromechanical recognition. This is due to the excess of the energy system associated with its daily solar radiation profile. All small islands that are found globally have the potential with a battery capacity of 5 GWh. Meanwhile, the RE share increased to 70% compared to the previous 46%. Meanwhile, LCOE can reduce by 6% compared to the previous 40/kWh [22]. However, the environmentally related utilization of batteries due to their use can be reduced from inadequate treatment of battery waste. The control system is the most important for the storage system to extend its useful life in the future. Furthermore, an introduction to the waste management program system is required for collection to replace and recycle batteries again. The overall battery recycling system that exists in some developed countries is sourced from lead-acid batteries. However, this system is expensive and more difficult to implement in developing countries [50]. The circular economy practice system is the most important for the future in overcoming various existing problems. The implemented business model requires support in restoring the battery system at the end of its use.

The latest breakthrough technology allows it to be installed in islands to overcome problems related to geology, geography, and renewable resources. Other problems include water, land, costs, the high selling price of electricity, and the stability of electricity services. SIDS Pacific is one of the islands that has a high population density. The Granite Island's geographical boundaries and the mountainous islands in Seychelles can prevent access to heavy equipment inland. However, both of these islands have installed energy grid systems that require much land for their development. The targets achieved from RE penetration have limitations such as insufficient capacity and financing, but not from technology. The installed capacity being analyzed in the islands of the Pacific and the Indian Ocean currently has a hybridization grid of 25% of the total 150 MW diesel power plant. Although technically, the introduction of ET aims to use as a backup diesel generator which is the main power plant in the islands of Tuvalu, Seychelles, and Galapagos. However, the islands desperately need a better/more reliable storage and control system to store RE for the next few hours. A hydroelectric storage pump system is an example where geographical conditions permit. In these islands, the pumping system can only be done with water as desalination. There are two main obstacles in implementing a water desalination system: the amount of electrical energy required and the initial investment capacity. The most common use of storage systems is lead-acid battery banks. This is because the price is lower than lithium batteries. Meanwhile, the storage system installed and used in the islands is only the flywheel. Renewable mini-grid systems have a significant opportunity to be installed in the islands due to their better storage capacity than diesel. Thus, capacity development and access to funding are priority challenges.

7. Discussion

Over the energy found in Small Island/rural areas is generally generated from the HRMG system. Meanwhile, the financing of this system depends on the business model that plans, starts, operates, and implements the system. Meanwhile, the business model specifically applied in rural areas has differences, especially such as funding. The identification carried out in this study applies the five existing business models and those applied in Remote Island/rural areas that do not have direct land connections. The HRE-MG network system and the public model, especially the public-private-community-based partnership-public-private partnership system, collaborate with international and public-private partnerships. Demands for the push to install RE energy power from the private and community models are not used because the costs are very high. RE projects are the ones that often use the community model. This is because the system of connectedness to the national network is larger. Besides, the funding program system and institutional arrangements are crucial for RE development projects. The design of a good business model can consider local limitations and conditions so that the ET penetration gets greater support. All of this depends on financial, political, social, technological, institutional, and environmental factors available in each archipelago. The application of the business model shown in several case studies to the share of the RE market is shown in Fig. 2. Meanwhile, the definition applied in the islands can be explained as Public business models that several developed countries have applied. However, this is not the case in Remote Island/rural areas, and this model has been directly taken over by the central government, special agencies, and local governments. Meanwhile, private companies participate in the implementation and are responsible to the public. A solid regulatory system is needed in this model because of the investment capacity and large discharge capacity of thermal power plant hybridization. The use of the island hybridization model is most common because it differentiates the ownership of developed countries that are still less developed.

The details of the hybridization model found in developed regions are the participation of the public and private sectors and even the culture of innovation in society itself.



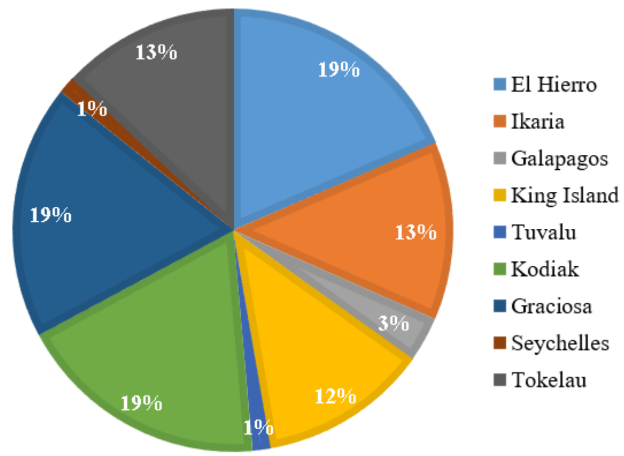


Fig. 2 Business strategies for implementing HRMGsvs RE sharing

Taking part in the business model from the research center has a constant innovation process to improve the HRE-MG's stability. A strong regulatory framework can assist such a business model so that attractive mechanisms can be promoted and profitable investment from RE is more adequate. The liability of private entities can be assigned to third parties. Cooperation between archipelagic and international governments for hybrid systems is the most common. This is done so that private participation in RE development can be limited. Although the public sector has created partnerships vertically and horizontally for management, it is very difficult to create a solid alliance. Meanwhile, local public companies have the responsibility for operation and maintenance activities that can ensure project sustainability. An appropriate incentive policy for project funding is a huge drawback. Besides, unfamiliar human resources represent a very bad transfer to the local technicians from the implementer. This model economic system cannot finance large sustainable renewable energy developments. When the demand for electrical energy is lower in remote islands/rural areas, it can reach a higher RE sector. Funding for international cooperation with the public sector, such as 70% of the total RE sector, amounting to 676 MWh/year. Likewise, cooperation between public, private, and international organizations has similar characteristics. As a result, this business model has failed to build a new market share for RE technology in island/rural areas. Limited private participation due to limited conservative policies, so that continuity overtime is not available.

The regulated electricity costs are comparable to the existing business model. Where the private and public partnerships in the islands are 100% for the RE sector. The HRE-MG grid system and wind energy applied by the community costs 11.6 USc/kWh. Meanwhile, hydroelectric energy is 6.8 USc/kWh, lower than the cost of a diesel power plant of 28.9-92 USc/kWh/liter of diesel. International cooperation in the subsidized

Galapagos Islands with regulated electricity costs of 24.31 USc/kWh and an average RE share of 17%. However, there is no comprehensive information on the actual cost of electricity generation. The economic impact of Elecgalapagos on local electricity companies can be reduced by the cost of electricity regulated by the National Interconnected System (SNI). Projects in the archipelago must be audited so that every decision-making can be encouraged by policies and business models based on real market conditions. Various kinds of incentives have been made to promote renewable energy used in the archipelago, especially in developing countries. However, this incentive is not sufficient for use in islands / rural areas in the Galapagos region. The investigation carried out in this study is made for two options to accelerate ET introduction in the region. The competitively auctioned Renewable Energy Service Company model is associated with lower auction financing of renewable technologies. The design of this auction is transparent and well-designed so that expanding technology, especially for PV and wind power, is a cost-effective option. Besides, the high risks in certain countries can be further reduced [44]. The application of fee-in tariffs found in some less developed countries can be replaced by this mechanism [47]. The power sector can be reactivated based on the previous feed-in tariff. Profits for investors can be obtained from the sale of electricity at a price set in the PPA, resulting from a competitive bid. This is the same as the result of the auction in advance. This model allows for a stronger financing process. The success of the Renewable Energy Service Company applied in the archipelago using the savings scheme collectively. The cost of electricity regulated in the most remote islands through RE projects has to be priced according to the non-subsidized thermal power plant. Thus, the government can measure the amount of profit obtained to save 2.4 million liters of diesel/year [19]. However, the application of tax incentives must provide opportunities for the application of RE.

Most of the islands/rural areas included in developing countries have been liberalized as a market with a sign of a safer investment, as in King Island. The institutional capacity is technically very likely to allow RE development to succeed when the power sector has become a monopoly. Meanwhile, the case that occurred in Necker was in particular because it had wealthy businessmen to lead its national energy diversification. The main obstacles in the Galapagos Islands against the spread of RE are the lack of institutional capacity and weak public awareness of efficient national energy use [23]. The target set in these islands was not achieved because the target was financed by the external level. Participation and support from the private sector are needed for regulations and policies to transfer experience and knowledge in solving funding problems. Improved project design and implementation can be undertaken if the community can be involved in decision-making and understands the context. The business model design is carried out with four main parts: environmental constraints, stakeholders, templates, and objectives. Meanwhile, the concept of transfers carried out in remote island/rural areas is carried out to determine which business systems can affect. Some of the problems that can affect the business model include the following:

1. *Stakeholders*

The collaborative system between the private and public and the international community and their donors is reserved only for the islands of the Indian and the Pacific oceans. Each participant who takes part in the business model is entitled to have the same interest regardless of various existing project developments. The business model towards public administration is the most important in establishing the regulatory framework for promotion and funding in formulating the effectiveness of RE financing.

2. *Environmental scope*

The environment has boundaries such as financial, technological, political, environmental, and institutional. The design and implementation of business models in the Seychelles and Pacific islands are among the main obstacles to institutional boundaries. This is due to limited human resources who have expertise in this field.

3. *Template*

This template is a design system for business models found in every Remote Island/rural area.

4. *Target*

The increase in RE penetration is aimed at mitigating climate change to reduce dependence on fossil fuels. Also, to increase access to electricity by making electricity prices cheaper, especially in remote rural/island areas.

The guidelines for implementing the business model and the HRE-MGM's success are very much dependent on the design results, especially the participation, interest, and commitment of the government in Remote Island/rural areas. Financial assistance in the archipelago is the most important for implementing and installing electrical energy with a business model from renewable sources. An energy transition must require genuine and secure financial assistance. Thus, policies, capacities, and exchange of experiences can be more effective, especially in developing and developed regions, to attract private investors. It aims to complete new RE development projects that provide market opportunities for companies and technology from donor governments. The collaborative agenda for the energy transition demands international assistance and financing for more transparency on financing power generation. Assistance from abroad must support the energy transition, especially in remote island/rural areas. Also, the business model must be defined by adjusting the underdeveloped conditions of an employee/rural area which is the aim of future research.

The interconnection of land and islands from RE implementation requires a deeper understanding of the context of ensuring security and access to electrical energy. This can adjust the demand and supply of lower electricity sales prices so that the responsibility for tackling climate change is acquired. Thus, the main factors to be identified must be planned and considered more carefully for HRE-MG implementation in remote islands/rural areas that are not directly connected to the land. These factors are listed in the planning, implementation, and design of RE projects that are more efficient for a sustainable economy, as shown in Table 5. An analysis of these aspects is carried out to identify the electric power system better suited to the conditions required during project implementation. For example, the limited availability of renewable sources for power plant installations such as solar and wind power in protected areas, especially in the Galapagos Islands/rural areas. The ET development project already has a place, as stated by the Galapagos Islands National Park agency. This is adjusted to the existing local capacity, where operating the PV system for three years can produce as much as 1.5 MW. Some inverters (60/93) have been replaced by operation and maintenance staff and modules (34/6007) by not carrying out prior analysis due to lack of knowledge of PV systems at the cost of half a million US Dollars [283]. The results of interviews with technical and administrative staff at Elecgalapagos revealed that there are two main limitations to sustainable RE. Therefore, the shortage of trained engineers and technicians to direct the planning of the area is the main reason for this funding with international assistance. It is important to develop a training program like this so that ET maintenance and operations can be carried out properly. Also, the transportation system for logistics in the islands for heavy equipment delivery is very limited. Initial investment costs are a major problem in the archipelago. This financial assistance is key to the success of RE development as recognized by the Elecgalapagos government. This is because the private sector has no chance of the current electricity law. Thus, the views may reflect opposites to improving the transitional system and existing energy and policy requirements. Besides, the capacity to change the model of the HRE-MG implementation system sustainably is also difficult to achieve.

Table 5 Key reasons for deploying HRE-MG

Categories	Primary Factors
Political, ecological, institutional	Effective policies for RE, EE, and access to electricity Promotion and financing Available incentives for RE, EE and access to energy Local knowledge in RE Current stakeholders Possibility for private participation financial support Concept of business model
Socio-economic	Electricity access rates Key economic activity Population growth rate Power demand
Scale, insularity, and remoteness	Degree of reliance on generating thermal electricity. The true cost of generating electricity (sans subsidies) Available land for use
Technical	Non-interconnected electricity systems/interconnection possibilities Environmental policy, institutional, financial technology Installed thermal power capacity Stability of power systems RE potential Additional orographic costs.
Environmental	Description of the region available for installing RE projects/Biodiversity Protection of environmental licenses Prevention of oil spills Climate change mitigation Decrease in the impact of natural disasters Decrease in greenhouse gas emissions.

8. Policies for Implication

One solution to save energy costs is to take advantage of the HRE-MG, especially in remote islands/villages that do not have a direct connection to the mainland. It is very important to define a business model with this kind of hybridization, especially for diesel power plants. Thus, the target for RE development in island/rural areas can be achieved with the support of this business model. The application of the business model can adjust to lower prices for electrical energy so that electricity services to customers can be improved and the environment and socio-economics are better. Target developing countries that have a large number of islands/villages have installed high-capacity RE. This can be achieved by private and public investors, social awareness, strong regulatory framework, attractive business incentives, RE technology, control systems, and storage systems are very supportive and highly available. Meanwhile, the investment system in the Galapagos islands/villages must have a strong legal framework so that capacity and funding are not guaranteed. Policies implemented in the region must not be contradictory and conservative by adjusting the 2030 Agenda. Also, the targeted RE system must be established with a realistic system, and the private sector must be an integral part of the introduction of RE. Thus, the suitability of the business model in the islands/villages results from cooperation from the private and public sectors. Effective policies must be focused on utilizing assistance from abroad so that the public can be involved in promoting it. Besides, advanced inter-island/rural cooperation can be programmed, especially human resource training. Experience and knowledge transferred to the community can provide satisfaction to the community because it has been involved in this. Finally, the tax reduction on the business model is the most attractive measure in financing large-scale projects, especially in developing islands/rural areas.

9. Conclusions

This study presents the HRE-MG network system implemented in the smallest island/rural areas without direct land connection based on the review of several previous scientific works. Identification was undertaken in this review to investigate constraints and drivers of RE development. Also, a business system in developing RE projects with some in-depth understanding and analysis of the smallest island/rural environment. The definitions offered, such as factors and business models, are the main keys in implementing HRE-MG to support decision making and planning. The achievement of the planned RE targets due to the encouragement of a change in the existing intervention paradigm. The ecological and natural conditions that are vulnerable are the result of the orientation of energy planning. The results of investigations conducted on the HRE-MG configuration show that solar PV, wind, control systems, and electromechanical storage systems are very promising, especially in islands/rural areas that do not have a direct connection. The RE technology applied to islands/rural areas is very dependent on the conditions of the area. The conditions of the area in question include resources, research capacity, geography, politics, and the funding system. Apart from that, technological innovations found in remote islands/rural areas are greatly assisted in overcoming obstacles related to their natural conditions. The HRE-MG network system available in islands/rural areas has a variation level between 1 MW -90 MW. Meanwhile, the largest capacities for solar PV and wind energy are found in the Pacific and Atlantic islands.

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References

[1] BAZILIAN M., NAKHOODA S., and VAN DE GRAAF T. Energy governance and poverty. Energy Research & Social Science, 2014, 1: 217–225.

[2] KYPRIANOU I., SERGHIDES D. K., VARO A., GOUVEIA J. P., KOPEVA D., and MURAUSKAITE L. Energy poverty policies and measures in 5 EU countries: A comparative study. Energy and Buildings, 2019, 196: 46–60, https://doi.org/10.1016/j.enbuild.2019.05.003.

[3] HONGBO W. United Nations Decade of Sustainable Energy for All. Keynote address at the Sustainable Energy for All Ministerial Panel, Abu Dhabi International Renewable Energy Conference. 2013. Available from https://www.un.org/en/development/desa/usg/statements/mr-wu/2013/01/sustainable-energy-for-all-2.html

[4] UNITED NATIONS. E-government for the future we want. United Nations E-Government Survey. New York: United Nations, 2014. Available from https://publicadministration.un.org/publications/content/PDFs/UN%20E-Government%20Survey%202014.pdf

[5] YADOO A. and CRUICKSHANK H. The role for low carbon electrification technologies in poverty reduction and climate change strategies: A focus on renewable energy mini-grids with case studies in Nepal, Peru and Kenya. Energy Policy, 2012, 42: 591–602.

[6] LIAN J., ZHANG Y., MA C., YANG Y., and CHAIMA E. A review on recent sizing methodologies of hybrid renewable energy systems. Energy Conversion and Management, 2019, 199, Article id: 112027, https://doi.org/10.1016/j.enconman.2019.112027.

[7] HUANG Y. W., KITTNER N., and KAMMEN D. M. ASEAN grid flexibility: Preparedness for grid integration of renewable energy. Energy Policy, 2019, 128: 711–726.

[8] YAN, J. ZHAI Y., WIJAYATUNGA P., MOHAMED A. M., and CAMPANA P. E. Renewable energy integration with mini/micro-grids. Applied Energy, 2017, 201: 241–244.

[9] IRENA. Policies and regulations for renewable energy mini-grids. International Renewable Energy Agency (IRENA), Abu Dhabi, 2018.

[10] NAGPAL D. & PARAJULI B. Off-grid renewable energy solutions to expand electricity access: An opportunity not to be missed. International Renewable Energy Agency (IRENA), Abu Dhabi, 2019.

[11] IEA. Energy Access Outlook 2017: From Poverty to Prosperity. Paris, IEA. 2017, https://doi.org/10.1787/9789264285569-en.

[12] D'ARLON R. Hybrid mini-grids for rural electrification: Lessons learned. Brussels: Alliance for Rural Electrification (ARE), 2014.

[13] AL-HAMMAD H., BECKER T., BODE A., GUPTA S., and KREIBIEHL S. Renewable energy in hybrid mini-grids and isolated grids: economic benefits and business cases. Frankfurt School – UNEP Collaborating Centre for Climate and Sustainable Energy Finance, 2015.

[14] ERDIWANSYAH, MAMAT R., SANI M. S. M., and SUDHAKAR K. Renewable energy in Southeast Asia: Policies and recommendations. Science of The Total Environment, 2019, 670: 1095-1102, https://doi.org/10.1016/j.scitotenv.2019.03.273.

[15] DORNAN M. Access to electricity in Small Island Developing States of the Pacific: Issues and challenges. Renewable and Sustainable Energy Reviews, 2014, 31: 726–735.

[16] KNUCKLES J. Business models for mini-grid electricity in base of the pyramid markets. Energy for Sustainable Development, 2016, 31: 67–82, https://doi.org/10.1016/j.esd.2015.12.002.

[17] GRAVEN M., ALLEN P., ALLEN V. M., SMITH I., and MACDONALD N. E. Achievement of the 2015 Millennium Development Goal 5A (Maternal Mortality) by Belize in 2011. Journal of Obstetrics and Gynaecology, Canada, 2012, 34(10): 913–916.

[18] MENDOZA-VIZCAINO J., SUMPER A., SUDRIA-ANDREU, A. and RAMIREZ J. M. Renewable technologies for generation systems in islands and their application to Cozumel Island, Mexico. Renewable and Sustainable Energy Reviews, 2016, 64: 348–361.

[19] MAHIDIN et al. Analysis of power from palm oil solid waste for biomass power plants: A case study in Aceh Province. Chemosphere, 2020, 253, Article id: 126714. https://doi.org/10.1016/j.chemosphere.2020.126714

[20] KUANG Y. et al. A review of renewable energy utilization in islands. Renewable and Sustainable Energy Reviews, 2016, 59: 504–513.

[21] PRAENE J.P. et al. Electricity generation from renewables in Madagascar: Opportunities and projections. Renewable and Sustainable Energy Reviews, 2017, 76: 1066–1079.

[22] BLECHINGER P., SEGUIN R., CADER C., BERTHEAU P., and BREYER C. Assessment of the Global Potential for Renewable Energy Storage Systems on Small Islands. Energy Procedia, 2014, 46: 294–300.

[23] WEIR T. Renewable energy in the Pacific Islands: Its role and status. Renewable and Sustainable Energy Reviews, 2018, 94: 762–771.

[24] FULDAUER L. I., IVES M. C., ADSHEAD D., THACKER S., and HALL J. W. Participatory planning of the future of waste management in small island developing states to deliver on the Sustainable Development Goals," Journal of Cleaner Production, 2019, 223: 147–162.

[25] DUIĆ N. and M. DA GRAÇA CARVALHO M. Increasing renewable energy sources in island energy supply: case study Porto Santo. Renewable and Sustainable Energy Reviews, 2004, 8(4): 383–399.

[26] GENAVE A., BLANCARD S., and GARABEDIAN S. An assessment of energy vulnerability in Small Island Developing States. Ecological Economics, 2020, 171, Article id: 106595.

[27] SELOSSE S., GARABEDIAN S., RICCI O., and MAÏZI N. The renewable energy revolution of Reunion Island. Renewable and Sustainable Energy Reviews, 2018, 89: 99–105.

[28] KARATAYEV M., HALL S., KALYUZHNOVA Y., and CLARKE M. L. Renewable energy technology uptake in Kazakhstan: Policy drivers and barriers in a transitional economy. Renewable and Sustainable Energy Reviews, 2016, 66: 120–136.

[29] BLECHINGER P., SEGUIN R., CADER C., BERTHEAU P., and BREYERA C. Corrigendum to Assessment of the Global Potential for Renewable Energy Storage Systems on Small Islands: EGYPRO 46C (2014) 294–300. Energy Procedia, 2014., 46, p. 324, https://doi.org/10.1016/j.egypro.2015.01.070

[30] WORLD BANK. Tracking SDG 7: The energy progress report 2018. International Bank for Reconstruction and Development/The World Bank, 2018.

[31] BUNKER K., S. DOIG, K. HAWLEY, and MORRIS J. Renewable microgrids: profiles from islands and remote communities across the globe. Rocky Mountain Institute and Carbon War Room, 2015.

[32] ERDINC O., PATERAKIS N. G., and CATALÃO J. P. S. Overview of insular power systems under increasing penetration of renewable energy sources: Opportunities and challenges. Renewable and Sustainable Energy Reviews, 2015, 52: 333–346.

[33] NATIONAL BUREAU of STATISTICS. Seychelles in Figures. Victoria, Seychelles, 2015.

[34] HEINRICH A. B. New approaches Umweltwissenschaften und Schadstoff-forsch., 2000, 12(1), p. 1.

[35] WOLF F., SURROOP D., SINGH A., and LEAL W. Energy access and security strategies in Small Island Developing States. Energy Policy, 2016, 98: 663–673.

[36] MOHAMMED Y. S., MUSTAFA M. W., and BASHIR N. Hybrid renewable energy systems for off-grid electric power: Review of substantial issues. Renewable and Sustainable Energy Reviews, 2014, 35: 527–539.

[37] CHAUHAN A. and SAINI R. P. A review on Integrated Renewable Energy System based power generation for stand-alone applications: Configurations, storage options, sizing methodologies and control. Renewable and Sustainable Energy Reviews, 2014, 38: 99–120.

[38] FERNANDES R. and PINHO P. The distinctive nature of spatial development on small islands. Progress in Planning, 2017, 112: 1–18, https://doi.org/10.1016/j.progress.2015.08.001.

[39] JANALOKA O. Potensi Energi Matahari di Indonesia. 2015. Available from: https://janaloka.com/potensi-energi-matahari-di-indonesia/

[40] ERDIWANSYAH, MAHIDIN, MAMAT R., SANI M. S. M., KHOERUNNISA F., and KADAROHMAN A. Target and demand for renewable energy across 10 ASEAN countries by 2040. Electricity Journal, 2019, 32(10), Article id: 106670, https://doi.org/10.1016/j.tej.2019.106670

[41] BRIGUGLIO L. Small island developing states and their economic vulnerabilities. World Development, 1995, 23(9): 1615–1632.

[42] PETKOV I. and GABRIELLI P. Power-to-hydrogen as seasonal energy storage: an uncertainty analysis for optimal design of low-carbon multi-energy systems. Appl. Energy, 2020, 274, Article id: 115197, https://doi.org/10.1016/j.apenergy.2020.115197.

[43] DÓNIZ-PÁEZ J., BECERRA-RAMÍREZ R., GONZÁLEZ-CÁRDENAS E., GUILLÉN-MARTÍN C., and ESCOBAR-LAHOZ E. Geomorphosites and geotourism in volcanic landscape: the example of La Corona del Lajial cinder cone (El Hierro, Canary Islands, Spain). GeoJournal of Tourism and Geosites, 2011, 2(8): 185–197.

[44] PLAFKER G., KACHADOORIAN R., ECKEL E.B. and MAYO L.R. Effects of the Earthquake of March 27, 1964 on Various Communities. Chapter G. In: The Alaska Earthquake, March 27, 1964: Effects on Communities. 1966, Washington, DC: U.S. Government Printing Office, https://doi.org/10.3133/pp542G

[45] LAMMERS K., BERTHEAU P., and BLECHINGER P. Exploring requirements for sustainable energy supply planning with regard to climate resilience of Southeast Asian islands. Energy Policy, 2020, 146, Article id: 111770.

[46] MENEGAKI A. N. On energy consumption and GDP studies; A meta-analysis of the last two decades. Renewable and Sustainable Energy Reviews, 2014, 29: 31–36.

[47] UCHE-SORIA M. and RODRÍGUEZ-MONROY C. Energy planning and its relationship to energy poverty in decision making. A first approach for the Canary Islands. Energy Policy, 140, Article id: 111423, 2020.

[48] HONG S., YANG T., CHANG H. J., and HONG S. The effect of switching renewable energy support systems on grid parity for photovoltaics: Analysis using a learning curve model. Energy Policy, 2020, 138, Article id: 111233.

[49] DEMSKI C., THOMAS G., BECKER S., EVENSEN D., and PIDGEON N. Acceptance of energy transitions and policies: Public conceptualisations of energy as a need and basic right in the United Kingdom. Energy Research & Social Science, 2019, 48): 33–45.

[50] PÉREZ-DÍAZ J. I., CHAZARRA M., GARCÍA-GONZÁLEZ J., CAVAZZINI G., and STOPPATO A. Trends and challenges in the operation of pumped-storage hydropower plants. Renewable and Sustainable Energy Reviews, 2015, 44: 767–784.

参考文:

[1] BAZILIAN M.，NAKHOODA S. 和 VAN DE GRAAF T. 能源治理与贫困。能源研究与社会科学，2014，1：217-225。

[2] KYPRIANOU I.，SERGHIDES D. K.，VARO A.，GOUVEIA J. P.，KOPEVA D. 和 MURAUSKAITE L. 欧盟 5 个国家的能源贫困政策和措施：一项比较研究。能源与建筑，2019，196：46-60，https://doi.org/10.1016/j.enbuild.2019.05.003。

[3] HONGBO W. 联合国人人享有可持续能源十年。在阿布扎比国际可再生能源会议的"人人享有可持续能源"部长级小组会议上的主题演讲。2013。可从 https://www.un.org/en/development/desa/usg/statements/mr-wu/2013/01/sustainable-energy-for-all-2.html 获取

[4] 联合国。我们想要的电子政务。联合国电子政务调查。纽约：联合国，2014。可从 https://publicadministration.un.org/publications/content/PDFs/UN%20E-Government%20Survey%202014.pdf 获取。

[5] YADOO A. 和 CRUICKSHANK H. 低碳电气化技术在减贫和气候变化战略中的作用：以尼泊尔，秘鲁和肯尼亚为例，重点研究可再生能源微型电网。能源政策，2012，42：591-602。

[6] 连建，张 Y，马春，杨 Y，柴马 E. 混合可再生能源系统的最新规模化方法综述。能源转换与管理，2019，199，文章 ID：112027，https://doi.org/10.1016/j.enconman.2019.112027。

[7] HUANG Y. W.，KITTNER N. 和 KAMMEN D. M. 东盟电网灵活性：可再生能源并网的准备工作。能源政策，2019，128：711–726。

[8] YAN J. ZHAI Y.，WIJAYATUNGA P.，MOHAMED A. M. 和 CAMPANA P. E. 与微型/微电网的可再生能源整合。应用能源，2017，201：241-244。

[9] IRENA。可再生能源微型电网的政策和法规。国际可再生能源机构（IRENA），阿布扎比，2018。

[10] NAGPAL D. 和 PARAJULI B. 扩大电力供应的离网可再生能源解决方案：一个不容错过的机会。国际可再生能源机构（IRENA），阿布扎比，2019。

[11] 国际能源署。2017 年能源获取展望：从贫困到繁荣。国际能源署巴黎。2017，https://doi.org/10.1787/9789264285569-en。

[12] D'ARLON R. 农村电气化的混合微型电网：经验教训。布鲁塞尔：农村电气化联盟（是），2014。

[13] AL-HAMMAD H.，BECKER T.，BODE A.，GUPTA S. 和 KREIBIEHL S. 混合微型电网和隔离电网中的可再生能源：经济利益和商业案例。法兰克福学校–环境署气候与可持续能源融资合作中心，2015。

[14] ERDIWANSYAH，MAMAT R.，SANI M. S. M. 和 SUDHAKAR K. 东南亚的可再生能源：政策和建议。全面

环境科学，2019，670：1095-1102，https://doi.org/10.1016/j.scitotenv.2019.03.273。

[15] DORNAN M. 太平洋小岛屿发展中国家的电力供应：问题和挑战。可再生能源与可持续能源评论，2014，31：726–735。

[16] KNUCKLES J. 金字塔市场基地的微型电网电力商业模式。能源促进可持续发展，2016，31：67-82，https://doi.org/10.1016/j.esd.2015.12.002。

[17] GRAVEN M.，ALLEN P.，ALLEN VM，SMITH I. 和 MACDONALD N.E. 在 2011 年实现伯利兹实现的 2015 年千年发展目标 5 一种（孕产妇死亡率）。加拿大妇产科杂志，2012，34（10）：913–916。

[18] MENDOZA-VIZCAINO J.，SUMPER A.，SUDRIA-ANDREU。A. 和 RAMIREZ J. M. 岛屿发电系统的可再生技术及其在墨西哥科苏梅尔岛的应用。可再生能源与可持续能源评论，2016，64：348–361。

[19] MAHIDIN 等。棕榈油固体废物用于生物质发电厂的动力分析：以亚齐省化学圈为例，2020，155: 126714，https://doi.org/10.1016/j.chemosphere.2020.126714。

[20] KUANG Y.等。岛屿可再生能源利用综述。可再生能源与可持续能源评论，2016，59：504–513。

[21] PRAENE J.P.等人。马达加斯加的可再生能源发电：机遇与预测。可再生能源与可持续能源评论，2017，76：1066- 1079。

[22] BLECHINGER P.，SEGUIN R.，CADER C.，BERTHEAU P. 和 BREYER C. 对小岛上可再生能源存储系统全球潜力的评估。能源学报，2014，46：294-300。

[23] WEIR T. 太平洋岛屿中的可再生能源：其作用和地位。可再生能源与可持续能源评论，2018，94：762-771。

[24] FULDAUER L.I.，IVES M.C.，ADSHEAD D.，THACKER S. 和 HALL J.W. 为实现可持续发展目标而参与的小岛屿发展中国家废物管理的未来规划，“清洁生产杂志，2019，223：147–162。

[25] DUIĆN. 和 M. DA GRAÇA CARVALHO M. 在岛屿能源供应中增加可再生能源：案例研究圣港。可再生能源与可持续能源评论，2004，8（4）：383-399。

[26] GENAVE A.，BLANCARD S. 和 GARABEDIAN S. 对小岛屿发展中国家能源脆弱性的评估。生态经济学，2020，171，文章 ID：106595。

[27] SELOSSE S.，GARABEDIAN S.，RICCI O. 和 MAÏZI N. 留尼汪岛的可再生能源革命。可再生能源与可持续能源评论，2018，89：99-105。

[28] KARATAYEV M.，HALL S.，KALYUZHNOVA Y. 和 CLARKE M. L. 哈萨克斯坦可再生能源技术的采用：转型经济中的政策驱动因素和障碍。可再生能源与可持续能源评论，2016，66：120-136。

[29] BLECHINGER P.，SEGUIN R.，CADER C.，BERTHEAU P. 和 BREYERA C. 小岛可再生能源存储系统全球潜力评估勘误表：爱格 46C（2014）294-300。，2014.，46，324，https：//doi.org/10.1016/j.egypro.2015.01.070

[30] 世界银行。追踪可持续发展目标 7：2018 年能源进度报告。国际复兴开发银行/世界银行，2018。

[31] BUNKER K.，S。DOIG，K。HAWLEY 和 MORRIS J. 可再生微电网：来自全球岛屿和偏远社区的概况。落基山学院和碳战争室，2015。

[32] ERDINC O.，PATERAKIS N. G. 和 CATALÃOJ. P. S. 在可再生能源日益普及的情况下，岛屿电力系统概述：机遇与挑战。可再生能源与可持续能源评论，2015，52：333–346。

[33] 国家统计局。塞舌尔的数字。维多利亚，塞舌尔，2015。

[34] HEINRICH A. B. 新方法环境科学和污染物研究，2000，12（1): 1。

[35] WOLF F.，SURROOP D.，SINGH A. 和 LEAL W. 小岛屿发展中国家的能源获取和安全战略。能源政策，2016，98：663-673。

[36] MOHAMMED Y. S.，MUSTAFA M. W. 和 BASHIR N. 用于离网电力的混合可再生能源系统：实质性问题的回顾。可再生能源与可持续能源评论，2014，35：527-539。

[37] CHAUHAN A. 和 SAINI R. P. 对基于独立应用的可再生能源综合发电的综述：配置，存储选项，尺寸调整方法和控制。可再生能源与可持续能源评论，2014，38：99-120。

[38] FERNANDES R. 和 PINHO P。小岛上空间发展的独特性质。规划进展，2017，112：1-18，https：//doi.org/10.1016/j.progress.2015.08.001。

[39] JANALOKA O. 印度尼西亚的太阳能潜力。 2015。可从以下网站获得：https：//janaloka.com/potensi-energi-matahari-di-indonesia/

[40] ERDIWANSYAH，MAHIDIN，MAMAT R.，SANI MSM，KHOERUNNISA F. 和 KADAROHMAN A. 到 2040 年之前 10 个东盟国家对可再生能源的目标和需求。电力学报，2019，32（10），文章编号：106670，https://doi.org/10.1016/j.tej.2019.106670

[41] BRIGUGLIO L. 小岛屿发展中国家及其经济脆弱性。世界发展，1995，23（9）：1615-1632。

[42] PETKOV I. 和 GABRIELLI P. 氢能作为季节性能源存储：低碳多能源系统优化设计的不确定性分析。应用能源，2020，274，文章 ID：115197，https://doi.org/10.1016/j.apenergy.2020.115197。

[43] DÓNIZ-PÁEZJ.，BECERRA-RAMÍREZR.，GONZÁLEZ-CÁRDENASE.，GUILLÉN-MARTÍNC. 和 ESCOBAR-LAHOZ E. 火山景观中的地貌变迁和地质旅游：拉吉尔王冠煤渣锥的例子（西班牙加那利群岛的耶罗岛）。旅游与地理杂志，2011，2（8）：185–197。

[44] PLAFKER G.，KACHADOORIAN R.，ECKEL E.B. 和 MAYO L.R. 1964 年 3 月 27 日地震对各个社区的影响。 G 章：1964 年 3 月 27 日的阿拉斯加地震：对社区的影响。1966，华盛顿特区：美国政府印刷局，https://doi.org/10.3133/pp542G

[45] LAMMERS K.，BERTHEAU P. 和 BLECHINGER P. 探索有关东南亚岛屿的气候适应力的可持续能源供应计划的要求。能源政策，2020，146，文章 ID：111770。

[46] MENEGAKI A.N. 关于能源消耗和国内生产总值的研究；最近二十年的荟萃分析。可再生能源与可持续能源评论，2014，29：31-36。

[47] UCHE-SORIA M. 和 RODRÍGUEZ-MONROY C. 能源规划及其在决策中与能源贫困的关系。前往加那利群岛的第一种方法。能源政策，140，文章编号：111423，2020。

[48] HONG S.，YANG T.，CHANG H.J.，和 HONG S. 切换可再生能源支持系统对光伏并网发电的影响：使用学习曲线模型进行分析能源政策，2020，138，文章 ID：111233。

[49] DEMSKI C.，THOMAS G.，BECKER S.，EVENSEN D. 和 PIDGEON N。接受能源过渡和政策：英国将能源作为一种需求和基本权利的概念化。能源研究与社会科学，2019，48：33-45。

[50] PÉREZ-DÍAZJ.I.，CHAZARRA M.，GARCÍA-GONZÁLEZJ.，CAVAZZINI G. 和 STOPPATO A. 抽水蓄能电站的运行趋势和挑战。可再生能源与可持续能源评论，2015，44：767-784。