



Review of the impact of renewable energy development on the environment and nature conservation in Southeast Asia

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Abstract Renewable energy development is growing rapidly due to vast population growth and the limited availability of fossil fuels in Southeast Asia. Located in a tropical climate and within the Ring of Fire, this region has great potential for a transition toward renewable energy utilization. However, numerous studies have found that renewable energy development has a negative impact on the environment and nature conservation. This article presents a systematic literature review of the impact of renewable energy development on the environmental and nature conservation in Southeast Asia. Based on a review of 132 papers and reports, this article finds that the most reported negative impact of renewable energy development comes from hydropower, biofuel production, and geothermal power plants. Solar and wind power might also have a negative impact, albeit one less reported on than that of the other types of renewable energy. The impact was manifested in environmental pollution, biodiversity loss, habitat fragmentation, and wildlife extinction. Thus, renewable energy as a sustainable development priority faces some challenges. Government action in integrated policymaking will help minimize the impact of renewable energy development.

Keywords Renewable energy · Negative impacts · Environment · Nature conservation

1 Introduction

Demand for energy in Southeast Asia has rapidly increased due to rapid population growth and economic development (IEA 2019). Energy is crucial for fulfilling household needs and allowing industry and commercial trade. To allow further economic development, a reliable energy supply is necessary. However, dependence on fossil fuels is still high, especially in rural development (Erdiwansyah et al. 2019). The depletion of fossil fuels and climate change forces society to achieve sustainable development goals (SDGs). These goals point out that human development needs to be achieved in an environmentally sustainable way (Malerba 2019; Yadav et al. 2018). As part of climate change mitigation strategies, countries try to reduce fossil fuels and greenhouse gas emissions by transforming energy systems into sustainable systems, based on renewable energy, as one of the priorities of sustainable development (Karakosta et al. 2009; Khuong et al. 2019). Given the close relationship between climate change and energy use, renewable energy (RE) is a global solution for sustainable development (IEA 2019), offering environmentally friendly, low-emission technology (Malerba 2019).

In 2011, the United Nations secretary general launched the Sustainable Energy for All (SE4ALL) initiative, one of the objectives of which was to double the share of RE in the global mix by 2030 (IRENA 2018) to support one of the sustainable development goals for increased access to clean energy (Haselip et al. 2017). Most of the countries are actually well positioned to benefit from the Kyoto Protocol through Clean Development Mechanism (CDM) projects, especially for the development of RE (Lidula et al. 2007; Uddin et al. 2010). Countries have set a number of policies and mechanisms, especially at the ASEAN level

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under the ASEAN Plan of Action for Energy Cooperation (APAEC) in 2004–2009 (ACE 2015). This action plan has three priorities: energy efficiency and conservation, renewable energies, and clean coal technologies (Lidula et al. 2007). Under a regime of low-carbon measures, RE has been used and has grown extensively in the past few years in Southeast Asia (IEA 2019).

The Southeast Asia region consists of 11 countries, all of which (except for Timor-Leste) are also members of the Association of Southeast Asia Nations (ASEAN). ASEAN was established in 1967 and consists of Malaysia, the Philippines, Singapore, Thailand, Indonesia, Brunei, Vietnam, Laos, Myanmar, and Cambodia. Southeast Asian countries have a high RE potential due to tropical climate conditions and the fact that some are located within the Ring of Fire (Erdiwansyah et al. 2019; IEA 2019; Kumar 2016). In 2016, RE accounted for 26% of the total energy demand from biomass, hydropower, and wind, solar, and geothermal energy sources. Among those, hydropower was the biggest source of power generation, contributing 14% (IEA 2019). The Philippines ranks second in the world in terms of total geothermal electricity generation, while Indonesia ranks third. Thailand shows rapid annual growth in solar photovoltaic power, and the Mekong countries (Laos, Vietnam, Cambodia, and Myanmar) have abundant hydropower potential (Kumar 2016). Each country has targeted a different percentage use of RE to reach 23% of ASEAN energy mix by 2030 (Erdiwansyah et al. 2019).

Nevertheless, the region is not yet ready to globally contribute to RE development due to various challenges (Erdiwansyah et al. 2019; Lidula et al. 2007). There are large gaps between the ambitious target of installed capacity and the reality of RE development in Southeast Asia (Khuong et al. 2019). The selection of sustainable RE technologies often causes problems for policymakers and conflicts in society (Karakosta et al. 2009). Despite the importance of deploying renewable energy as a sustainable energy technology in Southeast Asia, there are many discussions about the impact of RE development on the environment and nature conservation worldwide. Paradoxically, RE development might increase biodiversity loss and wildlife extinction (Sánchez-Zapata et al. 2016). This review paper looks at the impact of RE development on the environment and nature conservation in Southeast Asia, while the most frequent studies concern RE potential and technical preparation in several Southeast Asian countries (ACE 2015; Ahmed et al. 2017; Erdiwansyah et al. 2019; IEA 2019; IRENA 2018; Kumar 2016; Lidula et al. 2007). Although many researchers have shown that RE will have a lower carbon footprint (Ahmed et al. 2017; Ismail et al. 2015; Petinrin and Shaaban 2015; Rana et al. 2016), there is still an impact on the environment and nature conservation, which is often miscalculated by the researcher and

creates a cumulative impact on the future (Rudman et al. 2017). These trade-offs are often neglected by policymakers who experience knowledge gaps, since there is still little research on this topic worldwide. The importance of balancing trade-offs between RE development and environmental and natural conservation is likely to grow in the next decades, since the demand for RE is continuing to grow. Our study will help other researchers to assess the trade-offs from renewable energy development, the challenges, and its policy implications. This review makes relevant literature about the relationship between RE development and the environment easily available to policymakers. Thus, the government can formulate good planning and strong policy to achieve the goals of RE development without harming the environment and nature conservation.

2 Methods

2.1 Study area

RE resources are abundantly available in most Southeast Asian countries (Fig. 1). Located in tropical regions, almost all of the countries receive high daily solar radiation and are rich in water resources. Hydropower has the greatest potential in almost all countries, followed by wind and solar power. The biomass potential also varies due to differences in the production structures of agriculture, forestry, livestock, and industry. Indonesia, Malaysia, and Thailand lead the way in biomass development, which mainly comes from rice husks, bagasse, and palm oil waste (Lidula et al. 2007). Until 2016, the capacity and production of RE varied among countries. Countries with high water resources utilize hydropower to produce energy (the Philippines, Thailand, Malaysia, Indonesia, and Vietnam). Solar and wind power resources are also abundant and are expected to grow continuously in the coming decades (IEA 2019). The potential of geothermal energy varies from country to country depending on the presence of volcanic mountains, with the Philippines and Indonesia in leading positions (Kumar 2016; Lidula et al. 2007).

2.2 Data collection

This paper compiled the scientific literature on the impact of RE development on environmental and natural conservation in Southeast Asia. Information and data were obtained from published papers, databases, statistics, and reports. In the search for literature, various keywords and database sources were used. Studies were sought using keyword combinations from a first category (renewable energy, bioenergy, geothermal, hydropower, solar energy,

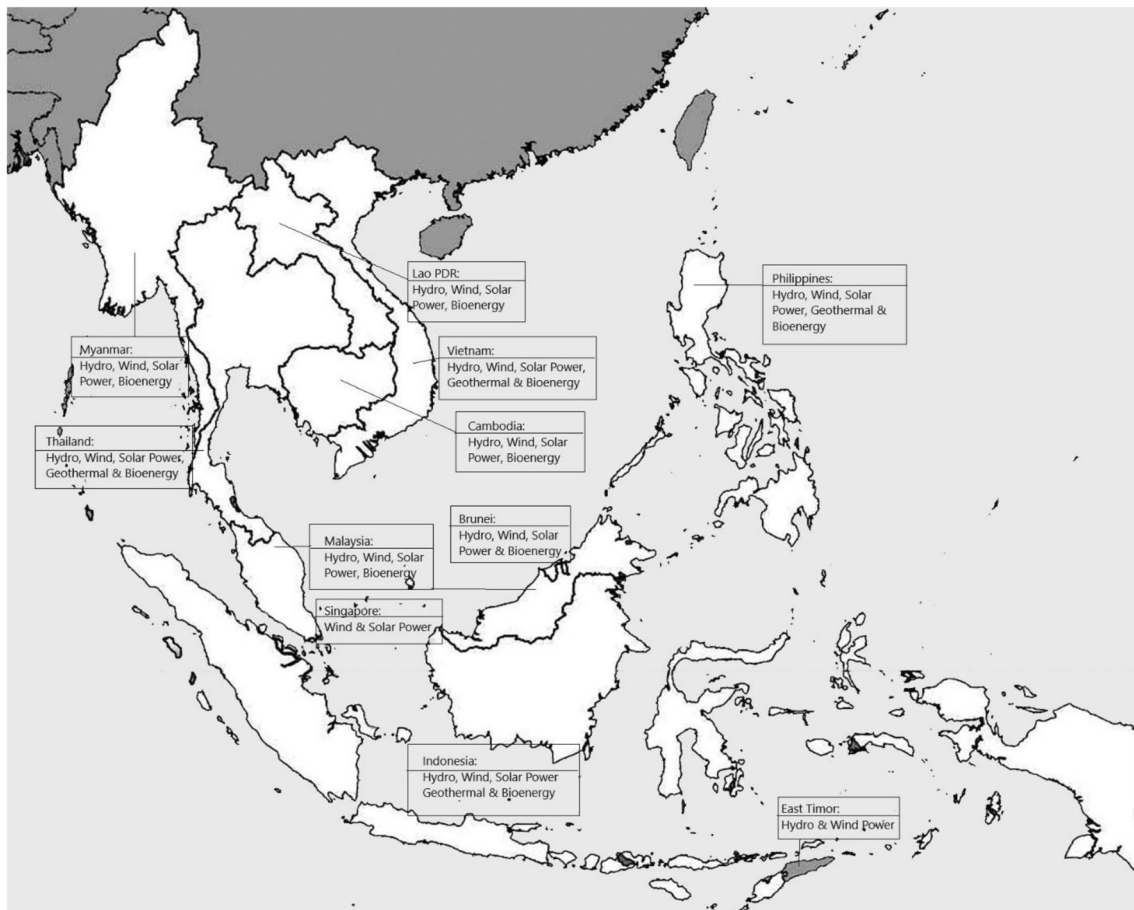


Fig. 1 Geographical distribution of RE potential in Southeast Asia

and wind power), a second category (conflicts, trade-off, impact, problem, and land use change), a third category (nature conservation, biodiversity, nature protection, forest, and environment), and a fourth category (Southeast Asia, Brunei, Cambodia, Timor-Leste, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Vietnam, and ASEAN). The database sources of Google Scholar, Web of Science, Science Direct, and JSTOR Search were used as search platforms.

Of the 303 papers found through this literature search, 132 papers were cited in this paper due to their relevance to the review topic. We considered relevant papers only if they mentioned the trade-off or impact from the type of renewable energy on the environment and nature conservation. The type of impact analyzed included air, soil, and water pollution, greenhouse gas emissions, hydrological changes, landslide/soil erosion, deforestation, habitat fragmentation, and biodiversity loss, as summarized in Table 1. We listed the relevant papers as a graph as shown in Fig. 2).

About 171 papers were considered irrelevant since they had no relation with the focus of our review and only discussed technical points. This article focuses on the most common type of RE (solar, wind, bioenergy, hydro, and

geothermal) in Southeast Asia. Other types of RE technologies, such as ocean energy, were excluded, as they were still considered to be under development (Fig. 3).

3 Environmental concerns

An important reason for the development of RE is the desire to produce more energy while protecting the environment. While RE systems are generally less polluting than fossil fuels at their point of use (Liu et al. 2017), their environmental impact can be high at other stages in the life cycle of the system (Quek et al. 2018). There are several animal and plant species that could be disturbed by the development of RE. (See “Appendix 1” for more details.) Therefore, the environmental sustainability of RE depends on many aspects and not just on greenhouse gas emissions at the point of electricity generation (Quek et al. 2018).

3.1 Solar power

Solar power has a lower environmental impact than other RE technologies. However, researchers have found some

Table 1 Summary of environmental and nature conservation trade-offs. Adapted from (Gasparatos et al. 2017)

Type	Air pollution	GHG emissions	Water pollution	Hydrological change (flooding, drought, sedimentation, etc.)	Landslide/soil erosion	Soil pollution/change	Deforestation	Habitat loss/fragmentation	Biodiversity loss
Solar	X	√	X	X	X	X	?	?	?
Wind	?	X	X	X	X	X	?	?	?
Hydro	√	√	√	√	√	√	√	√	√
Bioenergy	√	√	√	√	X	√	√	√	√
Geothermal	√	X	√	√	√	√	√	√	√

√: Existing evidence and theoretical links
 ?: theoretical link but no existing evidence in this research area
 X: no evidence found

Cited Paper based on type of RE

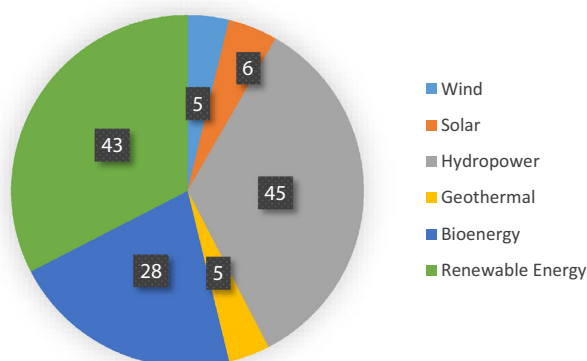
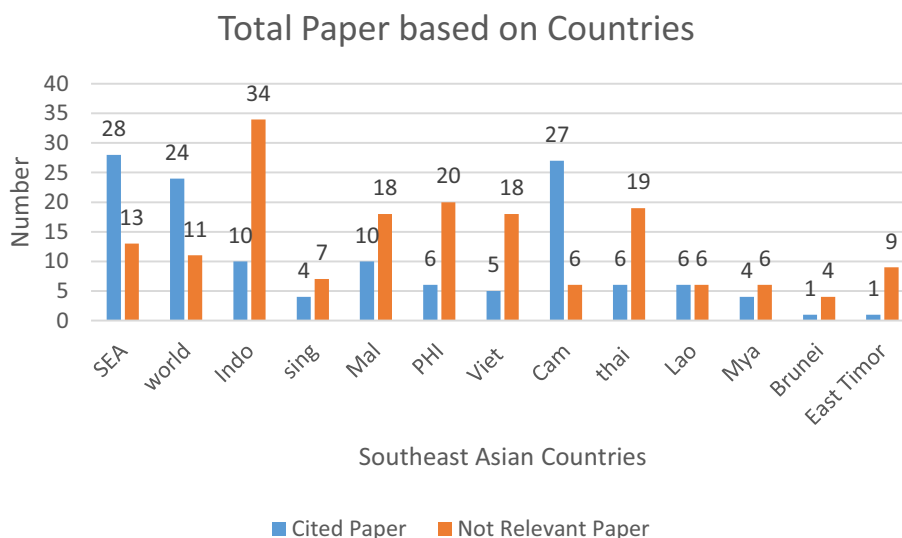


Fig. 2 The total of cited papers based on the type of renewable energy

impact of large-scale solar power on the environment. These trade-offs may occur during the construction, operation, and decommissioning of a utility-scale solar power plant. The manufacturing process of solar cells can produce dangerous waste (Delicado et al. 2016; Sánchez-Zapata et al. 2016). Solar power has the potential to increase water use and consumption (Rudman et al. 2017), dust and air pollution (Darwish et al. 2018), soil erosion, and land use change (Hernandez et al. 2014; Sánchez-Zapata et al. 2016), since solar power plants usually use large areas that need to be cleared of vegetation (Sánchez-Zapata et al. 2016). As a result of life cycle assessment in Singapore, solar photovoltaics contribute significantly to acidification potential (AP), eutrophication potential (EP), and human toxicity potential (HTP) (Quek et al. 2018). The highest environmental impact comes from solar energy in the form

Fig. 3 The total of cited papers based on the Southeast Asian countries



of HTP, which is mainly due to the manufacturing stage of the panels. The use of double-glazed windows and color-tinted modules in building-integrated photovoltaics (BIPV) also produces more greenhouse gas emissions (Ng and Mithraratne 2014).

3.2 Wind power

Wind power is considered the most environmentally friendly renewable technology. It has lower carbon emissions than other RE technologies. However, wind generators produce electric and magnetic fields, increasing the possibility that they will be struck by lightning (Saidur et al. 2011). Researchers have also found that wind turbines have some noise and visual impact on residences and wildlife (Delicado et al. 2016; Ladenburg 2009). The wind turbine also creates microclimate issues by changing the heat and moisture conditions around the wind farm (Rajewski et al. 2016; Sánchez-Zapata et al. 2016). The latest study found that wind turbines can induce weather modification with the possibility of climate change due to wind velocity, turbulence, and rough landscapes (Abbasi and Tabassum-Abbasi 2016). Recently, the governments of Thailand and Laos signed an agreement to build the Monsoon Wind Farm project near the Mekong River in southern Laos. Although the International Energy Agency (IEA) has confirmed that there will be no disruption to people's livelihoods and the environment, it will have an impact during the construction of plants (Saidur et al. 2011) that need to clear the land and remove all vegetation in the wind farm, creating soil erosion (Sánchez-Zapata et al. 2016).

3.3 Bioenergy (biomass, biofuel, and biogas)

For biogas, the generation of acidic substances during crop farming and combustion triggers acidification, while eutrophication impacts are associated with phosphorus concentration and nitrogen enrichment in water runoff from agricultural land (Quek et al. 2018). Air pollution has become a great environmental concern in Malaysia due to the combustion of wood and agricultural and animal waste (Shafie et al. 2011).

The conversion of land use had a significant effect in many cases, such as conflicts surrounding land and water resources. For example, the conversion of forests contributes 15–25% to global carbon emissions (Baral and Lee 2016). Indirect land use change for biofuel production can also add to greenhouse gas emissions, which are supposed to be reduced (Kumar et al. 2013). The whole chain of biofuel production (cultivation, processing, conversion, transport, and combustion) is considered to have more global warming potential than sequestered carbon

(Mukherjee and Sovacool 2014). A study on the greenhouse gas performance of bio-ethanol in Thailand showed that changing land use change from grassland to a cassava plantation causes more emissions than improving the yield of an existing plantation (Silalertruksa et al. 2009).

A study on the impact of the conversion of secondary peat swamp forest into mature palm oil plantations was conducted in Malaysia (Tonks et al. 2017), which found that the conversion decreased the swamp's carbon storage and water holding capacity. Peat lands are well known to house carbon reserves, which will cause greater carbon debt when they are converted into other land use. The carbon debt generated when carbon is emitted by converting native habitats (e.g., rainforest) into croplands will require years to be recaptured (Fargione et al. 2008). The land use change for biodiesel in Indonesia created the largest carbon debts (around 472.8–1743.7 t CO₂ ha⁻¹) due to the conversion of dense tropical forest into oil palm plantations. These plantations require another 59–220 years to offset the initial carbon debt (Achten and Verchot 2011). Another example is the establishment of palm oil plantations around the Danau Sentarum National Park, which has a negative effect by disrupting 96,519 ha of peat land, slowly releasing approximately 128 million tons of underground carbon into the atmosphere (Yuliani et al. 2000). Deforestation can lead to the diversion of waterways and swamps used as sources of freshwater for domestic needs. The villagers who live near palm oil plantations suffer from air pollution because of the burning of oil palm waste (Obidzinski et al. 2012). Others experienced soil erosion and changes in water quality and quantity, where the river floods in the rainy season and dries in the dry season. The increased use of insecticides and fertilizers to enhance biomass productivity may accelerate environmental degradation by causing a loss of biological control and water pollution for downstream communities (Baral and Lee 2016).

Furthermore, plantations of oil palm have grown in number, not only for biofuel production but also to meet demand from the food industry and other industries (Mukherjee and Sovacool 2014). Regarding the use of oil palm, the initial reason for the rapid development of oil palm plantations was the global demand of food (Susanti and Maryudi 2016). An IEA report shows that the use of oil is bigger in the industry than in the transportation sector (IEA 2019). Nevertheless, most of the Southeast Asian countries set themselves the goal of becoming the largest biodiesel producer as one of the valuable and promising alternatives to RE, especially Indonesia, Malaysia, and Thailand. For example, Malaysia retains 40% of its oil palm stock to produce biodiesel (Mekhilef et al. 2011), while Indonesia mandates that 20% of its oil palm stock be blended into diesel (Susanti and Maryudi 2016). This target

converts large swaths of forest into oil palm in order to generate more money and achieve national biodiesel production. When this process occurs, claims of sustainable palm oil or environmentally friendly biodiesel are not valid, since there is an environmental disturbance (Mekhilef et al. 2011).

Although biomass fuels provide many advantages, they have a negative impact on the utilization of fossil fuels and fly ash during combustion (Verma et al. 2017). Biomass fuel cycles are often not greenhouse-gas-neutral because of the substantial production of PIC (products of incomplete combustion), which have a negative impact on human health in rural households in Cambodia (San et al. 2012). In Thailand, biomass power plants that produce less than 10 MW using rice husk combustion systems have the potential to burden nearby villagers with environmental damage (air and water pollution due to black ash from smoke and dust), health problems (due to noise and smoke), and economic harm (due to lower farming productivity) (Yoo 2013). Furthermore, the burning of biomass energy and biogas emits CO₂, SO₂, and other greenhouse gas emissions, something also reported by other researchers (Andreae and Merlet 2001; Gadi et al. 2003; Pei-dong et al. 2007; Streets and Waldhoff 1998).

3.4 Hydropower

Several studies have reported the potential effects of hydropower project development in the Mekong River, including the Strategic Environmental Assessment (SEA) of Hydropower on the Mekong Mainstream (International Centre for Environmental Management 2010), the Lower Mekong Basin Development Plan 2 (MRC 2011), and the working paper on the economic, environmental, and social impacts of hydropower development in the Lower Mekong Basin (Intralawan et al. 2015). The Mekong River is one of the biggest rivers in Asia, flowing through six countries, from China through Myanmar, Laos, Thailand, and Cambodia, and ending in Vietnam. For years, hydropower projects have been altering the Mekong River Basin's riverine ecosystems (Sánchez-Zapata et al. 2016), which contain the world's largest inland fishery and provide food security (Hecht et al. 2019). Assessments have already concluded that the proposed dams would have significant effects on the movement of water and sediment, including changes in the timing and magnitude of seasonal flows. These cumulative impacts could destroy fisheries and riverside gardens, which would affect the livelihood of those who rely on river resources (Trung et al. 2018). Furthermore, sedimentation by mainstream dams would form a new delta (Trung et al. 2018). The planned dams will also cause erosion within the downstream floodplain and a 57% decrease in the wash load downstream.

Reservoir sediment trapping due to hydropower development could cause sediment starvation in downstream floodplains (Arias et al. 2014), altering the ecosystem services, aquatic productivity, and related ecological habitats (Kondolf et al. 2014). In Cambodia, hydropower dams change water levels in the lowland area, which may endanger riverine ecology and aquatic species (Dang et al. 2018). These studies, which are supported by other studies, find that the hydropower operations in the Upper Mekong Basin have caused considerable changes in the discharge regime in the Mekong River (Lauri et al. 2012; Piman et al. 2013; Räsänen et al. 2017) and dominate the changes in the floodplain sediment dynamics of the Mekong Delta (Manh et al. 2015). The discharge impact dampens the Mekong's annual flood pulse, thus reducing the sediment and nutrient transport for aquatic habitats (Lamberts 2008). The Mekong Delta experienced a decrease of up to 66% in the shoreline gradient rate (Li et al. 2017). Recently, a massive dam collapsed in Laos, resulting in casualties and loss of access to food and productive lowland paddy fields. This project diverts the waterway from one river to another through a tunnel, causing riverbank erosion and flooding, which negatively affects fisheries and drinking water (Barney 2007; International Rivers 2014; Shannon 2008). The extensive dam project in Laos also plays an important part in downstream vulnerability (Salmivaara et al. 2013) by reducing sediment flux, which affects biogeochemical cycles and ocean geochemistry (Robinson et al. 2007).

In addition, the Bakun Hydroelectric Project in Malaysia is a significant source of greenhouse gas emissions, especially carbon dioxide and methane, which arise from the microbial decomposition of submerged forests, vegetation, wildlife, and soil (Keong 2005). The dam project is also exposed to direct solar radiation and has a warming effect on the Bakun region. Large hydropower plants emit significant amounts of greenhouse gas (CO₂ and CH₄) due to the decomposition of submerged biomass in the reservoir and due to energy-intensive activities such as construction work (Gagnon and Vate 1997). Indirectly, such dams would contribute to environmental degradation through logging, clearing of the catchment area, and road construction. These emit a substantial amount of greenhouse gases and affect hydrology, water quality, and river flow in a dam project in Borneo (Sovacool and Bulan 2012). There is also the special case of the proposed hydroelectric power project in Timor-Leste, which, due to the karstic nature of the area, would result in water leaking through underground channels. Hydrological diversion would also be responsible for the water level drop around the site (White et al. 2006).

3.5 Geothermal

Hot spring water used as a tourist attraction in Laguna, the Philippines, due to its geothermal potential, is estimated to consume a large volume of groundwater. This could result in over-extraction, decreasing groundwater quantity and quality (Jago-on et al. 2017). The use of this geothermal energy for a hot spring area can also result in environmental damage, because the wastewater affects aquatic ecology near the geothermal power plants (Sánchez-Zapata et al. 2016). It is argued that geothermal power has the highest environmental impact, as it disrupts the geology in the site area (Asdrubali et al. 2015). The 1979 Lembata landslide and tsunami in Indonesia were primed by the hydrothermal alteration of rocks and soil in the geothermal environment. The area is located in a volcanic complex where the geothermal potential is evident due to numerous hot springs. The altered rocks and soils become loose, slightly lighter in weight, and change into clay minerals, which are more susceptible to landslides during the heavy rainfall season (Yudhicara et al. 2015). This was shown to be the case by the environmental impact assessment that was carried out in the Salak Geothermal Project. The assessment identified increasing surface soil erosion, increasing hydrogen sulfide in the air, temporary changes in stream water quality, and droughts during construction of the geothermal project (Slamet and Moelyono 2000). Geothermal power plants also have a social impact on the surrounding environment in the form of seismic activity, odor, and noise pollution. Moreover, the first-generation technology of geothermal power plants has a high potential for emissions because waste gases of 90% CO₂ are directly released (Evans et al. 2009).

4 The nature conservation concern

The production of RE can cause competition for land and water, resulting in an impact on biodiversity conservation (Popp et al. 2014; Sánchez-Zapata et al. 2016; Vijay et al. 2016). This is also related to deforestation, where land or forest needs to be cleared to build dams and reservoirs. In terms of nature conservation, this could lead to a loss of biodiversity (Sánchez-Zapata et al. 2016), habitat destruction (Urban et al. 2018), and a loss of terrestrial and aquatic habitats, which increases pressure on wildlife populations that are dependent on these habitats (Blake 2005; Mirumachi and Torriti 2012).

4.1 Solar power

Solar power is one of the most promising renewable energy technologies in Southeast Asia. All the countries in the

region are in the stage of developing solar power, especially in the form of solar photovoltaics (PV). Reports or studies on the impact of solar PV on nature conservation are still relatively scarce in Southeast Asia. Often, the researcher miscalculates the cumulative and longtime impact from the solar power plant. However, researchers have found direct and indirect impacts of large-scale solar energy on biodiversity. These impacts could vary based on the solar plant design and technology type. The installation of solar power requires an area of many acres, which may result in habitat fragmentation and local biodiversity loss (Hernandez et al. 2014). The construction and solar power plants could affect the habitat and movement of local birds (Rudman et al. 2017). Solar plants can introduce exotic species invasions due to the opening of project area (Sánchez-Zapata et al. 2016). Solar power plants have also affected vegetation structures and types through land clearing and preparation (Rudman et al. 2017).

4.2 Wind power

The most negative impact of wind power is fauna collision with the wind turbine, as many researchers have reported (Drewitt and Langston 2006; Sovacool 2012). It was found that birds and bats have high mortality rates from hitting wind turbines (Maftouni 2017). These collisions might be caused by the influence of lighting and attraction from the wind power plant, tower design, weather conditions, and height of flight (Saidur et al. 2011). Not only local species of birds and bats were affected by the wind farm but also species that regularly migrated from the Northern to the Southern Hemisphere (Hull et al. 2015; Sánchez-Zapata et al. 2016). Another indirect impact from wind power plants is habitat fragmentation (Saidur et al. 2011) and demographic imbalance because it changes ecosystem function by disrupting not only plants and animals but also the human population (Delicado et al. 2016; Sánchez-Zapata et al. 2016). Offshore wind projects also have some negative effects on fish, marine mammals, birds, and seabed communities by creating noise, electromagnetic fields, and migration barriers (Dannheim et al. 2019; Haslett et al. 2018). Wind power projects have been realized in Thailand, the Philippines, and Vietnam. Recently, there has been a lack of studies (Green et al. 2016) or reports on the existing trade-offs of these projects.

4.3 Bioenergy

Currently, bioenergy in Indonesia is produced primarily from oil palm, which has been criticized as being a reason for deforestation, biodiversity loss, peat land drainage, and other socio-environmental issues (Abram et al. 2017; Gaveau et al. 2016; Obidzinski et al. 2012; Sharma et al.

2018). Poorly planned bioenergy production will degrade natural forests, which are converted into monoculture plantations (Finco and Doppler 2010), by destroying biodiversity and, at the same time, increasing greenhouse gas emissions (Baral and Lee 2016). Forest conversion has been associated with the loss of biodiversity, including a decline in populations of endangered species such as the orangutan (in Borneo) and the Sumatran tigers (in Sumatra) (Obidzinski et al. 2012). Mostly, endangered species are threatened by fragmentation (Mukherjee and Sovacool 2014) and rapid extinction without the hope of regeneration (Koh and Wilcove 2008). In the riverine habitat, around 104 species of fish as well as a threatened crocodylian species, *Tomistoma schlegelii*, have dwindled in population because of water pollution and loss of refuges and breeding sites caused by the conversion of peat swamp forests around the Danau Sentarum National Park into palm oil plantations. Moreover, 134 species (12 reptiles, 78 birds, and 11 mammals) are expected to become extinct as a result of dense forests changing into monoculture plantations (Yuliani et al. 2000). The loss of biodiversity and habitat will eventually lead to land conflicts and poverty from the loss of means of livelihood for the surrounding populations (Baral and Lee 2016).

4.4 Hydropower

There are four types of environmental impacts from the hydropower project in Malaysia: land clearing and deforestation, flooding and greenhouse gas emissions, changes in hydrology and water quality, and the impact of downstream aluminum smelting (Sovacool and Bulan 2011, 2012). The most relevant impact on natural conservation was the land clearing and deforestation of 70,000 hectares of forest for a reservoir area. Another project was estimated to have destroyed 500 million cubic meters of biomass, and the home to six rare and endangered fish species, 32 protected bird species, and six protected mammals, including herons, eagles, woodpeckers, silvered leaf monkeys, Borneo gibbons, Langurs, and flying squirrels, as well as more than 1600 protected plants (Keong 2005). Most hydropower projects change the existing land use to open reservoirs, which releases carbon, threatens biodiversity, and affects livelihoods in the areas around the project.

Furthermore, extensive hydropower development in the Mekong River Basin will decrease ecosystem productivity (Arias et al. 2014; Baran and Myschowoda 2009; Campbell et al. 2006; Kuenzer et al. 2013; Lamberts 2006). Developing hydropower to increase energy security has a negative impact on natural systems (Ho 2014). Future dam projects on the tributaries will change the seasonal flow (drought and flood), which will affect biodiversity, create

environmental hotspots, and threaten the giant catfish and Irrawaddy dolphin in Laos and Myanmar (Intralawan et al. 2018). Enormous hydropower dams will also cause fragmentation, where the distribution and complexity of primary vegetation will be reduced (Li et al. 2012). In Cambodia and Vietnam, the proposed hydropower projects will also cause major changes to river hydrology and sediment/nutrient dynamics, which will then affect the fisheries' productivity and floodplains in the coastal zone (Kummu and Sarkkula 2008; Kummu and Varis 2007; Lamberts 2008). With the shift in natural flow seasons, aquatic organisms will also be affected by the new flow conditions (Ngor et al. 2018). At least 89 migratory species, including 17 endemic and 14 endangered or critically endangered species, are threatened with extinction in the Mekong River system. This was also supported by a study in Laos, where the planned dams would affect fish diversity basin-wide, disrupting the river network and fish productivity as far as the Cambodian and Vietnamese floodplains (Ziv et al. 2012). Furthermore, the impact of changing aquatic ecosystems alters the natural food chain, which is critical to food security and the well-being of the Mekong River populations, as other researchers have observed (Baran and Myschowoda 2009; Hortle 2007; Intralawan et al. 2018; Ngor et al. 2018; Ziv et al. 2012). In the hydropower project in Timor-Leste, the site consists of a wetland ecosystem, karst nature area, and a tropical forest habitat, which is believed to have been destroyed, although a proper environmental assessment has not been conducted. The damage to the great diversity of aquatic plants, fish, and subsurface fauna needs to be mitigated, especially in the karst landscapes and existing caves, which are sensitive to human activities (White et al. 2006).

4.5 Geothermal

Another threat to forestry results from the utilization of geothermal power, for example, in Indonesia. Up to 42% of potential geothermal resources (more than 12GW) are located in protected forest areas. The Environmental Impact Assessment (EIA) was carried out twice in the geothermal project located on Mount Salak, which was later declared a national park (Mount Halimun Salak National Park). The assessment identified a decline in standing trees and a temporary disturbance to the wildlife habitat during exploration and construction (Slamet and Moelyono 2000). Although geothermal projects require only small tracts of land, there is an impact in the form of habitat and terrestrial ecosystem loss. Forest fragmentation, which is caused by the development of roads and other infrastructures to facilitate the development of geothermal projects, can result in habitat changes or destruction of existing flora and fauna (Tuyor et al. 2005). The opening

process can provide great access to people (such as loggers, poachers, or settlers) and invasive species (Ashat and Ardiansyah 2012).

5 Challenges and policy implications

5.1 Challenges for RE development

To move forward along the path of RE, it is necessary to identify the challenges related to the impact on environmental and nature conservation and RE development in Southeast Asia.

5.1.1 Financial challenges

The high costs of technology have led to a slow development of RE in countries with limited financial resources (IEA 2019; Lidula et al. 2007; Rahmadi et al. 2017). The high potential of RE resources in Southeast Asia opens opportunities for many donors to support the development of RE projects. For example, the high potential of water resources attracts many foreign capital investors to build hydropower projects (Urban et al. 2013). Nevertheless, it is not clear whether large-scale hydropower projects are economically sustainable (Kim and Jung 2018). Various case studies have reported that the project countries remain dependent due to the failure of economic growth (Thomas 2005). For example, the projects of solar power installation for rural electrification supported by international donors (GTZ, AusAID, UNDP, USAID) in the Philippines showed their unsustainability by ceasing operation, or faced severe problems after the project finished. There was no technical and financial capacity to maintain RE projects, which then went to waste (Marquardt 2014). The development of many RE projects without assured financial backing has a negative impact on the environment, due to unsustainable project and maintenance issues.

5.1.2 Institutional challenges

The IEA also concluded that most of the countries have administrative and regulatory barriers, including gaps in the legal framework (IEA 2019) and a lack of authoritative institutions tasked with RE issues (Yadav et al. 2018). Inadequate policies and regulations that neglect sustainability in developing RE will lead to trade-offs with the environment and nature conservation (Erdiwansyah et al. 2019; Khuong et al. 2019). Even though there is an environmental impact assessment (EIA), weak coordination and planning among stakeholders does not provide effective harm prevention for nature and the environment. For example, in the case of mega hydropower development in the Lower Mekong Basin countries, an EIA was conducted, but

there was a substantial impact on the environment (International Centre for Environmental Management 2010).

5.1.3 Social challenges

A lack of scientific studies and updated databases on the potential and status of RE can cause chaos in the planning process. These problems can lead to a lack of involvement by stakeholders, especially in local communities. A lack of awareness and involvement by local communities due to scarce information and the political situation (Erdiwansyah et al. 2019; Khuong et al. 2019) has resulted in the rejection of several RE development projects in countries such as Vietnam, Myanmar, and Indonesia. Some forms of RE, such as hydropower dams and geothermal energy, are still considered by local populations to be damaging to the environment. The Save Mekong campaign is a successful example of influencing the policy process and increasing public awareness of the environmental issues surrounding hydropower projects (Dore et al. 2012). In Thailand and Malaysia, RE is still considered to be immature, risky, and unproven (Sovacool 2010), while in Myanmar, resistance has often led to violence (Dore et al. 2012). Furthermore, these instances of rejection could cause an increase in consumption and the creation of subsidies and a general bias toward conventional energy technologies (IEA 2019).

5.1.4 Technical challenges

Some countries still have minimal sources and infrastructure and a lack of the skilled human resources that are needed to build RE projects. A lack of advanced knowledge in recent RE technology and innovation can have serious consequences for the environment and nature conservation. These consequences would be worse when there are limited financial resources that would lead to the irrelevant use of RE, for example, with low efficiency rates or low-quality equipment. Environmental sustainability can only be achieved through the deployment of efficient and affordable RE technologies (Kaygusuz 2012) and a wide range of approaches (IEA 2019). Insufficient grid capacity and extension represent a major bottleneck in the expansion of the market insertion of RE electricity. An example of this is Laos, which still has limited grid facilities and a technology-specific barrier (Lidula et al. 2007) (Table 2).

5.2 Policy implications

Currently, Southeast Asian countries are trying to reduce greenhouse gas emissions by reducing the utilization of fossil fuels and introducing more RE utilization. These objectives are in line with the SDG's targets of clean energy and climate action. To foster this change, countries are

Table 2 Summary of important barriers

Type of barriers	
Financial	Limited financial resources
	Lack of favorable pricing and investment policies
	Lack of capital and economic incentives
Institutional	Inadequate policies and supporting mechanisms
	Weak institutional framework and regulation
	Weak coordination and planning
Social	Lack of static information and update database
	Lack of awareness and public participation
	Lack of scientific local studies
Technical	Lack of qualified and skilled human resources
	Weak technological and innovative changes
	Limited infrastructure and transmission lines

developing regulations, policies, plans, and supporting mechanisms to reach their own target of RE utilization (Erdiwansyah et al. 2019; Gill et al. 2018). Clean technologies definitely require energy resources complemented by advanced technology and materials (Brook and Bradshaw 2012). Together, these factors accelerate the damage to natural systems. Thus, there will be more challenges to the energy and economic systems, since these countries have committed to reducing greenhouse gas emissions (Tran et al. 2016). However, climate change does not seem to be the main reason for the pursuit of RE development by these countries. The deployment of RE technology is highly driven by political situations and different interests. Climate change mitigation and sustainable energy development have not yet been fully integrated in global climate governance (Blohmke 2014). For example, biofuel development in Indonesia, Malaysia, the Philippines, and Thailand is driven mainly by the need for energy security and socioeconomic development (Kumar et al. 2013), while air quality considerations do not seem to be the objective of the introduction of climate policy in Vietnam (Zimmer et al. 2015).

A mega hydropower project in the Lower Mekong Basin countries is considered to be the cause of the fragmentation of river systems, changing the ecosystem and the livelihood of the rural population. This leads to environmental and social costs, making these ambitious hydropower plans highly controversial and politically charged (Fu et al. 2010; Räsänen et al. 2012). In the Philippines, RE is utilized to secure the energy supply and to enhance energy access by means of rural electrification, while climate protection, environmental, and other sustainability concerns remain as driving factors (Marquardt et al. 2016). Large-scale energy infrastructure networks can decrease rather than increasing energy security, especially if there is international conflict (Sovacool 2009). There is a conflict of interest between the upstream and downstream countries along the Mekong River (Kuenzer et al. 2013). The Mekong elite decision

makers directly and indirectly profit from the dams and put the majority of the rural poor at risk. This project also became a politically charged topic, in which many studies and assessment reports are biased and guided by the interests of their respective institutions. Recently, ASEAN has halted a large hydropower project due to its impact on the environment (Khuong et al. 2019).

In Vietnam, there is confusion about the overlapping strategies for green growth, sustainable development, and tackling climate change, including competing policies that favor different stakeholders' interests (Urban et al. 2018). There is significant tension between building the highest hydropower project in the region and safeguarding the great Irrawaddy River in Myanmar, though the country has tackled the costs of development and environmental integration (Erdiwansyah et al. 2019). Due to minimal RE sources and technology, Brunei and Singapore are still engaged in intensive research on RE potential. Despite the renewable portfolio standards in the Philippines and Thailand, investments in fossil fuels continue to be greater than investments in alternative sources (Lidula et al. 2007). In Indonesia, forest laws intended to stop the expansion of palm oil plantations have stunted (perhaps unintentionally) the development of geothermal power sources (Sovacool 2010). The regulatory frameworks were not harmonized and were inappropriate, leading to the conclusion that the region as a whole was "not yet ready" for RE development (Lidula et al. 2007).

Sustainable development needs good governance to be successful. Thus, government intervention is needed to overcome these challenges to the promotion of RE development in each country (Khuong et al. 2019). A shift must be made away from the state-centric geopolitics of mastering nature and toward a sustainability paradigm with a link between the economy and ecology (Saroch 2008). A sustainable energy policy formulation, with a strong deployment of RE, could minimize the challenges and make climate change mitigation policy more feasible (Erdiwansyah et al. 2019; Tran et al. 2016). It is also necessary to integrate long-term environmental, social, and economic sustainability targets in all RE plans and programs in the future. Furthermore, international donors could also support the countries by exploiting negative cost options, raising awareness for potential co-benefits, and financing through the CDM (Uddin et al. 2010; Zimmer et al. 2015). There are some RE mechanisms to support this, such as renewable portfolio standards, green power programs, public research and development expenditures, system benefit charges, investment tax credits, production tax credits, tendering, and feed-in tariffs in Europe and the USA (Sovacool 2010). Southeast Asian countries will also need to increase cooperation within the region in order to speed up the deployment of RE technologies through the ASEAN Power Grid (Erdiwansyah et al. 2019; IEA 2019).

Table 3 Summary of important policy implications

Policy implications	Adjust the competing policies and mechanisms
	Reformulate overlapping and misdirect development strategies
	Harmonize conflicting regulation by different interests

This will help ASEAN countries incorporate higher percentages of RE. The expansion of energy supply from RE sources in Southeast Asia will result in socioeconomic and environmental benefits (Erdiwansyah et al. 2019; Huang et al. 2019) (Table 3).

6 Conclusion

Considering the trade-offs between RE development, environment, and nature conservation, it is clear that RE is not always green and sustainable. These trade-offs usually have further implications in social and economic consequences, especially for the livelihoods of local communities near the RE project areas. Therefore, it is also important to raise public awareness and knowledge regarding the deployment of RE. Further scientific research and evaluation is needed to better understand the socioeconomic impact of RE and mitigate the impact of RE development in Southeast Asia.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Appendix 1

List of affected animal and plant species by RE development		IUCN category	Type of RE	Country
No.	Animal			
1.	Southeast Asian long-fingered bat (<i>Miniopterus fuscus</i>)	Endangered	Wind power, hydropower	Philippines
2.	Mindanao homed frog (<i>Megophrys stejnegeri</i>)	Least concern	Hydropower, geothermal	Philippines
3.	Southeast Asian shrew (<i>Crocidura fuliginosa</i>)	Least concern	Hydropower, solar power, bioenergy	Myanmar, Thailand, Laos, Vietnam, Cambodia,
4.	Asiatic softshell turtle (<i>Amyda cartilaginea</i>)	Vulnerable	Hydropower, wind power	Southeast Asia
5.	Southeast Asian box turtle (<i>Cuora amboinensis</i>)	Vulnerable	Hydropower, wind power	Southeast Asia
6.	Friilled tree frog (<i>Kurixalus appendiculatus</i>)	Least concern	Hydropower, wind power, geothermal, solar power, biofuel	Southeast Asia
7.	The yellowtail rasbora (<i>Rasbora tornieri</i>)	Least concern	Hydropower	Laos, Thailand, Cambodia, Malaysia, Indonesia, Singapore
8.	Asian narrow-headed softshell turtle (<i>Chitra chitra</i>)	Critically endangered	Hydropower, wind power	Thailand, Malaysia, Indonesia, Singapore
9.	The Himalayan mole (<i>Euroscaptor micrura</i>)	Least concern	Hydropower, biofuel	Myanmar, Malaysia
10.	Kloss’s mole (<i>Euroscaptor klossi</i>)	Least concern	Hydropower, wind power, biofuel	Vietnam, Laos, Myanmar, Thailand, Malaysia
11.	<i>Rhacophorus Indonesianis</i>	Vulnerable	Geothermal, hydropower	Indonesia

No.	Animal	IUCN category	Type of RE	Country
12.	Indonesia wart frog (<i>Limnonectes microdiscus</i>)	Least concern	Geothermal, hydropower	Indonesia
13.	Indonesian toad (<i>Ingerophrynus biporcatus</i>)	Least concern	Geothermal, hydropower	Indonesia
14.	Indonesian goby (<i>Mugilogobius platystomus</i>)	Least concern	Hydropower	Indonesia
15.	Indonesian shortsnout spurdog (<i>Squalus hemipinnis</i>)	Near threatened	Hydropower	Indonesia
16.	Java Indonesian treefrog (<i>Nyctixalus margantifer</i>)	Least concern	Geothermal	Indonesia
17.	Indonesian gizzard shad (<i>Anodontostoma selangkai</i>)	Least concern	Hydropower	Indonesia, Philippines, Malaysia,
18.	Porcupine (<i>Hystrix pumila</i>)	Vulnerable	Hydropower, biofuel, geothermal	Indonesia, Philippines
19.	Indonesian longfinned eel (<i>Anguilla borneensis</i>)	Vulnerable	Hydropower	Indonesia
20.	Spiny Indonesian treefrog (<i>Nyctixalus spinosus</i>)	Least concern	Hydropower, biofuel, geothermal	Indonesia, Philippines
21.	Indonesian bubble-nest frog (<i>Philautus vittiger</i>)	Near threatened	Geothermal, hydropower	Indonesia
22.	Indonesian short-nosed fruit bat (<i>Cynopterus titthaechellus</i>)	Least concern	Hydropower, geothermal	Indonesia
23.	Assam Indonesian treefrog (<i>Theلودerma moloch</i>)	Vulnerable	Hydropower,	Indonesia, Myanmar
24.	Bleeding toad (<i>Leptophryne cruentata</i>)	Critically endangered	Geothermal	Indonesia
25.	Indonesian mountain weasel (<i>Mustela lutreolina</i>)	Least concern	Hydropower, geothermal	Indonesia
26.	Spitting cobra (<i>Naja sputatrix</i>)	Least concern	Hydropower, geothermal	Indonesia
27.	Tricolored ringneck (<i>Liopeltis tricolor</i>)	Least concern	Hydropower, geothermal	Indonesia
28.	Cinnamon frog (<i>Nyctixalus pictus</i>)	Near threatened	Hydropower	Malaysia, Indonesia, Brunei D
29.	Sunda stink badger (<i>Mydaus javanensis</i>)	Least concern	Hydropower	Indonesia, Brunei, Malaysia
30.	Tomimanga aurea	Near threatened	Hydropower	Indonesia
31.	<i>Tomimanga sanguicauda</i>	Near threatened	Hydropower	Indonesia
32.	<i>Leptophryne javanica</i>	Endangered	Hydropower, geothermal	Indonesia
33.	Hourglass toad	Least concern	Hydropower	Indonesia
34.	Sumatran tiger (<i>Panthera tigris sumatrae</i>)	Critically endangered	Hydropower, geothermal, biofuel	Indonesia
35.	Javan rhinoceros (<i>Rhinoceros sondaicus</i>)	Critically endangered	Hydropower	Indonesia
36.	Sumatran rhinoceros (<i>Dicerorhinus sumatrensis</i>)	Critically endangered	Geothermal, hydropower, biofuel	Indonesia
37.	Orangutan (<i>Pongo pygmaeus</i>)	Critically endangered	Geothermal, biofuel, hydropower,	Indonesia, Malaysia
38.	Javan hawk-eagle (<i>Nisaetus bartelsi</i>)	Critically endangered	Geothermal	Indonesia
39.	Bali myna (<i>Leucopsar rothschildi</i>)	Critically endangered	Solar power	Indonesia
40.	Javan lapwing (<i>Vanellus macropterus</i>)	Critically endangered	Wind power	Indonesia
41.	The Bawean deer (<i>Hyalaphus kuhlii</i>)	Critically endangered	Geothermal, hydropower	Indonesia
42.	Bali cattle (<i>Bos javanicus</i>)	Endangered	Hydropower	Indonesia, Cambodia, Vietnam, Thailand, Laos, Myanmar
43.	Midget buffalo (<i>Bubalus depressicornis</i>)	Endangered	Hydropower, geothermal	Indonesia

No.	Animal	IUCN category	Type of RE	Country
44.	White-winged duck (<i>Asarcornis scutulata</i>)	Endangered	Hydropower, geothermal	Indonesia, Cambodia, Vietnam, Thailand, Laos, Myanmar
45.	Maleo (<i>Macrocephalon maleo</i>)	Endangered	Geothermal	Indonesia
46.	Malayan tapir (<i>Tapirus indicus</i>)	Endangered	Geothermal, hydropower, biofuel	Indonesia, Malaysia, Myanmar
47.	Sunda pangolin (<i>Manis javanica</i>)	Critically endangered	Hydropower, geothermal, wind power, biofuel	Indonesia, Malaysia, Cambodia, Laos, Thailand
48.	Philippine pangolin (<i>Manis culionensis</i>)	Critically endangered	Hydropower	Philippine
49.	Long-nosed monkey (<i>Nasalis larvatus</i>)	Endangered	Biofuel	Indonesia, Malaysia, Brunei
50.	Tarsier (<i>Tarsius sp</i>)	Endangered	Geothermal, hydropower	Indonesia, Philippines
51.	Cassowaries (<i>Casuarius casuarius</i>)	Least concern	Biofuel	Indonesia
52.	Green peafowl (<i>Pavo muticus</i>)	Endangered	Geothermal, hydropower	Indonesia, Myanmar, Cambodia
53.	Moluccan cockatoo (<i>Cacatua moluccensis</i>)	Vulnerable	Hydropower	Indonesia
54.	Sparrowhawk (<i>Accipiter sp</i>)	Least concern	Hydropower, wind power	Indonesia, Malaysia, Brunei
55.	Flores green pigeon (<i>Treron floris</i>)	Vulnerable	Hydropower, wind power	Indonesia
56.	Javan blue-banded kingfisher	Critically endangered	Geothermal, hydropower	Indonesia
57.	Southern Vietnam box turtle	Critically endangered	Wind power, hydropower, solar power	Vietnam
58.	Mekong giant catfish (<i>Pangasianodon gigas</i>)	Critically endangered	Hydropower	Laos, Vietnam, Cambodia
59.	Giant pangasius (<i>Pangasius sanitwongsei</i>)	Critically endangered	Hydropower	Laos, Vietnam, Cambodia
60.	Philippine crocodile (<i>Crocodylus mindorensis</i>)	Critically endangered	Hydropower	Philippines
61.	Elongated tortoise (Indotestudo elongata)	Critically endangered	Hydropower	Myanmar, Thailand, Cambodia, Vietnam
62.	Philippine eagle (<i>Pithecochaga jefferyi</i>)	Critically endangered	Hydropower, geothermal	Philippine
63.	Delacour's langur (<i>Trachypithecus delacouri</i>)	Critically endangered	Solar power, hydropower	Vietnam
64.	Tonkin snub-nosed monkey (<i>Rhinopithecus avunculus</i>)	Critically endangered	Hydropower	Vietnam
65.	Black crested gibbon (<i>Nomascus concolor</i>)	Critically endangered	Hydropower	Laos
66.	Celebes crested macaque (<i>Macaca nigra</i>)	Critically endangered	Biofuel	Indonesia
67.	Bourret's box turtle (<i>Cuora bourreti</i>)	Critically endangered	Hydropower, solar power, wind power	Vietnam
68.	Silvery pigeon (<i>Columba argentinia</i>)	Critically endangered	Wind power	Indonesia, Singapore
69.	Red orchid bee (<i>Caridina glaubrechti</i>)	Critically endangered	Hydropower	Indonesia
70.	Mini blue bee shrimp (<i>Caridina loehae</i>)	Critically endangered	Hydropower	Indonesia
71.	Red line shrimp (<i>Caridina striata</i>)	Critically endangered	Hydropower	Indonesia
72.	Negros bleeding heart (<i>Gallinolumba keayi</i>)	Critically endangered	Geothermal, wind power	Philippines
73.	Thongaree's disc-nosed bat (<i>Eudiscoderma thongaree</i>)	Critically endangered	Hydropower	Thailand
74.	Yellow-breasted bunting (<i>Emberiza aureola</i>)	Critically endangered	Hydropower, wind power	Myanmar, Thailand, Cambodia, Vietnam
75.	Saola (<i>Pseudoryx nghetinhensis</i>)	Critically endangered	Hydropower	Laos, Vietnam
76.	<i>Leptobranchella botsfordi</i>	Critically endangered	Hydropower	Vietnam

No.	Animal	IUCN category	Type of RE	Country
77.	Giant carp (<i>Catlocarpio siamensis</i>)	Critically endangered	Hydropower	Thailand, Cambodia
78.	White-rumped vulture (<i>Gyps bengalensis</i>)	Critically endangered	Hydropower	Cambodia
79.	Rufous-headed hornbill (<i>Rhabdotorrhinus waldeni</i>)	Critically endangered	Wind power	Philippines
80.	Slender-billed vulture (<i>Gyps tenuirostris</i>)	Critically endangered	Wind power	Cambodia, Myanmar
81.	Negros fruit dove (<i>Ptilinopus arcanus</i>)	Critically endangered	Geothermal	Philippines
82.	Calamian deer (<i>Axis calamianensis</i>)	Endangered	Geothermal	Philippines
83.	Moluccan woodcock (<i>Scolopax rochussenii</i>)	Endangered	Wind power	Indonesia
84.	Black-faced spoonbill (<i>Platalea minor</i>)	Endangered	Wind power, biofuel	Vietnam, Malaysia
85.	White edged freshwater whiphay (<i>Flavivrygon signifer</i>)	Endangered	Hydropower	Thailand, Malaysia, Indonesia
86.	Masked Finfoot (<i>Helipais personatus</i>)	Endangered	Wind power, hydropower	Myanmar, Malaysia, Cambodia, Vietnam, Indonesia
87.	Visayan hornbill (<i>Penelopides Panini</i>)	Endangered	Wind power	Philippines
88.	Greater adjutant (<i>Leptoptilos dubius</i>)	Endangered	Wind power	Vietnam, Cambodia
89.	Misty moss frog (<i>Thelodroma nebulosum</i>)	Endangered	Solar power, hydropower	Vietnam
90.	Asian elephant (<i>Elephas maximus</i>)	Endangered	Hydropower, geothermal, biofuel, solar power	Indonesia, Thailand, Cambodia, Vietnam, Laos, Myanmar
91.	Storm's stork (<i>Ciconia stormi</i>)	Endangered	Biofuel, wind power, hydropower	Indonesia, Malaysia, Brunei, Singapore
92.	Siamang (<i>Symphalangus syndactylus</i>)	Endangered	Biofuel, hydropower	Indonesia, Malaysia
93.	<i>Barbourula kalimantanensis</i>	Endangered	Biofuel	Indonesia
94.	Green racket-tail (<i>Prioniturus luconensis</i>)	Endangered	Wind power	Philippines
95.	Scaly-sided merganser (<i>Mergus squamatus</i>)	Endangered	Hydropower, wind power	Thailand
96.	Thorny tree frog (<i>Gracixalus lumarius</i>)	Endangered	Solar power, hydropower	Vietnam
97.	Bornean peacock-pheasant (<i>Polypectron schlegelii</i>)	Endangered	Biofuel, wind power, hydropower	Indonesia, Malaysia
98.	Steppe eagle (<i>Aquila nipalensis</i>)	Endangered	Biofuel, wind power	Malaysia, Myanmar
99.	Timor green pigeon (<i>Trogon psittaceus</i>)	Endangered	Wind power	Indonesia, East Timor
100.	Mekong freshwater stingray (<i>Hemirhynchus laosensis</i>)	Endangered	Hydropower, wind power	Laos, Cambodia
101.	Crested argus (<i>Rheinaridia ocellata</i>)	Endangered	Wind power	Vietnam
102.	Red-and-blue lory (<i>Eos histrio</i>)	Endangered	Wind power	Indonesia
103.	Eld's deer (<i>Rucervus eldii</i>)	Endangered	Biofuel, hydropower	Cambodia, Myanmar
104.	<i>Rhacophorus helenae</i>	Endangered	Solar power, hydropower	Vietnam
105.	Quyet's treefrog (<i>Gracixalus quyeti</i>)	Endangered	Wind power, hydropower	Vietnam
106.	Red-shanked douc langur (<i>Pygathrix nemaeus</i>)	Endangered	Hydropower, solar power, wind power	Vietnam
107.	Francois langur (<i>Trachypithecus francoisi</i>)	Endangered	Hydropower	Vietnam

No.	Animal	IUCN category	Type of RE	Country
108.	Japanese eel (<i>Anguilla japonica</i>)	Endangered	Hydropower	Vietnam, Philippines
109.	<i>Leptobranchella firthi</i>	Endangered	Hydropower	Vietnam
110.	Irrawaddy Dolphin (<i>Orcaella brevirostris</i>)	Endangered	Hydropower	Myanmar, Cambodia, Thailand, Vietnam, Malaysia, Indonesia, Brunei
111.	White cockatoo (<i>Cacatua alba</i>)	Endangered	Wind power, biofuel	Indonesia
112.	Dhole (<i>Cuon alpinus</i>)	Endangered	Biofuel, hydropower, solar power	Malaysia, Indonesia, Cambodia, Vietnam, Laos, Thailand, Myanmar
113.	Wetar ground dove (<i>Alopecoenas hoedtii</i>)	Endangered	Geothermal, wind power	Indonesia, East Timor
114.	Tawitawi brown dove (<i>Phapitreron cinereiceps</i>)	Endangered	Wind power	Malaysia
115.	Milky stork (<i>Mycteria cinerea</i>)	Endangered	Wind power	Indonesia
116.	Cloaked moss frog (<i>Thelodroma palliatum</i>)	Endangered	Hydropower	Vietnam
117.	Wild water buffalo (<i>Bubalus arnee</i>)	Endangered	Hydropower	Cambodia
118.	Owston's civet (<i>Chrotogale owstoni</i>)	Endangered	Hydropower	Laos, Vietnam
119.	Large-spotted civet (<i>Viverra megaspila</i>)	Endangered	Hydropower	Cambodia, Vietnam, Myanmar, Thailand
120.	Matano tiger (<i>Caridina holthuisi</i>)	Endangered	Hydropower	Indonesia
121.	Mindoro hornbill (<i>Penelopides mindorensis</i>)	Endangered	Wind power	Philippines
122.	<i>Philosina alba</i>	Vulnerable	Hydropower, wind power	Laos
123.	Sumatran serow (<i>Capricornis sumatraensis</i>)	Vulnerable	Biofuel, hydropower	Indonesia, Malaysia
124.	Green turtle (<i>Chelonia mydas</i>)	Endangered	Hydropower	Indonesia
No.	Plant	Category	Type of RE	Country
1.	<i>Diospyros celebica</i>	Vulnerable	Hydropower, geothermal	Indonesia
2.	<i>Dalbergia latifolia</i>	Vulnerable	Hydropower, geothermal	Indonesia
3.	<i>Bruguiera hainesii</i>	Critically endangered	Hydropower	Malaysia
4.	<i>Heritiera globosa</i>	Endangered	Hydropower, wind power	Malaysia, Indonesia
5.	<i>Magnolia sirindhorniae</i>	Endangered	Hydropower, biofuel	Thailand
6.	<i>Magnolia borneensis</i>	Near threatened	Hydropower, biofuel	Malaysia, Brunei
7.	<i>Magnolia thailandica</i>	Vulnerable	Hydropower, biofuel	Thailand
8.	<i>Magnolia nitida</i>	Vulnerable	Hydropower	Myanmar
9.	Tsong's tree (<i>Magnolia odora</i>)	Vulnerable	Hydropower, wind power, solar power	Laos, Vietnam
10.	Champi Doi (<i>Magnolia gustavii</i>)	Critically endangered	Hydropower	Thailand
11.	<i>Sonneratia ovata</i>	Near threatened	Wind power, hydropower	Indonesia, Malaysia, Philippines
12.	<i>Campostemon philippinense</i>	Endangered	Hydropower, wind power	Indonesia, Philippines
13.	<i>Phoenix paludosa</i>	Near threatened	Wind power, hydropower	Indonesia, Singapore, Malaysia, Vietnam, Cambodia
14.	Resak Kanthan (<i>Vatica kanthanensis</i>)	Critically endangered	Biofuel, hydropower	Malaysia
15.	<i>Heritiera formes</i>	Endangered	Hydropower, biofuel	Myanmar
16.	<i>Hopea subulata</i>	Critically endangered	Biofuel	Malaysia

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