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PERSPECTIVE

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Climate Resilience of Energy Infrastructures in Southeast Asia

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This photograph taken on 3 February 2021 shows a general view of a floating solar power farm on the Tengeh reservoir in Singapore. Photo by Roslan RAHMAN AFP.

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EXECUTIVE SUMMARY

- Energy infrastructures in Southeast Asia are becoming increasingly vulnerable to extreme weather events.

- The impact of global warming on energy systems will vary across sectors. Thermal systems will be affected by heat waves and droughts, while grids and renewable energy technologies will be vulnerable to flooding, heavy winds and storms.

- More regional cooperation on climate modelling of energy infrastructures will make predictions more accurate and generate consensus on adaptation priorities.

- A regional adaptation strategy can improve the resilience of cross-border renewable energy infrastructures to climate change.

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INTRODUCTION

Energy security and environmental sustainability in Southeast Asia hinge on the development of energy systems that are low-carbon and resilient to the impacts of climate change. The immediate priority of Southeast Asian governments is mitigation, as demonstrated by ASEAN's goal of increasing the share of renewables in primary energy supply to 23% by 2025.[1] At the same time, scientific evidence[2] suggests that climate change will undermine the efficiency, reliability and physical security of energy infrastructures. This calls for urgent policy action on the adaptation of energy systems. Currently, extreme weather events already pose significant challenges to energy infrastructures in North America, Europe and Asia.[3] Between 2000 and 2017, extreme weather events caused 74% and 37% of total power outage in the United States and Europe respectively.[4] While there is less data on the link between extreme weather events and blackouts in Southeast Asian countries, present studies highlight the increasing vulnerability of the region's energy infrastructures to heavy winds, floods and rainfall[5].

Due to the enormity of these threats, climate adaptation is becoming increasingly relevant in the development of energy projects. The need for early policy intervention is particularly important in Southeast Asia, given the assumption that the region will need to invest USD 80-150 billion annually by the late 2020s to meet its clean energy targets[6].

This article provides an overview of the impact of climate change on energy infrastructures in Southeast Asia. It also outlines best practices in climate modelling and adaptation of energy systems, with the help of multiple examples. The final section provides policy recommendations.

IMPACTS OF CLIMATE CHANGE ON ENERGY SYSTEMS IN SOUTHEAST ASIA

The Global Climate Risk Index[7] ranks several Southeast Asian countries as being extremely vulnerable to climatic shocks. As shown in Figure 1, the Philippines is considered the second most vulnerable country in the world, while the rest of the region faces moderate to high levels of risk to extreme weather events. Four of the top ten countries in the world which were most affected by extreme weather events between 1999 and 2018 were from Southeast Asia, namely Myanmar, Vietnam, the Philippines and Thailand.[8] Between 2009 and 2020, natural hazards resulted in more than 33,000 fatalities and over USD 97 billion in economic damages in the region.[9]

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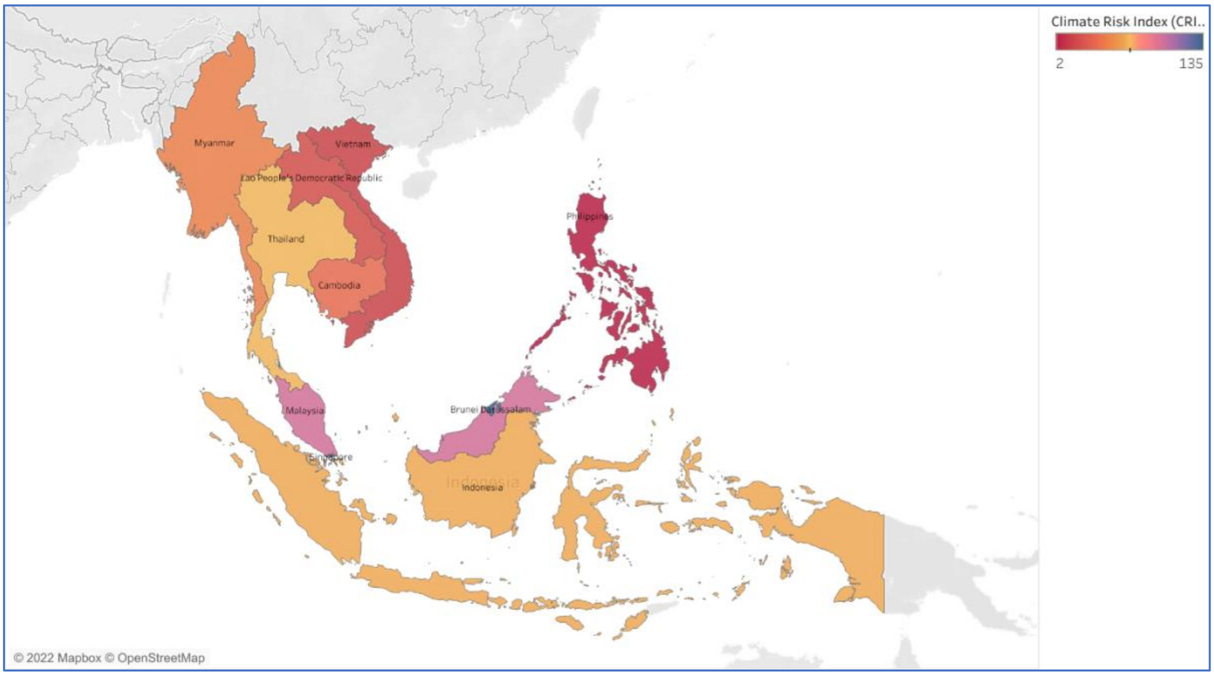
Figure 1: Climate Risk Index 2020 of Southeast Asian Countries[10]



Hawchar et al.[11] proposes that a key factor for determining a society's climate change resilience is the preparedness of infrastructures to withstand natural shocks. While the intensity of natural shocks in Southeast Asia is certainly daunting, the weak resilience of energy infrastructures to these threats is also a cause for immediate concern. The University of Notre Dame Global Adaptation Index (ND-GAIN)[12] reveals some interesting trends about adaptation in Southeast Asia. It illustrates a country's vulnerability to climate disruptions as well as its readiness to leverage private and public sector investment for adaptive actions, measuring the vulnerability of a country through six indicators: food; water; health; ecosystem services; human habitat; and infrastructure. The score for the infrastructure indicator is developed through data in six areas: projected change of hydropower generation capacity; projected change of sea-level rise; dependency on imported energy; population living under 5m above sea level; electricity access; and disaster preparedness. As shown in Table 1, while Singapore receives a high rank in the overall ND-Gain country index, it received a much lower score for energy infrastructure, as its dependence for energy imports makes its vulnerable to crises. At the same time, according to the ASEAN Risk Monitor and Disaster Management Review (ARMOR), Singapore has high coping capacity towards adverse climatic conditions.[13] Meanwhile, the energy infrastructures of the Philippines, Thailand, Vietnam, Myanmar and Cambodia received low scores, indicating high levels of vulnerability to climate change.

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Table 1: ND-GAIN Country Index and Infrastructure Score of Southeast Asian Countries[14]

Country	ND-Gain Country Index	ND-Gain Infrastructure Score
Brunei Darussalam	37	11
Cambodia	149	125
Indonesia	100	52
Lao People's Democratic Republic	137	
Malaysia	49	40
Myanmar	156	135
Philippines	113	104
Singapore	6	139
Thailand	68	111
Vietnam	97	149

Evidence of the impact of extreme weather events on the region's energy infrastructures has been increasingly apparent. The 2021 floods in Malaysia caused the closing down of 333 electricity substations,[15] while in 2020, more than a million people in Vietnam were left without electricity after storms destroyed power lines.[16] In 2019, Cambodia's hydroelectricity production dropped by 30% due to severe drought.[17] Regional data on the link between extreme weather events and blackouts in Southeast Asia are scarce. There is, however, a study by Handayani et al. which provides a historical analysis of the impact of severe weather events on the power sector in Indonesia. The researchers found that between 2014 and 2015, heavy precipitation caused 1,048 power outages in the Java-Bali region, resulting in an estimated loss of 0.5 million USD and impacting more than 3.1 million people.[18]

In any case, for Southeast Asia, there is limited planning[19] for future scenarios stemming from increased global warming. Insights into climatic impacts of energy infrastructures in Southeast Asia can be implied and obtained from global studies on climate modelling of energy infrastructures which use a range of technological tools to predict future energy-climate scenarios.

These studies predict that the intensity of climatic threats to energy systems will vary across sectors and geographic regions.[20] The greatest threat to thermal power systems[21] will be from heat waves and droughts influencing the temperature and availability of water required for cooling. Transmission grids and renewable energy technologies will be more vulnerable to cold waves, wild fires, flooding, heavy winds, landslides and storms. Very high and low temperatures are predicted to reduce the efficiency of electricity transmission systems.[22] Climate change is also likely to decrease the potential for solar energy.[23] According to Patt et al,[24] the efficiency of photovoltaic modules could drop by about 0.5 percent for every 1°C increase in temperature.[25] Many of these scenarios have important repercussions for energy systems in Southeast Asia, although specific data are available only for a few sectors, such as hydropower. The International Energy Agency predicts that inconsistent waterflows with more intense rainfall and droughts will reduce hydropower capacity in Cambodia, Lao PDR, Myanmar, Thailand and Vietnam. If global temperature increases exceed 4°C, hydropower capacity in 2060-2099 is projected to be 8.2% lower than in 1970-2000.[26]

BEST PRACTICES IN CLIMATE ADAPTATION OF ENERGY INFRASTRUCTURES

Energy infrastructures in Southeast Asia can be made more resilient through two broad policy measures. First, climate modelling tailored specifically to Southeast Asia can be used to assess the impact of future climatic conditions on energy infrastructures. Second, adaptation measures based on the models can reduce climatic impacts. In the next paragraphs, these two areas are explored with reference to best practices and relevance to Southeast Asia.

a) Climate Modelling

Currently, climate modelling of energy infrastructures uses multiple methodological tools such as quantitative techniques, economic tools and artificial intelligence. Three types of climate modelling have gained prominence in recent years: dynamic downscaling, satellite imagery and remote sensing, and big data. These are briefly described below:

- Dynamic downscaling is the process of obtaining high-resolution data on climate change for a particular region from global but coarse estimates generated by Global Climate Models. This process has become an important element in addressing climate-driven environmental changes at the regional level and can be used for planning the adaptation of infrastructures, including electricity grids and renewable energy plants.[27] For example, the U.S. Department of Energy's Argonne National Laboratory recently collaborated with the telecommunications company AT&T to develop the 'Climate Change Analysis Tool' which predicts risks to infrastructure from extreme winds and heat. The Tool uses models developed by downscaling global climate projections to local scales.[28] In recent years, the Centre for Climate

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Research Singapore (CCRS), a research department of the Meteorological Service Singapore (MSS), has collaborated with the National Supercomputing Centre to downscale global climate models to develop regional climate models for Southeast Asia.[29] Such technologies can be used to identify threats to electricity grids and power plants and generate consensus on the need for urgent action.

- Satellite imagery and remote sensing are increasingly used to make informed decisions on infrastructure development, given that high-resolution images are able to provide reliable information on optimal location and routes of roads, railways and pipelines.[30] Currently, satellite imagery is used to analyse electricity access and identify key features of power plants and transmission lines. This technology can also be used to identify climatic risks to energy infrastructures. For example, policymakers can use hazard maps supported by satellite imagery to design climate-resilient energy infrastructure that can respond to climatic risks.[31] Satellite imagery and remote sensing can also facilitate assessment of damages to energy infrastructure from natural disasters with a high level of accuracy and without the risks of manned emergency missions.[32] For example, the Norwegian company DNV uses satellite-based remote sensing to monitor the vulnerability of energy infrastructures to natural hazards such as floods and fires.[33] These technologies can be used by Southeast Asian policymakers to access real-time data on the structural integrity of energy infrastructures, which can facilitate timely responses during natural disasters. There is great scope within the region for improving response times to natural disasters through the use of remote sensing imagery and AI machine learning. Such technologies can detect infrastructural vulnerabilities in flood-prone cities.[34]

- Big Data, or large datasets that are computationally processed to reveal patterns, are another important tool in climate adaptation polices. Big data can be used to measure carbon emissions, improve sustainability in supply chains and inform the utilization of natural resources.[35] One example of the use of Big Data to counter climatic threats in Southeast Asia is Haze Gazer, a crisis analysis tool that helps disaster management units to visualize haze crises in Indonesia.[36] The tool uses advanced data mining and analytics to inform decision-making efforts in areas affected by fire and haze events.[37] These data analysis technologies can potentially be used for developing climate resilient energy infrastructures in Southeast Asia. A study by Ji et al.[38] claims that data collected by Distribution System Operators (DSO)[39] can identify vulnerabilities of energy infrastructures from climate change and natural disasters. Regional collaboration can facilitate the development of reliable datasets and analysis tools on existing domestic and cross-border energy infrastructures in Southeast Asia, which can inform adaptation policies.

b) Climate Adaptation Measures

Climate adaptation involves the use of legislative, technical and financial means to increase the resilience of energy systems. Some of these mitigation measures are currently being

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implemented in Southeast Asian countries. For example, Indonesia has implemented flood control systems in power plants, altered hydropower operation patterns and increased monitoring of energy systems. However, Handayani et al.[40] argues that these adaptation responses are reactive and fragmented and not part of a national strategy. In this context, Finland provides an interesting case study for climate adaptation. The Finnish Electricity Market Act requires the electricity network to be designed so that storms or snow load do not cause more than 6 hours of breakdowns in town areas or more than 36 hours breakdowns in other areas.[41] This incentivises Finnish energy companies to invest heavily in underground electricity cables that are less vulnerable to climatic threats. Elenia, the second largest electricity distribution system operator in Finland, has 41% of its cabling underground, with a 75% target for 2028.[42] A study by the Asian Development Bank shows that in some contexts, it may not be feasible to change entire distribution networks from overhead to underground, and underground cables can be used along with overhead systems to improve resilience of energy systems[43]. However, the Finnish example highlights the fact that overarching frameworks such as national policies or legislation can facilitate a proactive rather than a reactive approach to mitigation.

Not all successful examples of resilient energy systems are from the developed world. Tonga, for example, invested heavily in upgrading its electricity infrastructure, which enabled the county's transmission systems to withstand the impact of Cyclone Gita in 2018. Some notable adaptation practices included the installation of aerial-bundled conductors and underground cables and the moving of transformers above the maximum possible sea flood levels.[44] Mitigation efforts can also be enhanced through international cooperation. For example, in 2020, the United States Agency for International Development undertook a comprehensive assessment of the vulnerability of the Lao power sector to climate hazards, and developed a resilience plan to address identified challenges.[45] In addition to the examples mentioned, existing energy systems can be made more resilient by the 'hardening of infrastructure' or retrofitting existing assets to enhance their resilience. For example, wind turbines can be made more resilient to high winds through the use of shorter blades, and transmission lines can be strengthened through the use of concrete or steel poles instead of wooden ones.[46]

CONCLUSION

Southeast Asian countries have made some progress in recent years towards enhancing climate adaptation. Singapore has initiated important initiatives on climate modelling, which has provided key insights on weather patterns in the coming decades. However, climate modelling is a complex and resource-intensive process and unilateral efforts may not be sufficient. In fact, climate models that specifically focus on energy systems in Southeast Asia are not widely available. A collaborative regional approach to climate modelling of energy systems can inform the development of effective adaptation policies.

In terms of adaptation measures, Southeast Asian countries have also taken steps to strengthen existing infrastructures, including international cooperation on designing better cooling systems and retrofitting existing infrastructure.[47] Yet, a lot more needs to be done to enhance

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the resilience of energy infrastructures at the national level. In addition, given increasing energy cooperation in the coming decades, a regional strategy on climate adaptation may benefit the development of cross-border projects.[48] Greater dialogue and exchanges by ASEAN will be crucial to the enhancing of the resilience of the region's energy infrastructures.

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