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# ASEAN power grid: A secure transmission infrastructure for clean and sustainable energy for South-East Asia

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ABSTRACT

The efficient utilization of clean energy resources to meet increasing electricity demand is imposing the integration of the electricity market and the construction of secure transmission mechanisms around the globe. Accordingly, the Association of Southeast Asian Nations (ASEAN) is integrating its large geographical power transmission infrastructure via the ASEAN power grid (APG). This study extensively reviews the energy resources (i.e., fossil fuels and renewables), the current utilization, and the future projection for ASEAN. Electricity export-import scenarios and renewable generation based transmission expansion planning practices in ASEAN will also be critically reviewed in this work. Additionally, the major barriers and technical challenges for establishing an ASEAN grid will be briefly analyzed. Finally, this work suggests possible techniques that help expedite the renewable power generations to overcome the limitations associated with the establishment of the APG, as well as future research direction in enhancing the utilization of APG for ASEAN.



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## 1. Introduction

Association of Southeast Asian Nations (ASEAN) consists of 10 member countries which includes Thailand, Vietnam, Laos, Indonesia, Philippines, Myanmar, Brunei, Malaysia, Singapore, and Cambodia. According to World Bank (WB), in 2014 the total GDP in this region was 2478 USD [1]. The Asian Development Bank (ADB) forecasting report shows that ASEAN countries would have an annual average GDP of 5.22% between 2015 and 2016, whereas, WB forecast shows that ASEAN countries, except Brunei and Singapore, would have an average annual GDP of 6.08% for the period between 2015–2017 [1,2]. In addition, the projected incremental rate of ASEAN countries GDP would be 4.6% until 2040 and could contribute to global GDP increment from 5.9–7.7% within this period [3,4]. Due to the fast economic growth of the ASEAN region, the energy demand increases significantly compared to other regions of Asia. It has been reported that, the primary energy consumption of the ASEAN region would increase from 556.28 (Million ton of oil equivalent) Mtoe, to 1414 Mtoe within the period of 2012–2030 [5,6]. This incremental rate of primary energy consumption will result in an increment of energy related CO2 emission of 5.7% per annum [5]. The amount of CO2 emission for primary energy consumption would increase from 1.354 gigatonnes (Gt) to 1.962Gt from 2015 to 2030, due to fossil fuel dependency in meeting the primary energy demand as opposed to carbon free sources, such as renewable energies [3,4,7,8].

The primary energy consumption rate in the ASEAN region is not also uniform [3]. Indonesia is the largest energy consumer, consumes 36% of overall ASEAN energy demand, and Indonesia's energy consumption is 66% more than the second largest energy consumer, Thailand, as well as 50 times more than the lowest energy consumer Brunei Darussalam [3]. From the primary energy consumption, electricity demand has the highest growth rate at 6.4% per annum, making it the largest contributor of $CO_2$ emission [5,9,10]. It will be very challenging for ASEAN to meet such electricity demand at its regular business pace. Also, electricity access in this region varies greatly from country-to-country. For example Brunei Darussalam, Malaysia, Thailand, and Singapore are capable of providing adequate electricity to their respective nations, while 50% population in Myanmar and Cambodia have access to electricity [3]. ASEAN countries have an abundance of renewable resources throughout its geographical region. However, the distribution is far from uniform; regions such as Cambodia, Myanmar and Lao PDR are rife with hydropower resources, whereas Indonesia and the Philippines possess many geothermal sources. This geographical distribution of renewable energy sources limits its eventual utilization [11–15]. In addition, the utilization of these renewables energy in generating electricity is not appreciable, due to high capital investment costs and the lack of financial means, as well as inadequate knowledge transfer [16,17]. Furthermore, unbalanced economic development prevents the development of renewable energy based generation [18]. Therefore, most of the electricity in this region is generated from fossil fuels, which in turns increase the $CO_2$ emissions of the region [19,20]. Geographically distributed renewable power generation can be promoted by integrating the ASEAN energy market in order to expedite cross-border trade and free movement of green electricity within the ASEAN region. Cross border trade in integrated energy market enhances the electricity trade from countries with abundant renewable energy sources to countries with less renewable sources, and the developed countries will encourage investments in the renewable sources to developing or least developed countries, which will in turn, enhance knowledge and technology transfer between these countries [21]. Moreover, introducing carbon pricing after the establishment of cross border trade facility may eventually shift the dependency of base load power from coal, natural gas, and hydro, to renewables [13].

In order to meet the growing demand for electricity, the ASEAN power grid (APG) is being implemented among ASEAN countries via ASEAN Heads of States/Governments, under the ASEAN Vision 2020 [22,23]. The primary aim of APG is to ensure regional energy security by promoting the effective utilization and sharing of resources for common regional benefit. It also aims to enhance cross border electricity trade by interconnecting the national power grid with reliable, efficient, and economical operations; sharing of surplus generated electricity for improving system security via the reduction of system cost amongst member countries. APG will contribute to the creation of the provision for future energy trade and mutually exploit the abundant energy resources within ASEAN and reduce the dependency of fuel imports from other regions [22].

It is important to perform a comprehensive analysis of the technical, economical, and environmental issues related to the integration of remotely located renewable generation into APG from the transmission expansion planning paradigm perspective. Moreover, pointing out the major barriers and limitations for the establishment of APG is also important for enhancing the establishment of APG in the Southeast Asian region. This paper aims to present the issues towards the development of a transmission structure to exchange clean and sustainable energy in the ASEAN region, and the future research direction to enhance APG development by overcoming barriers and limitations.

The paper is organized as follows: Section 1 contains an introduction specifying the rational of the project described in this paper. Large-scale renewable power generation potential, including energy status, primary energy demand as well as electricity demand, generation and import and export scenarios of the ASEAN countries are briefly described in Section 2. Section 2 also contains present renewable electricity generation potentials and future targets taken by the ASEAN countries followed by transmission expansion planning practices by the ASEAN countries for renewable power generation in Section 3. In Section 4, the present status of ASEAN grid is presented and major barriers and technical challenges of establishing ASEAN grid are discussed. Future research directions for efficient ASEAN grid establishment are highlighted in Section 5. At last, Section 6 includes the conclusion drawn from all the above discussed section.

## 2. Large-scale renewable power generation potential

### 2.1. Energy status of ASEAN countries

Energy resources, including fossil fuels and renewables, are