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Carbon intensity of electricity in ASEAN: Drivers, performance and outlook

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HIGHLIGHTS

- Aggregate carbon intensities (ACIs) of ASEAN countries analysed temporally and spatially using index decomposition analysis.
- Bleak future for emissions and ACI of ASEAN countries with increasing inclination towards coal for electricity production.
- National circumstances impact ability of countries to improve electricity generation mix.
- Significant unexploited potential for improvements in thermal efficiency of generation.

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ABSTRACT

The Association of Southeast Asian Nations (ASEAN), with its ten member countries, has a total population exceeding 600 million. Its energy-related CO_2 emissions have been growing and in 2013 amounted to 3.6% of total global emissions. About 40% of ASEAN's energy-related CO_2 emissions are currently attributable to electricity production. In view of this high share, we study the CO_2 emissions of ASEAN's electricity production sector with a focus on the aggregate emission intensity (ACI) given by the level of CO_2 emissions for each unit of electricity produced. Drivers of ACI are analysed for individual countries and spatial analysis is conducted by comparing factors contributing to differences between the ACIs of individual countries and that of the ASEAN average. Arising from these analyses and in light of the current developments, it is concluded that drastic actions need to be taken both at the national and regional levels in order to reduce growth in the region's electricity-related CO_2 emissions. Two key policy issues, namely overcoming national circumstances to improve electricity generation mix and improving power generation efficiency, are further discussed.

1. Introduction

The Association of Southeast Asian Nations (ASEAN) has ten member countries.[1] Its population which exceeds 600 million is nearly 9% of the world total and the third largest in Asia after China and India. The regional economy expanded at an average rate of about 5% per year in the past two decades. The gross regional product in 2013 was about three times that in 1990 in real terms. Continued increases in energy consumption resulting from economic expansion and improvements in living standards have led to substantial growth in the region's energy-related CO_2 emissions. Estimates show that the region's CO_2 emission level increased from 94 million tonnes of CO_2 ($MTCO_2$) in 1990–456 $MTCO_2$ in 2013.[2] Correspondingly, the region's share in global CO_2 emissions has risen from 1.7% in 1990 to 3.6% in 2013.

The main contributor to CO_2 emissions in ASEAN is the electricity production sector. The sector, which depends heavily on fossil fuels as energy sources, accounted for 39% of the total CO_2 emissions in the region in 2013. Current average per capita electricity consumption in the region is low and only about 40% of the world average.[3] Electricity demand and economic growth are known to be closely related, especially in developing countries. Most ASEAN countries are low or middle income developing countries and several of them are experiencing rapid economic growth. Continued economic development, coupled with the relatively low level of electricity consumption and high income

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[1] ASEAN has ten member countries, namely Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam.

[2] The CO_2 emissions have been computed based on the data given in IEA (2015a, 2015b). In this study, CO_2 emissions refer to energy-related emissions.

[3] In 2013, ASEAN's annual electricity production per capita was 1293 kWh while the global average was 2013 kWh (IEA, 2015a).

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elasticity for electricity demand, point towards a future where there will be significant growth in electricity demand. As a result, the potential for growth in the related CO_2 emissions is great.

The assertion that growth in electricity demand will remain strong in ASEAN is supported by a number of recent studies. Electricity production in the region is projected to increase at an average annual growth rate of 3.9% between 2013 and 2040 in IEA (2015c). It is projected in a business-as-usual scenario to increase at an even higher rate of 5.9% per year in ACE (2015) from 2013 to 2035. At this growth rate, ASEAN's electricity production in 2035 would be 3.5 times the 2013 level. Between 1990 and 2013, growth in electricity consumption in ASEAN averaged 5.1% per year.

In view of the important role of the electricity production sector in contributing to CO_2 emissions, the demand for electricity and the way electricity is produced will greatly influence how emissions in ASEAN will evolve in the next few decades. A better understanding of the key determinants or drivers of emissions in the sector is essential for evaluating the region's future emission trends and developing strategies to reduce emissions.

As is well known, CO_2 emissions from electricity production are dependent on four determinants, namely the level of electricity production (or demand), fuel mix in electricity production, thermal efficiency of fossil-fuel power plants and the quality of fossil fuels used (Ang et al., 2011). The level of electricity demand, the first determinant, is in turn dependent on several well-known factors such as economic growth or income level, structure of economic activities or energy demand, energy prices and energy end-use efficiency. The relationships between electricity demand and these factors is a widely researched area, and many studies for a wide spectrum of countries have been reported in the literature. One of the earliest studies on ASEAN countries can be found in Ang (1988).

Other than reducing growth in electricity consumption through demand management, another approach to help reduce growth in the CO_2 emissions from the electricity production sector is to focus on the supply side. This means through managing the other three determinants, i.e. generation fuel mix, power plant thermal efficiency and fossil fuel quality. From a systems analysis perspective, the impacts of these three supply-side related determinants are captured by an indicator in energy studies known as the "aggregate emission intensity" (ACI) of electricity (Ang et al., 2011). The indicator is defined as the average level of CO_2 emissions per unit of electricity produced in a country or region, and is measured as an aggregate at that level. It is normally expressed in kilograms of CO_2 emissions per kilowatt-hours ($kgCO_2/kWh$).

Growth in a country's electricity demand and that in its related CO_2 emissions can be decoupled if measures are taken to reduce ACI. It follows from the foregoing that this can be achieved through strategies such as development of non-fossil energy sources in electricity production, changing fossil fuel mix by using cleaner fossil fuels, in particular natural gas, and improving electricity generation efficiency in thermal power plants. In this study, our main focus is on ACI and more specifically its developments in and variations among ASEAN countries and the related policy issues. Given by the ratio of two physical measures, ACI is not scale-dependent and is easy to compute and use. It has a performance connotation where a smaller value implies better emission performance. Comparisons can be easily made between countries based on the indicator. These desirable properties simplify the analysis for ASEAN countries which are extremely diverse in many aspects.

The next section provides an overview of ASEAN countries. In Section 3, a temporal decomposition analysis that evaluates the drivers of ACI change over time for ASEAN countries from 1990 to 2013 is presented. In Section 4, each country's ACI is compared with the ASEAN average and the spatial decomposition results for 1990 and 2013 are discussed. The findings of the above analyses provide valuable insights on the possible levers for reducing ACI and also help to inform policymakers of the possible trajectories of CO_2 emissions from electricity production, possible future paths and policy implications. These issues will be discussed in Section 5 in which future challenges and areas for policy intervention are also discussed.

2. Electricity production and related CO_2 emissions in ASEAN countries

Tables 1 and 2 summarise key socio-economic, electricity and CO_2 emission statistics of ASEAN countries and the region for 1990 and 2013.[4] The diversities in population, size of economy and level of electricity production can be seen from Table 1. Significant growth in both gross domestic product (GDP) and electricity production from 1990 to 2013 are observed in all the countries. The last column of Table 1 shows the electricity elasticity. Except for Singapore, it exceeds unity, indicating growth in electricity output has generally been higher than that of GDP. Further breakdown by shorter time periods reveal that the elasticity has declined over time in some of the countries. Computed separately for the periods 1990–2005 and 2005–2013, it has actually increased for Brunei, Myanmar and Vietnam, remained about the same for Malaysia, while it decreased for Indonesia, the Philippines, Singapore and Thailand. These variations to some extent are an indication of the different stages of economic development for the countries. Overall for ASEAN the elasticity of 1.44 which far exceeds unity shows the high potential for growth in electricity demand in the region.[5]

From Table 2, CO_2 emissions from electricity production as a share of total CO_2 emissions in 2013 varied from 13% in Cambodia to 48% in the Philippines. Except for Myanmar and Singapore, this share has increased from 1990 to 2013. For ASEAN as a whole, the share has increased from 26% to 39%. The 1990 and 2013 ACIs for ASEAN countries are shown in the last two columns of Table 2. There were large variations among countries and over time. In 1990, the intensity in $kgCO_2/kWh$ varied from 0.332 in the Philippines to 0.921 in Brunei. In 2013, it varied from 0.194 in Myanmar to 0.754 in Indonesia. The intensity has decreased in Brunei, Myanmar, Singapore, Thailand and Vietnam, but increased in Indonesia, Malaysia and the Philippines.

To put the ACIs in Table 2 in perspective, it is useful to note that the ACI of a country can range from practically zero (where all the electricity is produced from renewable energy sources) to about 2 $kgCO_2/kWh$ (where all the electricity is produced from coal-fired power plants with a low thermal efficiency). In 2013, the ACIs of world 124 countries ranged from practically zero to 1.5 $kgCO_2/kWh$, and the global averages were respectively 0.540 and 0.520 $kgCO_2/kWh$ in 1990 and 2013 (Ang and Su, 2016). While there was an improvement in ACI from 1990 to 2013 for ASEAN as a region, the intensities for both years (as shown in the last row of Table 2) were higher than the corresponding global average. On average and in 2013, about 10% more CO_2 was emitted to generate each kWh of electricity in ASEAN as compared to the global

[4] In this study, the raw data are taken from IEA (2015a, 2015b). CO_2 emissions and ACI are derived by the authors in the same way as that reported in Ang and Su (2016). The emission factors for computing CO_2 emissions from fuel consumption, measured in tonnes of CO_2 per tonne of oil equivalent, are taken as 3.99 for coal, 3.08 for oil and 2.33 for natural gas. They are assumed to be the same for both years in all countries.

[5] Ang (1991) provides a detailed analysis of electricity elasticities of five ASEAN member states for the period 1960–1986 and a discussion on how energy elasticity tends to change over time can be found in Ang (2006).