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Multi-level decomposition of ASEAN urbanization effects on energy

ASEAN
urbanization
effects on
energy

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Abstract

Purpose – The connection between urbanization and energy consumption in the context of cross-country and cross-sector analyses is poorly understood, especially in the Association of South East Asian (ASEAN). This paper aims to present the first extensive multi-level analysis of the relationship between urbanization and energy consumption in ASEAN countries from 1995 to 2013.

Design/methodology/approach – The multi-level (across country and sector) index decomposition method is used to analyze urbanization, energy mix, energy intensity and activity effects on energy demand. Urbanization is measured by two representative factors, name the urban population and the number of non-agriculture workers.

Findings – Despite the decreasing rate of urbanization, its effect on energy consumption has played the most important role since 2000. Since then, the effect has continued to increase at the national and sectoral levels across the whole region. The strongest urbanization impacts are encountered in the residential sector, followed by transportation and industrial sectors with much weaker effects in the commercial sector. The way in which urbanization impacts energy consumption depends strongly on the income level of the country studied.

Practical implications – The results provide quantitative relationships between urbanization and energy demand. For example, if the urban population and the non-agriculture workers decreased by 0.1 per cent per year, this would reduce energy demand by 1.4 per cent and 2.6 per cent per year respectively.

Originality/value – This contribution provides detailed quantitative insights into the relationships between urbanization and energy demand at sectoral, national and international levels, which are invaluable for policymakers in the region.

Keywords Decision-making, Energy sector, ASEAN, Urbanization, End-use models, Decomposition, Energy conversion, Energy balance

Paper type Research paper

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1. Introduction

The relationship between energy consumption, economic and demographic changes has been intensively researched, especially for emerging economies such as India and China. Much of this research addresses the challenge of ensuring sustainable development, in the context of resource shortages and reduced environmental quality, while maintaining economic growth (Wang *et al.*, 2013, Wang, 2014, Pachauri and Jiang, 2008, etc.).

These issues also burden many other developing countries such as ASEAN (the Association of South East Asian Nations), whose economy has been growing rapidly since the mid-1980s and has become a growth engine of the global economy[1] (see Figure 1). ASEANs' GDP growth rate is projected to continue to increase at on average 5.2 per cent over the period 2019-2023 (Economic Outlook, 2019). In its 5th State of the Environment Report (SOER 5th, 2017) ASEAN identified the urgent situation of air and solid polution in the region as a result of uncontrolled rapid development. As member countries pursue their economic goals, ASEANs' energy demand is projected to more than double and CO₂ emissions to triple by 2040 (ASEAN Energy Outlook, 2017), which would worsen the alarming level of pollution in most of the ASEAN countries due to increasing fossil fuel consumption (Global megatrends, AIMD, 2017).

While ASEAN countries have attempted to lessen these problems, a new challenge may be arising in the form of naturally rapid urbanization. Recently, urbanization (refer to section 2 for a detailed definition) in ASEAN has been considerably increasing by 3 per cent per year during the period 1995-2014, higher than the average global rate of 2 per cent per year. Futher urban growth is expected in ASEAN, with the projected percentage of urbanites increasing from today's 47 per cent to 56 per cent in 2030 and 67 per cent in 2050 respectively (UN, 2014). ASEAN governments are finding it difficult to cope with the rapid increases in the urban population, resulting in serious energy-related environmental problems, especially in the pressure of growing demands for constructing basic infrastructure (SOER 5th, 2017).

However, a superficial look shows that energy consumption seems to increase faster in the country with the lower annual urban growth rate in ASEAN, except for the Philippines (see Figure 2). It could mean urbanization reduces energy consumption, and therefore reduces its effects on the environment. Moreover, as urbanization is the main

Figure 1.
Average annual GDP
growth rate over the
World and ASEAN
from 1995-2017

Source: Own calculation based on the database of
World Bank, last accessed (3 December 2018)

Source: Own calculation based on database of World Bank (2018) and IEA (2018) last accessed (1 December 2018)

Figure 2.
Average annual
energy consumption
and urbanization
growths in ASEAN
between 1995 and
2014

factor driving renewable energy development in the region (Khuong *et al.*, 2019), it may speed up the energy transition process towards higher shares of renewables in the total energy mix, and therefore help to reduce the effect of increasing energy consumption on the environment.

The two possible and contradictory effects of urbanization on energy consumption reveal a problem of lacking or incomplete knowledge on this issue that could impede ASEANs progress towards achieving their sustainable development goals (Global megatrends, AIMD, 2017). Moreover, as ASEAN has deepened cooperation in sustainable development (ASEAN Community Vision 2025), it is necessary to extend the investigation of the effects on energy consumption not only in national sectoral interactions but also international interactions. The literature review in Section 2 illustrates the research gap in comparing the differential impact of urbanization on energy consumption across countries and sectors, as well as discussing the decomposition method over the regression method for investigating the problem. Answering this and related questions is of primary importance for academics and ASEAN policy makers to make a horizontal and vertical scan of the effect on international-national-sectoral scales.

With this purpose, this paper proposes the multi-level Index Decomposition Analysis (IDA) capable of cross-country-sector comparison to investigate the issues related to the relationship between energy consumption, economic growth and urbanization. The paper aims to:

- estimate the urbanization effect and the other contributing effects (population, economic development etc.) on energy consumption changes;
- compare the effects at multi-levels between ASEAN countries; and
- propose some suggestions for policy makers in the context of economic development and urbanization.

The remainder of the paper is structured as follows. Section 2 presents a literature review and thus demonstrates the gaps filled by this study. Section 3 introduces components of the dataset and explains the methodology for assessing the urbanization

effect. Section 4 provides the results from multi-level analyses. Section 5 discusses the effects of demographic factors on energy consumption and critically reflects on the methodology used in this paper. Finally, section 6 gives a conclusion and outlook, including some suggestions for policymakers about urbanization-energy issues and further research requirements.

2. Literature review

This section aims to review, summarize, and synthesize the arguments and ideas of previous research that focused on analyzing the relationship between urbanization and energy consumption (see [Figure 3](#)). After scrutinizing these studies, we identified certain research areas that have been given little attention in this area. These areas are highlighted in blue in [Figure 3](#) to demonstrate this paper's novelties, and a detailed explanation is given in the following sections.

2.1 Issue 1 – lacking multi-level comparisons in research scope

As shown in the first column of [Figure 3](#), previous research mostly focused on proving and comparing the effects of urbanization on energy consumption between countries with similar economic conditions, such as in developed countries ([Parikh and Shukla, 1995](#); [Liddle and Lung, 2014](#); [York, 2007](#)), and developing countries ([Jones, 1989, 1991](#); [Madlener and Sunak, 2011](#); [Mishra et al., 2009](#); [LENZEN et al., 2006](#)). Or they investigated the relationship in one country within different energy consuming sectors such as [Lariviere and Lafrance \(1999\)](#) in Canada, [Wang et al. \(2013\)](#) in China, [Halicioglu \(2007\)](#) in Turkey, [Ewing and Rong \(2008\)](#) in the USA.

Some researchers investigated the effect between different countries for one sector such as transportation, agriculture ([Jones, 1991](#); [Liddle and Lung, 2014](#); [Poumanyong and Kaneko, 2010](#)), building energy consumption ([Li and Yao, 2009](#)) and national residential energy use ([Holtedahl and Joutz, 2004](#); [Poumanyong et al., 2012b](#)).

However *the comparison of relative impacts of urbanization between sector-sector and sector-country has not been carried out in general, as well as specifically for ASEAN.*

2.2 Issue 2 – limited results due to the method

2.2.1 Revealing general relationships but not individual factor contributions. The regression analysis with dynamic and statistical models was used in most studies in this field, accounting for 34/45 studies. However, this method can reveal general relationships but not individual factor contributions ([Liu, 2009](#)). [Liu \(2009\)](#) concluded that using regression showed only unidirectional Granger causality between China's urbanization and its total energy consumption, but to find out the contribution share of urbanization on energy consumption required a decomposition analysis.

2.2.2 Obstacles in data processing and analysis. Regression requires large data sets, which are quite challenging to obtain for developing countries ([Zeng et al., 2017](#)), such as ASEAN, where the database has only been developed over the past 15 years or so. Moreover, regression models using cross-sectional data ([Jones, 1991](#); [York, 2007](#); [York et al., 2003](#)) as well as time-series data ([Liu, 2009](#); [Holtedahl and Joutz, 2004](#)), and even panel data ([Poumanyong et al., 2012b](#)) typically overlook the comparison with the base year, i.e. using data with current currency instead of constant currency [purchasing power parity (PPP)]. [Liu \(2009\)](#), [York \(2007\)](#) and [Zeng et al. \(2017\)](#) claimed the method runs into difficulties when dealing with unbalanced data (i.e. a panel that has some missing data for at least one year or one period, or for at least one entity), and nonlinear data in explaining the relationship and the changes.

ASEAN urbanization effects on energy

Author, year	Research scope				Method			Considered relationships							Results		Purpose
	M	C	P	S	L	R	O	D	GDP	EC	Em	In	EI	Others	S	L	
Parikh, Shukla 1995	X					X			X	X					+		Sus
Imai 1997	X					X			X	X					+		ED
York 2007	X					X			X	X					+	+	ED
Lenzen <i>et al.</i> 2006	X					X			X	X					-/+		Sus
Fang <i>et al.</i> 2012	X					X			X	X					-		CC
Liddle, Lung 2014	X					X			X	X					-		Sus
Jones 1989	X					X			X	X	X				+		Eco
Poumanyvong, Kaneko 2010	X					X			X	X	X				+/-		Sus
Sharif Hossain 2011	X					X			X	X	X				+		Eco
Poumanyvong <i>et al.</i> 2012	X					X			X	X	X				+		Eco
Al-mulali <i>et al.</i> 2013	X					X			X	X	X				+		Sus
Sadorsky 2013	X					X			X			X	X		-	+/+	CC
Li, Lin 2015	X					X			X	X	X	X		X	-/+		Eco
Asif <i>et al.</i> 2015	X					X	X		X	X		X			+		Eco
Burney 1995	X						X		X	X					+		Eco
Mishra <i>et al.</i> 2009	X						X		X	X					-	+	Eco
Wang 2015	X					X				X	X				+		Sus
Zhang <i>et al.</i> 2017	X					X			X	X	X			X			RE
Jones 1991		X				X			X			X	X		+		ED
Lin <i>et al.</i> 2008		X				X			X					X	+	+	CC
Liu 2009		X				X		X	X	X				X	+	~	ED
Ghosh, Kanjilal 2014		X				X			X	X					~		Sus
Belloumi, Alshehry 2016		X				X	X		X	X		X	X		+	+	ED
Wei <i>et al.</i> 2003		X					X		X	X				X	-/+		Eco
Li <i>et al.</i> 2011		X					X		X	X				X	-/+		ED
O'Neill <i>et al.</i> 2012		X					X		X	X	X				~		ED
Yang <i>et al.</i> 2015		X					X	X	X	X				X	-	+/+	RE
Franco 2017		X				X			X	X	X		X		+		Sus
Newman, Kenworthy 1998			X			X			X	X					-		Sus
Wang 2014			X					X	X	X				X	-	+/+	ED
Kenworthy, Laube 1996				X	X				X	X					-		Sus
Isabelle Larivi'ere 1999			X		X				X	X					-		ED
Jiang, O'Neill 2007			X	X	X				X	X							ED
Ewing, Rong 2008				X	X				X	X					-		ED
Adom <i>et al.</i> 2012			X	X					X	X					+		ED
Li, Yao 2009				X	X				X					X			ED
Sun <i>et al.</i> 2014				X	X				X					X	+		ED
Holtedahl, Joutz 2004				X	X	X			X	X					+	+	ED
Halicioglu 2007				X	X	X			X	X				X	+		ED
Shahbaz, Lean 2012				X	X	X			X	X		X		X	+		ED
Shen <i>et al.</i> 2005				X		X			X						+		Eco
Jiang, Lin 2012				X		X			X			X			+		Eco
Fan <i>et al.</i> 2017				X				X	X	X			X		+		ED
Liu <i>et al.</i> 2018				X				X	X	X					+		ED

Notes: Acronyms – Scope: M: Multi-country, C: Country, P: Province, S: Sector, L: Linking between multi-country and country and sector levels. Method: R: Regression, O: Other methods, D: Decomposition. Considered relationship: GDP: gross domestic product, EC: energy consumption, Em: emission, In: industrialization, EI: energy intensity. Results: S: short term, L: long term, +: Positive effect, -: negative effect Purpose: ED: energy demand, Eco: Economic development, Sus: sustainable development, CC: climate change. Blue column: covered by this research

Figure 3.
Summary of relevant literature on the relationship between urbanization and energy consumption

Furthermore, when analyzing individual sectors or whole countries, many approaches overlook the volatility and interactions among types of energy users. The combined resource requirements of energy input in manufacturing and transportation activities, for example, may increase energy consumption end-used but reduce energy utilization in residential areas. This offsetting impact could eliminate energy consumption fluctuations, i.e. it could erroneously imply unchanged or only slightly changed total energy consumption. If only the total energy consumption is considered, the regression typically overlooks the hidden effect from this phenomenon such as inefficient energy use, and issues relating to energy system structure and economic structure.

2.3 Issue 3 – partly conflicting results

When considering multi-countries, the results often present contradictory effects (see [Figure 3](#)). Two-thirds of the reviewed studies revealed a positive correlation between urbanization and energy consumption in multi-country approaches as well as in sectoral-level research. For example, with the “fixed effect” [2] “[Jones \(1989, 1991\)](#), [Parikh and Shukla \(1995\)](#), [York \(2007\)](#), [Shahbaz and Lean \(2012\)](#) and [Elliott et al. \(2014\)](#) determined an urbanization elasticity of around 0.29-0.66 for energy consumption. On the other hand, some studies identified a negative link between urbanization and energy consumption at country level such as [Lariviere and Lafrance \(1999\)](#) conducted for 45 cities in Canada, and [Mishra et al. \(2009\)](#) analyzed panel data for Pacific Islands from 1980-2005.

At the sector level, while some authors mention that urbanization causes several important reductions in residential energy use e.g. [Ewing and Rong \(2008\)](#) researching in the USA and [Wang \(2014\)](#) studying China, others (such as [Holtedahl and Joutz, 2004](#)) conclude that urbanization is responsible for energy use increasing in this sector. The same contradictory findings were obtained for the transportation sector between [Liddle and Lung \(2014\)](#), who showed a negative effect in 23 OECD countries and [Poumanyong et al. \(2012a\)](#), who found a positive influence of urbanization in 92 countries.

The controversy in earlier literature can be at least partly ascribed to differences in methodologies, data and economical and/or regional characteristics. Therefore, it is necessary to investigate further the relationship between urbanization, energy use and other factors (such as GDP, industrialization, emissions) by placing it within a region-country-sector context.

2.4 Issue 4 – the urbanization definition

One of the common issues encountered in the research is the definition of “urbanization”. Most of the previous studies ([Jones, 1991, 1989, 2004](#); [Parikh and Shukla, 1995](#)) considered the variable “urbanization” as the number of people living in urban areas. The term “urbanization growth rate” is used to refer to the growth rate of urban population in each considered period. Urban areas are categorized by urban morphology such as cities, towns, conurbations or suburbs.

Other authors ([Ewing and Rong, 2008](#)) used several forms of urbanization when investigating urban effects on energy use, including the percentage of the population living in urban areas, the population density in urban areas, and the average apartment size, which more accurately reflects the specific energy consumption in the residential and commercial sectors ([Liddle and Lung, 2014](#); [Liu and Xie, 2013](#)). In researching the residential sector, [Pachauri and Jiang \(2008\)](#) compared India and China and used the number of households as an urbanization indicator.

The influence of urbanization on energy consumption changes based on the urbanization form considered. Therefore, this paper uses the most common urban indicators in the

research field, namely urban population, symbolized as Urban 1, and non-agriculture employee, symbolized as Urban 2, to conduct the investigation.

2.5 The potential of decomposition analysis

The decomposition analysis has frequently been used in energy-related studies from the late 1970s until the present to analyze the impact of changes in product mix on energy consumption (Ang and Zhang, 2000; Hoekstra and van den Bergh, 2003). It was introduced with two techniques for decomposing indicator changes, structural decomposition analysis (SDA), which analyzes the input-output effect, and the index decomposition approach (IDA), which compares different effect factors. In assessing the influence of urbanization on energy consumption, Liu (2009) suggested the decomposition method as a new approach.

Wang (2014) and Liu *et al.* (2018) applied SDA to investigate the effects of China's urbanization on residential energy consumption. Wang (2014) conducted independent research on household usage and product usage by dividing total energy consumption into residential energy consumption (REC) and production energy consumption (PEC). Liu *et al.* (2018) analyzed the changes in indirect (IEC) and direct (DEC) energy consumption in household. However, both studies suggested urbanization has a positive effect on household energy consumption.

Secondly, Yang *et al.* (2016) and Fan *et al.* (2017) used IDA to assess the impact of urbanization on renewable energy consumption growth and on residential energy consumption in China respectively. Yang *et al.* (2016) focused on the macro analysis and concluded that the urbanization effect is insignificant for renewable energy use, while Fan *et al.* (2017) concluded that urbanization contributes 15.4 per cent of the residential energy consumption increase.

This paper therefore uses decomposition analysis to investigate the contribution of urbanization to energy consumption growth with a multi-perspective analysis including national and sectorial comparison, order to explore the diverging influences from nations to sectors.

3. Methodology

3.1 Method

IDA is used in this study to implement index approach and to conduct time-series analysis and cross-country comparisons. An the advantage of IDA over SDA is a lower data requirement, and the ability to assess the effect of a shift in the economic shares and energy mix. Moreover, IDA is based on the specification of the decomposition, whereas SDA has focused attention on distinguishing a large number of input-output effects. IDA is suitable for a top-down approach, whereas SDA is suitable for a bottom-up approach (Hoekstra and van den Bergh, 2003; Wang *et al.*, 2017).

As a result, with limited available data, this paper uses the IDA method with a top-down approach to break down energy consumption data to gain insight into its compositional sub-systems such as sectorial energy demand (commercial, transportation, industrial, residential) in a reverse-engineering technique. The energy consumption characteristics are analyzed in detail until they are reduced to their base elements in terms of the effect of each factor on each sector. This paper separates five factors including activity change (activity effect), modification of activity composition (structure effect), changes in sectorial energy intensity (intensity effect), adjustment in used energy types (energy mix effect) and especially urbanization changes (urban effect).

This paper suggests two approaches to assess the urban effect. The first one examines the energy consumers and estimates all effects mentioned above, except for the structure

effect. The second approach analyzes the structure effect by separating the activity effect into the two effects including structure and production effects, to provide more details of economic growth and economic structure change than the first case.

For the first approach, assume that E is an aggregate composed of n factors ($x_1, \dots, x_n$) and from period 0 to T the aggregate changes from E_0 to E_t . The objective is to derive the contribution of the n factors to the change in the aggregate, which can be expressed as given in [equation \(1\)](#):

$$\Delta E_{tot} = E_t - E_0 = \Delta E_{x1} + \dots + \Delta E_{xn} + \Delta E_{rsd} \quad (1)$$

Implementing the concept to analyze the effect of urbanization on energy consumption for each sector is given in [equation \(2\)](#):

$$E_j = \sum_i \frac{E_{ij}}{E_j} \times \frac{E_j}{VA_j} \times \frac{VA_j}{D} \times D \quad (2)$$

whereby:

E_i : Energy consumption of energy type i (including fuel, electricity and renewables) in sector j ;

E_j : Total energy consumption in sector j (including commercial, industrial, residential, and transportation);

VA_j : Typical activity for sector j (value added for industrial, commercial and transportation; number of households for residential); and

D : Demographic factor (Population or Urban 1 or Urban 2).

Foreshortening [equation \(2\)](#) by replacing $\frac{E_i}{E_j} = M_{ij}$, $\frac{E_j}{VA_j} = I_j$, $\frac{VA_j}{D} = A_j$ we have [equation \(3\)](#):

$$E_j = \sum_i M_{ij} \times I_j \times A_j \times D \quad (3)$$

To separate the effect of each of the factors, we calculate the change of energy consumption between years 0 and T following each component by using a logarithmic mean function $L(a, b) = (a - b)/(\ln a - \ln b)$. As a result, the final decomposition function is carried out in [equation \(4\)](#):

$$\Delta E_j = \Delta E_{mix,ij} + \Delta E_{int,j} + \Delta E_{act,j} + \Delta E_{D,j} + \Delta E_{rsd,j} \quad (4)$$

with:

- $\Delta E_{mix} = \sum_i L(E_i^t, E_i^0) \ln\left(\frac{M_{ij}^t}{M_{ij}^0}\right)$ – Energy mix effect: the change in the aggregate associated with a change in the mix of energy used type;
- $\Delta E_{int} = \sum_j L(E_j^t, E_j^0) \ln\left(\frac{I_j^t}{I_j^0}\right)$ – Intensity effect: the change in the aggregate associated with changes in the energy intensities;
- $\Delta E_{act} = \sum_j L(E_j^t, E_j^0) \ln\left(\frac{A_j^t}{A_j^0}\right)$ – Activity effect: the change in the aggregate associated with a change in the overall level of the activity;

- $\Delta E_D = \sum_i L(E_i^t, E_i^0) \ln\left(\frac{D_t}{D_0}\right)$ – Demographic effect: the change in the aggregate associated with a change in demographic factor; and
- ΔE_{rsd} – Residual term.

The cumulative effect's formula is therefore:

$$\Delta E = \sum_j \Delta E_j = \sum_j \Delta E_{mix,ij} + \sum_j \Delta E_{int,j} + \sum_j \Delta E_{act,j} + \sum_j \Delta E_{D,j} + \sum_j \Delta E_{rsd,j} \quad (5)$$

where $\sum_j \Delta E_j$ is the total of the change of energy consumption between years 0 and T in sector j.

In a second approach, this paper implements the same method for the country calculation with an additional factor that is the economic structural factor. Therefore, it is capable of comparing each factor's change between sectorial and national levels. To estimate the effect of the shift in the mix of products (production structural effect), the article proposes adjusting the calculation to eliminate residential energy consumption from total energy consumption. Thus, the final effects in this case reflect the ratio of the final energy use of three sectors including commercial, industrial and transportation sectors.

The formulas are converted to [equation \(6\)](#):

$$E_j \sum_i \frac{E_{ij}}{E_j} \times \frac{E_j}{VA_j} \times \frac{VA_j}{\sum_j VA_j} \times \frac{\sum_j VA_j}{D} \times D \quad (6)$$

Foreshortening [equation \(6\)](#) by replacing $\frac{E_i}{E_j} = M_{ij}$, $\frac{E_j}{VA_j} = I_j$, $\frac{VA_j}{\sum_j VA_j} = S_j$, $\frac{\sum_j VA_j}{D} = A_j$

we have [equation \(7\)](#):

$$E_j = \sum_i M_{ij} \times I_j \times S_j \times A_j \times D \quad (7)$$

The cumulative effect is calculated following [equation \(8\)](#)

$$\Delta E = \Delta E_{mix,ij} + \Delta E_{int,j} + \Delta E_{str,j} + \Delta E_{act,j} + \Delta E_D + \Delta E_{rsd} \quad (8)$$

With:

- $\Delta E_{mix} = \sum_{ij} L(E_{ij}^t, E_{ij}^0) \ln\left(\frac{M_{ij}^t}{M_{ij}^0}\right)$ – energy mix effect: the change in the aggregate associated with a change in the mix of energy used type;
- $\Delta E_{int} = \sum_{ij} L(E_{ij}^t, E_{ij}^0) \ln\left(\frac{I_j^t}{I_j^0}\right)$ – intensity effect: the change in the aggregate associated with changes in the energy intensities;
- $\Delta E_{str} = \sum_{ij} L(E_{ij}^t, E_{ij}^0) \ln\left(\frac{S_j^t}{S_j^0}\right)$ – economic structure effect: the change in the aggregate associated with a change in the mix of the activity by sub-sector;

- $\Delta E_{act} = \sum_{ij} L(E_{ij}^t, E_{ij}^0) n\left(\frac{A_j^t}{A_j^0}\right)$ – activity effect: the change in the aggregate associated with a change in total value added per capita;
- $\Delta E_D = \sum_{ij} L(E_{ij}^t, E_{ij}^0) n\left(\frac{D_i^t}{D_i^0}\right)$ – demographic effect: the change in the aggregate associated with a change in demographic factor.
- ΔE_{rsd} – Residual term

This paper considers different demographic factors including population and two urbanization indicators to compare their contributions to energy consumption changes among the different factors. The first urbanization indicator is the total population living in urban areas, named Urban 1, reflecting the general rural-urban migration. The second is the number of non-agriculture employees in the total workforce, named Urban 2, representing the effect of urban pull factors with industrialization and urban-biased policies.

3.2 Data selection

The study is based on multi-country and cross-sectoral data for the period 1995-2013. The demographic data are collected from the World Bank database. Energy consumption is divided into whole consumption and sectorial consumption as well as into fuel energy, renewable energy and electricity. It is collected from the International Energy Agency (IEA 2016) database.

GDP data is collected by cross-country and cross-sectional data. The panel data covers the value-added contribution of all major economic sectors consisting of commercial, industrial, and transportation, and the GDP of the whole economy is summed up from the [Asian Development Bank \(2015\)](#) source. The dataset is validated between alternative sources such as [The World Bank \(2015\)](#), [Asian Development Bank \(2015\)](#) and International Monetary Fund (2015).

Particularly for the residential sector, this paper suggests considering the number of households as an activity indicator. This data is summarized from annual national population reports. Some missing data is encountered, which is accounted for by linear interpolation, see [Table I](#) for details.

Missing data is a problem in some countries such as Singapore and Laos, and leads to incalculable results. Moreover, the inconsistency in collecting data in Indonesia when combining value-added from transportation with commercial value-added made it impossible to compare the results with other countries. Therefore, this paper only presents the results for 7 countries, consisting of 1 high-income country (Brunei), two upper-middle-income countries (Malaysia and Thailand) and four low-middle-income countries (Cambodia, Myanmar, the Philippines and Vietnam).

Table I.
Summary of the data set and their sources

Sector	Activity	Energy data	Demographic
Residential	Number of households - National population censuses report	Fuel, renewable, electricity - IEA 2015	World Bank 2015
Commercial	Added value, GDP – World Bank 2015 and ADB database 2015		
Industrial			
Transportation		Fuel – IEA 2015	

4. Results

The empirical analysis is conducted by comparing the impact of the energy mix, energy intensity, activity, structure, and three demographic indicators (Population, Urban 1, and Urban 2) on the energy consumption in ASEAN during 1995-2013. Overall results are shown in [Tables II](#) and [III](#) for the approach without and with the economic structure indicator. In general, energy consumption growth in ASEAN countries is mostly caused by demographic and economic changes. Energy mix contributed positively but insignificantly. Meanwhile, energy intensity is the only factor continuously supporting energy consumption reductions (see [Tables II](#) and [III](#)).

Without the economic structure approach, demographic effects are the strongest drivers of energy consumption growth in ASEAN from 1995 to 2013, especially from the 2000s (see [Figure 4](#)), with average contributions of around 30-70 per cent, 60-150 per cent and 60-240 per cent for population, Urban 1 and Urban 2 respectively (see [Table II](#)). Exceptional contributions occur in the Philippines and are discussed in detail in Section 5. With the economic structure approach, production growth is revealed as the strongest driver instead of the demographic effects (see [Table III](#)).

For country comparisons, the demographic effect of population change influence on energy consumption is weighted at 1, thus providing a basis for comparison of the three demographic indicators Population, Urban 1, and Urban 2 across countries and sectors (see [Tables IV](#) and [V](#)). For example, overall the Urban 1 and Urban 2 effects are on average 1.8 and 2.7 times stronger than the population effects on total energy consumption in all considered countries ([Table IV](#)). For individual countries, Urban 1 and Urban 2 have a

Table II.
Average weight of
each factor's
contribution in
energy consumption
changes in ASEAN
between 1995 and
2013 without
economic structure
concern

Country	Energy mix	Energy intensity	Economic – Population case	Economic – Urban 1 case	Economic – Urban 2 case	Population	Urban 1	Urban 2
Brunei	0.48	-25.49	57.40	35.14	30.61	67.62	89.88	94.41
Cambodia	0.50	-35.81	67.22	34.43	-105.37	68.09	100.88	240.68
Malaysia	0.34	-5.49	67.39	36.83	46.49	37.77	68.33	58.66
Myanmar	0.19	-100.04	131.69	47.27	-32.42	68.16	152.57	232.26
Philippines	1.17	-1235.80	815.90	911.24	366.17	520.61	425.27	970.34
Thailand	0.14	-0.39	66.56	-15.69	-8.55	33.69	115.94	108.80
Vietnam	2.06	-49.16	123.32	85.93	36.18	23.78	61.16	110.92

Note: Unit: %/a

Table III.
Average weight of
each factor's
contribution in
energy consumption
changes in ASEAN
between 1995 and
2013 with economic
structure concern

Country	Energy mix	Energy intensity	Economic structure	Production – Population case	Production – Urban 1 case	3Production – Urban 2 case	Population	Urban 1	Urban 2
Brunei	0.26	-33.67	-80.80	146.75	124.54	119.97	67.46	89.67	94.23
Cambodia	0.48	-42.29	3.22	95.16	74.33	-15.46	43.43	64.27	154.05
Malaysia	0.23	-10.11	15.54	58.19	28.94	38.19	36.15	65.40	56.15
Myanmar	0.83	-118.95	-220.23	200.80	409.18	293.96	32.50	207.65	322.87
Philippines	0.79	-277.75	66.92	188.72	211.11	84.04	121.33	98.93	226.00
Thailand	0.04	-4.71	19.02	52.21	-29.40	-22.31	33.43	115.04	107.95
Vietnam	2.19	-66.45	16.05	130.72	103.07	66.68	17.50	45.14	81.53

Note: Unit: %/a

Figure 4.
The impact of Urban 1 in relation to other impacts on energy consumption changes in seven ASEAN countries from 1995 to 2013 by decomposed economic effect approach

Note: The milestone marks the transition from decreasing to increasing energy consumption of Urban 1

relatively equal influence in Brunei, Malaysia and Thailand. But Urban 2 is significantly stronger than Urban 1 in the other countries (Table V).

For sectorial comparison and cross country-sector comparisons, the demographic effect of population change influence on commercial energy consumption is weighted at 1. Tables VI and VII respectively describe the demographic effect on energy consumption changes across sector and country over the past two decades, relative to this value of unity. Out of all sectors in all cases, Urban 2 or non-agricultural workers ranked highest in industrial and residential sectors with 13.21 and 15.12 respectively

(Table VI). The Urban 1 factor affects most strongly the residential energy consumption in the case of the cumulative economic effect at 8.69, and in transportation in case of the decomposed economic effect at 6.86. Exceptional cases are recorded in Malaysia and Thailand, where Urban 1 impacts stronger than Urban 2, and in the Philippines where the Urban 1 has less influence than population and Urban 2 (Table VII).

Figure 5 provides an assessment of the scaled impact of demographic factors on energy consumption in the 7 analyzed ASEAN countries. This figure describes the relevance of demographic size and its impact on total energy consumption changes. The size of the circles shows the strength of the respective demographic effects (Urban 1, Urban 2, population) over the whole period and the y-axis shows the average annual rate of change. The x-axis is arranged in order of increasing income. The figure clearly illustrates the three different groups of countries according to their income level. In the lower-middle-income group the Urban 2 effect is strongest, followed by Urban 1 and Population, with

Table IV.
The overall
comparison of
demographic factors
impact on energy
consumption change
in ASEAN in the
period 1995-2013
(population = 1)

Overall	Population	Urban 1	Urban 2
Without economic structure concern	1.00	1.82	2.80
With economic structure concern	1.00	1.84	2.54

Table V.
Comparison of
demographic factors
impact on energy
consumption growth
by country in the
period 1995-2013
(population = 1)

Country	Population	Urban 1	Urban 2
Brunei Darussalam	1.00	1.33	1.40
Cambodia	1.00	1.48	3.53
Malaysia	1.00	1.81	1.55
Myanmar	1.00	2.24	3.41
Philippines	1.00	0.82	1.86
Thailand	1.00	3.49	3.25
Vietnam	1.00	2.57	4.66

Table VI.
Overall sectorial
comparison of
demographic factors
impact on energy
consumption growth
in ASEAN in the
period 1995-2013
(population in
commercial
sector = 1)

Urban indicator	COM	IND	RES	TRA
<i>Without economic structure concern</i>				
Population	1.00	6.50	5.48	5.28
Urban 1	1.99	7.45	8.69	7.39
Urban 2	2.85	13.21	15.12	10.99
<i>With economic structure concern</i>				
Population	1.00	5.66		4.91
Urban 1	1.73	6.41		6.86
Urban 2	2.51	11.69		10.29

Notes: Acronyms: COM – commercial; IND – industrial; RES – residential; TRA – transportation

Table VII.
Cross country-sector
comparison of
demographic factors
impact on energy
consumption growth
in ASEAN in the
period 1995-2013
according to two
different approaches
(percentage change
in energy
consumption per
0.1% change in
respective
demographic factor)

Urban indicator	Without economic structure concern				With economic structure concern		
	COM	IND	RES	TRA	COM	IND	TRA
<i>Brunei</i>							
Population	0.39	1.28	1.70	1.01	0.37	0.69	1.03
Urban 1	0.52	1.70	2.25	1.33	0.49	0.91	1.36
Urban 2	0.55	1.82	2.48	1.46	0.52	1.01	1.49
<i>Cam</i>							
Population	0.11	0.55	1.38	1.32	0.11	0.55	1.32
Urban 1	0.17	0.85	2.07	2.14	0.17	0.84	2.12
Urban 2	0.37	1.89	4.84	2.62	0.37	1.88	2.72
<i>Malay</i>							
Population	0.22	0.42	0.60	0.31	0.22	0.42	0.31
Urban 1	0.40	0.76	1.09	0.57	0.40	0.76	0.57
Urban 2	0.35	0.65	0.96	0.49	0.35	0.60	0.49
<i>Myan</i>							
Population	0.19	0.31	1.57	0.62	0.19	0.31	0.62
Urban 1	0.39	0.63	3.08	1.37	0.39	0.63	1.37
Urban 2	0.65	1.03	5.60	2.12	0.65	1.03	2.12
<i>Phil</i>							
Population	0.16	6.20	1.44	3.47	0.29	6.20	3.47
Urban 1	0.40	5.35	1.36	2.79	0.25	5.35	2.79
Urban 2	0.78	11.48	3.19	6.13	0.57	11.45	6.13
<i>Thai</i>							
Population	0.20	0.35	0.71	0.69	0.20	0.35	0.69
Urban 1	0.56	0.88	1.53	2.03	0.56	0.88	2.03
Urban 2	0.61	0.93	2.15	2.15	0.61	0.93	2.15
<i>Viet</i>							
Population	0.16	0.22	0.46	0.16	0.16	0.22	0.16
Urban 1	0.40	0.53	1.10	0.38	0.40	0.53	0.36
Urban 2	0.78	1.15	2.48	0.80	0.80	1.16	0.80
Notes: Acronyms: COM – commercial; IND – industrial; RES – residential; TRA – transportation							

the exception of the Philippines (see next section). The upper-middle-income group is characterised by higher Urban 1 effects, followed by Urban 2 and Population. The third group, high income countries, shows similar effects of both Urban 1 and 2, both stronger than the Population effect.

The overall influence of the different demographic factors on each sectorial energy consumption in the 7 countries is presented in [Figure 6](#). The sectors are shown in turn from left to right including commercial, industrial, and residential sectors and transportation. The vertical axis represents the impact of the demographic factor on the relative sectorial energy consumption changes, in dimensionless units of percentage change of the energy consumption per 1 per cent change in Urban 1. The rectangular boxes show the upper and lower quartiles of the data, the whiskers outside the box indicate the spread outside these quartiles, and the circular points show outliers. In general, changes in both urban dwellers (Urban 1) and employees in the non-agricultural field (Urban 2) made the largest contribution to increasing energy consumption in households. The influence seems to be smaller for the transportation and industrial sectors and very small for the commercial

ASEAN urbanization effects on energy

Notes: X-axis: considered countries corresponding with their factors divided into four groups. Y-axis: average demographic growth rate including population, Urban 1 and Urban 2. Bubble size: the level of demographic factor impact on energy consumption by each factor in each country

Figure 5.
Cross-country
comparison of impact
levels by different
demographic factors
on energy
consumption growth
in 7 ASEAN
countries from 1995
to 2013

Note: Percentage change in respective effect per 1% change in Urban 1 indicator

Figure 6.
Groups of different
annual average
effects of Urban 1 on
sectors in the 7
ASEAN countries
from 1995 to 2013

sector. Detailed results for each sector per year during the considered period can be seen in [Table VII](#).

5. Discussion and policy implications

In this section, we discuss our main results and the applied method. The first section focusses on the effects of urbanization on the energy mix, in the context of the question whether urbanization could promote the energy transition. The second section then examines which factors policies are required to consider, to ensure sustainable development. The third section highlights the different impacts of urbanization on energy consumption, according to the income level of the country. The subsequent sections present a sensitivity analysis and critically discuss the method, respectively.

5.1 The correlation between urbanization, energy mix and energy consumption effects, and the example of the Philippines

The decomposition results show that the energy mix effect contribution to the energy changes is generally quite weak, with from 0.1 per cent to 3 per cent (with the exception of the Philippines, discussed below) from 1995 to 2013 ([Tables II, III](#) and [Figure 7](#)). Despite the extensive government efforts to encourage renewable energy development through national energy policies, the regional reliance on fossil fuels is increasing with an average annual growth rate at 0.8 per cent during the considered period ([Figure 7](#)). The results also show that the transition rate from fossil fuels to electricity and renewable energy is happening even more slowly in the considered countries, with an average annual growth rate of 0.35 per cent from 1996 to 2004 compared with a rate of -0.11 per cent from 2005 to 2013 ([Figure 7](#)). The decrease is mainly due to the increase in using fossil fuel within the industrial and residential sectors. This could be evidence that the swelling population in cities and industrialization is putting pressure on the region's energy security.

The exception here is the Philippines with a negative impact of the energy mix recorded during the period of 2006 to 2010 ([Figure 7](#)). A deeper look at the energy mix impacts by sectors ([Figure 8](#)) reveals that these negative values are caused by the dramatic reduction in the residential sector in the Philippines during the 18 studied years, with an average decreasing rate of 1.7 per cent per year. The energy consumption in the residential sector in the Philippines counteracts positive effects in other sectors, thus accounting for the overall negative energy mix effect seen across the entire economy.

The successful strategy in dealing with urbanization in the Philippines could be seen as a positive example to counter increasing energy demand. Since the urbanization crisis became a concern of the Government in the 2000s, the Philippines has played a key role in the global debate on sustainable urbanization. As an active member on Human Settlements or Habitat

Figure 7.
Fossil fuel share in TPES (own calculation based on database of IEA, 2015) and the energy mix effect share in TPES changes from 1995 to 2013 in seven ASEAN countries

II, the Philippines' commitments on infrastructure development have made significant achievements after 20 years[3], by effectively reducing the rapid rate of urbanization growth. Thereby, it successfully limited the urbanization effect on energy consumption to remain even smaller than the population effect (Figure 5). Since 2016, under the auspices of the Habitat III[4] process, this may enable the Philippines to further reduce the urbanization effect on energy consumption as well as providing a good practice example for other countries.

5.2 The focus of ASEAN energy policy

Among the studied demographic influences, the urbanization factors generally exhibit a stronger effect on energy demand increases than population in the region (with the exception of the Philippines, Table V and Figure 5). After 1990, along with economic development, ASEAN entered a period of rapid urban population growth (Urban 1), which rose to an average of 3.2 per cent per year (World Bank, 2018). However, after more than 10 years of increasing, since the 2000s, Urban 1 has started to put pressure on energy consumption in ASEANs. It started in Brunei, which has the highest rate of urbanization, in 2000 and then spread all over ASEAN. Vietnam has been affected since 1995, but the effect has become relatively strong since 2004 (Figure 4).

Moreover, ASEAN economies are likely to expand at a rapid pace and have attained high rates of Urban 2 – non-agriculture employment growth. Consequently, Urban 2, which reflects the growth in industrial development in this region, is the strongest effect among the demographic indicators (Tables V and VI).

The results show that, if Urban 1 and Urban 2 would increase by only 0.1 per cent, it will require an energy demand increase by on average 1.44 per cent and 2.59 per cent respectively (Tables II and III). Urbanization is leading to rapidly increasing domestic energy demand, especially in Cambodia, Myanmar and Vietnam (Figure 9), followed by significant growth in industry and transport (ASEAN as a whole in Table VI and detailed by country in Table VII and Figure 9). The urbanization effect on transportation is gradually becoming stronger than on industry, especially in Thailand (Figure 9).

Facing the urbanization challenge, this paper provides an estimation for the energy consumption change in each sector of each considered country corresponding to 0.1 per cent urbanization changes (Table VII). It reveals the potential that controlling urbanization could reduce the pressure on energy supply. For example, Urban 1 in Vietnam is 34 per cent, which indicates that around 32 million people are living in urban areas. Based on the estimation, if the government could avoid 0.1 per cent in Urban 1 increase (meaning 32,000

Figure 8.
Comparing energy
mix and energy
consumption changes
in Philippines by
sector – Unit: 1000
TOE

Figure 9.
Cross country-sector
comparison of
urbanization effects
on energy
consumption growth
in seven ASEAN
countries between
1995 and 2013

Notes: Acronyms: RES – residential, TRA – transportation, IND – industrial, COM – commercial

people) per year, it could help to avoid 0.4 per cent, 0.53 per cent, 1.1 per cent and 0.38 per cent energy demand increases in the commercial, industrial, residential and transportation sectors respectively. The results could be used as a reference for policy makers to integrate energy policy with urban and economic plans.

Because urbanization, and not population, is one of the main drivers for increasing energy consumption and is concentrated in the residential sector, there is an obvious need for specific energy policy at the regional and city levels. It is beyond the remit of government agencies to coordinate among all local bodies and conduct comprehensive policy analysis and performance evaluation, because of lacking capacity and resources at the national level. In addition, responsibility in energy policy, planning and implementation at the city level could be fragmented and contradictory, compared to the respective current sub-sector energy policy. This lack of attention and capacity from national institutions to subnational energy policy could present an opportunity for regional and local organizations. However, city-level decision makers at least need signals and guidelines from the national level to develop effective policies, and the state has to coordinate these activities as much as is feasible. This includes ensuring that local policymakers can effectively engage with stakeholders at all levels and that local experiences with new policies are considered in the national context.

5.3 Insights for countries’ income-levels on urbanization and energy consumption

This paper analyzed the two urbanization indicators including Urban 1 (urban population in urban areas) and Urban 2 (non-agricultural employment), which represents industrialization, to investigate the difference between the two indicators on energy consumption. The results show there are three typical groups (Figure 5), which are closely linked to the national income levels:

- *Group 1 as Brunei* – high-income country (based on World Development Indicators, World Bank data, 2016) where Urban 1 and Urban 2 have similar effects on energy consumption growth.
- *Group 2 including Malaysia and Thailand*, upper middle-income countries, where Urban 1 is stronger than Urban 2.
- *Group 3 including Cambodia, Myanmar, Philippines and Vietnam*, lower middle-income countries, where Urban 2 has stronger effect on energy consumption growth than Urban 1.

Thus, it can be seen that, the lower income the country is, the stronger urbanization and industrialization effect energy consumption growth. In other words, lower-income countries are more severely affected by urbanization in increasing energy consumption. Accordingly, the demand for urban management in the context of energy consumption growth in these countries becomes more urgent and the policy development process needs to consider this fact. For example, the high-income countries exhibit effects based on all three factors that are very similar (Figure 5), hence little or no specific urbanization policy is required. The upper-middle-income countries, on the other hand, exhibit strong urbanization according to Urban 1, therefore need effective policies to manage this process and should look to the Philippines for inspiration. The lower-middle-income countries have a much stronger industrialization effect (Urban 2), and therefore need to focus attention on effective policies to manage this rapid change alongside energy demand increases. Whilst the three remaining ASEAN countries were not included in the analysis because of a lack of data, these broad policy insights could also be generalized towards them (i.e. high-income: Singapore, lower-middle-income: Laos PDR, and upper-middle-income: Indonesia).

5.4 Sensitivity analysis

This study analyzed the robustness of the results in the presence of uncertainties. The calculated data units and the estimated percentage statistical errors of each variable are listed in Table VIII.

The statistical errors in Table VIII are estimated by comparing different data resources. To calculate the statistical errors in GDP data, this paper determined the difference in percentage in the same referred time and currency between two data sources including the World Bank database 2018 and the ADB database 2015. The statistical errors of population, Urban 1 and Urban 2 are estimated by comparing between the World Bank database 2018, the ADB database 2015 and the IMF database 2015. The results show that the difference between them is around 0.01 per cent to 0.2 per cent respectively. On the other hand, the energy statistical errors from the IEA database represent the amount by which an observation differs from itself, before and after the IEA revises the data every year when they update the database.

To account for the case of unknown statistical errors, the paper varies the input values within the range of ± 50 per cent for given input parameters such as demographics, activity

Variable	Data units	Statistical errors
Demographic	Billion people	0.01-0.2
GDP	Billion \$	0.01-0.2
Energy	1000 TOE	0.1-7

Table VIII.
Analysis of the
statistical errors

and energy consumption. Figure 10 shows that, for every 1 per cent variation in the input, the activity effect will change by around -5.5 per cent and the demographic effect would change by 5.5 per cent. However, it will not affect the energy intensity effect. Similarly, if the activity value changes, every 1 per cent of this will cause energy intensity effect changes of 5.5 per cent and activity effect changes of -5.5 per cent, but this has no impact on the demographic effect.

Furthermore, every 1 per cent error in the energy consumption statistics could cause a 1 per cent change in the energy intensity effect, a -0.5 per cent change in activity effect and a -0.6 per cent error in the demographic effect. The results also show the limitation of the decomposition method, especially for the logarithmic mean divisia index (LMDI). It has trouble dealing with zero values so the results can give an incorrect value. For example, in this case this effect occurs at the point of a 20-25 per cent negative change in the energy consumption.

5.5 Critique of the decomposition method in analyzing the relationship between energy and urbanization

This section discusses the strengths and limitations within the study. Regression may produce unreliable results in describing the relationship between energy consumption and other factors. For example, in the case of Brunei, the r -squared is relatively low, around 6 per cent and 16 per cent in the case of analyzing the relationship between energy consumption and GDP, Urban 1 respectively (Figure 11). The decomposition method does not encounter many obstacles in comparing the correlation between variables (Figure 12). Thus, it is an alternative approach to analyze the relationship between energy consumption and urbanization. The decomposition is also superior to regression in case of horizontal (cross-country) and vertical (cross-sector) comparisons.

However, the decomposition method also has its disadvantages, which are the process of collecting and synchronizing data, choosing the appropriate decomposition analysis method, problems associated with considering new variables (e.g. population and urbanization factors), and the errors resulting from a zero difference between the value in two considered periods. The data capable for computing needs to be collected with the same

Figure 10.
The results of the
sensitivity analysis
for selected variables
– Unit: %

ASEAN urbanization effects on energy

Notes: Unit: GDP: million USD 2005,
Urban: million people, Energy consumption:
1,000 TOE

Figure 11.
The results of relation
analysis for selected
variables by using
regression in Brunei

Figure 12.
The results of relation
analysis for selected
variables by using
decomposition in
Brunei with
cumulative economic
approach – Unit: 100
MTOE

reference year and statistical method in all countries. Therefore, the end-use database is calculated and synchronized with the reference year as 1995. Moreover, the zero problem was handled following the suggestion of [Ang and Liu \(2007\)](#) by replacing with ∂ , where $\partial < 10^{-20}$.

Finally, the decomposition method describes a relative comparison between variables instead of considering the dependence of different variables. It can therefore provide the correlation of different effects on one or several variables; however, it cannot determine an exact weight representing the level of influence. Hence, the choice of appropriate method always depends on the application and should be made with the above issues in mind.

6. Conclusion and outlook

The essential requirement of restraining energy consumption and promoting energy efficiency is becoming more important in the context of economic and urban growth. The first priority of ASEAN governments should therefore be to identify factors that have an effect on energy consumption and developing appropriate policies. A deeper analysis of the disaggregate results for each sector and country enables a more accurate understanding of the urban impacts on energy consumption.

With this purpose, the decomposition method has been implemented in this paper for seven ASEAN countries from 1995 to 2013 to assess the effects of urbanization on energy consumption and compare this effect based on multi-level indicators. This analysis is based on two types of urbanization, including the general urban indicator of urban population and the pull urban indicator of non-agriculture workers. The results decompose the changes of overall energy consumption into intra- and international effects and isolate the contribution of each component factor including energy mix, energy intensity, activity, and urbanization. To the authors' knowledge, this is a novelty, as previous studies have only shown results across sectors or countries.

While there was some controversy about the effect of urbanization on total energy consumption as well as sectorial energy consumption, this paper demonstrates the positive effect of urbanization at national and sectorial levels in the ASEAN region. Although effects are different among the countries, the urbanization effect on energy consumption is stronger in lower income countries. The results show that the effect of urbanization factors is much more significant than the population effect and the other effects including energy intensity and activity in the whole country, as well as in each of the sectors in the region.

The detailed results about urbanization-related energy consumption changes in [Table VII](#) could serve as a suggestion for the whole ASEAN region in controlling urbanization and its effects on energy consumption. The strong effect of urbanization on domestic energy consumption poses new questions for policy makers in this field. In particular, they should focus efforts on finding an optimal solution to decentralized, efficient energy systems for current and future urban cities, especially in the commercial and household sectors. Therefore, the paper suggests three key recommendations to policy-makers in setting energy policy: (1) urban areas should be considered as one of the core targets for energy policy; (2) the lower-middle-income countries should pay attention to effective policies to manage the rapid change of the non-agriculture workers' effect; and (3) there is an essential need for energy policy at city-levels besides subsector-levels.

Looking to the future, instead of using energy consumption to assess the impact of urbanization, energy intensity analyses could be implemented. These would require updated and improved databases, and should apply direct approaches, based on energy service demands, rather than the indirect decomposition approach adopted here. For example, a complete dataset should be built, consisting of different and more detailed factors such as housing area for households, commercial building area for the commercial sector, and freight of goods for transportation. Such a database would enable the underlying causes of the urbanization and energy phenomena highlighted here to be examined more closely. Researchers should approach this problem from diverse disciplines, to more fully understand the complex relationship between the urbanization process and the carbon cycle. Moreover, whilst this study was able to provide valuable insights into the relationship between urbanization and energy consumption at the sector level, across ASEAN, for a period of a few decades, future work should analyze these phenomena at the national level and below, as well as differentiating between energy carriers.

Notes

1. Divided by income group, ASEAN has ten members in three groups: two high-income countries including Brunei Darussalam and Singapore, two upper-middle-income countries including Malaysia and Thailand and six lower-middle-income countries including Cambodia, Indonesia, Lao PDR, Myanmar, the Philippines and Vietnam (World Bank, 2018, last accessed 03.12.2018).
2. The “fixed effect” method is used to treat pooled cross-sectional and time series data. It means the model is calculated with one variable fixed and in a constant proportion across countries.
3. For more information about the Philippines achievements on urbanization programs under Habit II see: www.hudcc.gov.ph/HABITAT_III
4. Habitat III is the New Urban Agenda. It is the outcome of the action plans agreed upon at the Habitat III cities conference in Quito, Ecuador, in October 2016.

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