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Research article

Urbanization and renewable energy consumption in the emerging ASEAN markets: A comparison between short and long-run effects☆

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ABSTRACT

The emerging markets in the ASEAN region, such as Indonesia, Malaysia, the Philippines, Thailand and Vietnam, have put great effort into achieving dual objectives: (i) supporting economic growth and (ii) combating environmental degradation simultaneously. These objectively depend on the fast urbanization taking place in these countries. While increased energy consumption from urbanization supports economic growth, urbanization is a key driver of environmental degradation. This paper examines a potential link between urbanization and renewable energy consumption, primarily ignored in current literature, particularly in the ASEAN-5 countries. Findings from this paper indicate that, despite the adverse effect of urbanization on renewable energy consumption in the short run, a positive effect is found in the long run for these emerging ASEAN markets, except Malaysia. The Philippines appears to balance well between urbanization and renewable energy consumption in the short and long run. Policy implications have emerged based on the findings of this paper.

1. Introduction

Amid the third industrialization (1960–1990), academists centered on the determinants of vitality utilization and environmental debasement. In any case, most writing has as of late concentrated on the relationship between energy uses, economic growth, financial development, and urbanization. Previous research contended that the urbanization consumes significant amount energy which puts a tremendous pressure on the environment [1–4].

The *ASEAN Sustainable Urbanisation Forum* [5] reported that an additional 70 million civilians are forecasted to live in the ASEAN urban areas by 2025, making sustainable and inclusive urbanization a key priority to achieve the objectives of the ASEAN Community Vision for 2025. On the other hand, the ASEAN Centre for Energy [6] reported that a 5 per cent annual increase in clean cooking is associated with increased electrification in the household sector, including using cleaner wood stoves in rural areas and electric induction stoves in urban households. In addition, the penetration of efficient air conditioning and refrigeration units is forecasted to increase by 60 per cent to 100 per cent by 2050.

World Energy Balances [7] reported that energy-intensive industries (including iron and steel, cement, and petrochemicals) producing the basic materials for infrastructure needs are directly related to the regional development toward rapid economic, population

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and urbanization growth. In 2020, fossil fuels contributed approximately 62 per cent of the ASEAN's energy input to the industrial sector, whilst electricity accounted for nearly 23 per cent. At the same time, renewables remained less than 10 per cent of the power generation for the industrial sector in 2020 [7].

On the other hand, urbanization and industrialization require a substantial electric power supply. Most electricity generation in ASEAN uses fossil sources, including coal, oil, and natural gas [8]. Until 2018, natural gas had accounted for the largest share, but coal has been rising. In 2020, installed coal capacity has been reported to increase more than four times compared to 2005. A decline in oil and gas power generation was due to the dwindling reserves in the last few decades. The ASEAN region was deficit of trading oil before 2005 but gained surplus of gas and coal trading. Total deficit of oil trading balance, including petroleum products, rose from 48 per cent in 2005 to 79 per cent in 2020 [6]. The figure implies a reliance on oil imports in the ASEAN region. Therefore, ASEAN members encourage renewable energy production and consumption, and the total share of renewable energy grew from 19.1 per cent in 2005 to 33.3 per cent in 2020.

Transportation, fuel economy, vehicle loading, and vehicle mileage are closely related to the growth in population, urbanization, and per capita income. Promoting fuel switching to bioenergy in transportation reduces demand for imported oil, improves environmental quality, and ensures energy security for the ASEAN region [6]. Biofuel usage has increased by more than 200 times in 2022 compared to the 2005 level [6]. However, biofuel production from feedstock can harm the ecology, the environment, and the food supply [9,10]. Therefore, the electric vehicle can be an alternative solution. The electric vehicle utilizes prominent technology that directs a shift from conventionally fossil fuels to electricity. Several ASEAN members have planned for electric vehicle penetration. For example, Singapore targets 100 per cent of public buses and taxis to use electricity by 2040. Cambodia targets 40 per cent of all cars and urban buses and 70 per cent of motorbikes to be electric-powered by 2050 [6]. Promoting the use of renewable energy entails less dependence on imported fossil fuel but, more essentially, enhances urban health due to less CO_2 emissions from fossil fuel combustion.

Furthermore, the British Petro (BP) Statistics [11] indicated that the consumption of hydroelectricity increased from two to six times in several ASEAN countries, especially more than 55 times in Vietnam from 2005 to 2018 (see Table 1 for details). Malaysia and Vietnam significantly differed in hydroelectric consumption between 1985 and 2005 and 2005 and 2019, respectively. Hydroelectric consumption increased to 0.52 million tons of oil equivalent from 1985 to 2005 and 4.11 million from 2005 to 2019 in Malaysia. The consumption increased to 3.41 and 14.52 million tons of oil equivalent from 1985 to 2005 and from 2005 to 2019 in Vietnam. Other ASEAN countries showed decreased growth (Indonesia and the Philippines) or remained constant (Thailand) regarding hydroelectric consumption during these two periods.

With regards to economic growth, Table 1 also indicates that the total GDP increased by two or three times in ASEAN nations, and by four times in Vietnam during the 2005–2019 period. Table 1 presents the dispersion of energy efficiency across five ASEAN countries. The Philippines and Thailand show renewable energy efficiency. A GDP growth rate is higher than a hydroelectric consumption growth rate. Vietnam exhibits a lower GDP growth than increased hydroelectric consumption. These statistics confirm the inefficient growth effect of renewable energy in Vietnam.

In addition, urban population recorded that most of ASEAN countries still have high speed of urbanization, such as Indonesia, Malaysia, Thailand, and Vietnam with 42 %, 41 %, 46 %, and 48 % increasing in urban population, respectively (from 2005 to 2019, see in Table 1). These statistical numbers exhibit some potential connection between urbanization process and renewable energy consumption in the ASEAN region, with regards to sustainable development goals.

Economic growth is generally perceived as an important goal for developing and emerging countries not limited to the ASEAN region. Energy is arguably one of emerging countries' most important sources to foster economic growth. However, the industrialization and modernization of those countries require a huge supply of energy, which relies heavily on fossil sources due to their affordability [12,13]. Consequently, the rapid urbanization in developing countries and emerging markets significantly raises the demand for affordable energy (such as energy for fossil sources) and presses enormous pressure on environmental sustainability and

Table 1
Statistical summary of urbanization, economic growth and hydroelectric consumption in ASEAN-5 countries In 1985, 2005, and 2019.

	Urban population (Million people)			GDP (billion USD)			Hydroelectric consumption		
Year	*1985*	*2005*	*2019*	*1985*	*2005*	*2019*	*1985*	*2005*	*2019*
Indonesia	43	104	148	85.3	285.9	1042.2	0.63	2.43	3.71
Malaysia	7	17	24	31.2	143.5	354.3	0.84	1.36	5.47
The Philippines	23	39	50	30.7	103.1	330.9	1.26	1.90	2.12
Thailand	15	24	35	38.9	189.3	505.0	0.84	1.28	1.72
Vietnam	12	23	34	14.1	57.6	244.9	0.33	3.74	18.26

Period	*1985–2005*	*2005–2019*	*1985–2005*	*2005–2019*	*1985–2005*	*2005–2019*
Indonesia	142 %	42 %	235 %	265 %	286 %	53 %
Malaysia	143 %	41 %	360 %	147 %	62 %	302 %
The Philippines	70 %	28 %	236 %	221 %	51 %	12 %
Thailand	60 %	46 %	387 %	167 %	52 %	34 %
Vietnam	92 %	48 %	309 %	325 %	1033%E	388 %

Note: Hydroelectric consumption is calculated as equivalent to million tons of oil.
Urban population and GDP are from World Development Indicators (WDI) database.
Hydroelectric consumption is from British Petro (BP) statistics database.

social security.

Previous research has investigated in the urbanization-energy nexus [4,14–19]. On the one hand, the majority of studies put attention on populous and emerging markets including China and India [2,18–21]. On the other hand, the other main stream of research has focused on EU and the OECD countries, which are developed nations [22,23]. One significant effort from Ref. [24] confirmed that urbanization in ASEAN formed a significant and urgent demand on fossil energy. However, limited research has been conducted on the relationship between urbanization and renewable energy consumption, a prominent alternative to fossil resources in the ASEAN. Because of rapid growth and efforts to foster economic development, severe challenges of environmental degradation have been arising in most of ASEAN countries [25,26]. Therefore, the relationship between urbanization and renewable energy consumption in ASEAN region still attracts investigation of academists to contribution to the sustainable development in the region.

Regarding these critical motivations, our research objective is to examine how urbanization improves renewable energy demand in the ASEAN emerging markets, as discussed in numerous sustainable development forums organized by the ASEAN Economic Community (AEC). Our research contributes to current literature of urbanization-energy nexus in twofold. *First*, we focus on the long- and short-term effects of urbanization on renewable energy consumption using a time-series analysis of five emerging ASEAN countries (including Indonesia, Malaysia, the Philippines, Thailand, and Vietnam). These countries have been considered actively emerging markets in the Asia-Pacific region. These countries have experienced a significant increase in urbanization in the past three decades. Their strong commitment to climate change (the ASEAN joint statement to the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement) is widely recognized [27]. *Second*, we investigate a causality relationship between urbanization and renewable energy consumption to highlight policy implications for the governments to start formulating and implementing appropriate policies supporting sustainable urbanization and preventing further environmental degradation.

The paper is structured as follows. Following this introduction, section 2 presents a literature review on the topic. Data and research methodology are discussed in section 3. Section 4 presents the empirical findings from this paper, followed by the conclusions in section 5.

2. Review of the literature

Majority of previous research focused on the growth-energy nexus [4,17,28–34]. On the one hand, research confirms the growth effect of energy consumption [28,32]. On the other hand, an inversed effect of economic growth on energy consumption has also been demonstrated [4,14,22]. Specifically, Li & Lin and Poumanyvong & Kaneko [4,17] proved that while in low-income countries, economic growth associates with lower energy usage, the opposite picture, at which economic growth encourages more energy consumption, is found in middle- and high-income nations. Besides these two unidirectional effects, the bidirectional causality between energy consumption and economic growth has also been discovered [30,33]. Being distinct from this significant relationship between economic growth and energy consumption [31], found numerous countries that revealed an insignificant relationship between economic growth and energy consumption.

Later, the research stream of the growth-energy nexus focuses on other socioeconomic aspects and the consumption of energy power in various countries at different levels of development. An attracting research flow is about the urbanization-energy nexus. There are two major streams of empirical research focusing on the urbanization-energy nexus. First, urbanizing and industrializing foster energy consumption [35–37]. Second, the urbanization enhances energy use efficiency by reducing per capita energy consumption [38,39]. However, few studies of urbanization-energy nexus focus on a specific kind of energy source, such as renewable energy consumption [40] or fossil energy consumption [24].

The importance of renewable energy for sustainable growth or development, the growth effect of renewable energy, and its consequences in mitigating environmental degradation have attracted attention. Most empirical studies confirm renewable energy's reliability for sustainable development [3,41,42]. As a result, policymakers and practitioners determine the determinants of renewable energy consumption and production. Meanwhile, economic growth, CO_2 emissions, energy price, and many other aspects have been considered determinants of renewable energy consumption (or production). However, urbanization, perceived as the critical component of modernization, has been largely ignored in the current literature. Some research did not directly consider urbanization as a determinant of renewable energy consumption [41]. Other studies directly examined the effect of urbanization on energy consumption in terms of fossil resources [3,43]. Some efforts investigated the direct relationship between urbanization and renewable energy consumption in some developed nations (such as European nations) and large industrialized countries (such as China and India) [34,44–46].

Recent research focusing on the ASEAN region has specifically addressed different roles of urbanization in sustainable development. Most of these recent efforts pay attention on environmental impacts of urbanization or energy consumption separately [24,47–50]. Most research indicates that urbanization relates to the ASEAN region's energy consumption and environmental degradation. Especially [24], revealed a link between urbanization and fossil energy consumption in the ASEAN region. However, despite significant efforts from various studies above, a direct link between urbanization and renewable energy within the context of ASEAN emerging markets has not yet been addressed.

Our literature review indicates that the current literature mainly focuses on the energy-growth nexus and energy consumption to prevent environmental. There are inconsistent conclusions of the effect of urbanization on energy consumption which particularly focuses on fossil resources [35–39]. Limited study considers different kinds of energy such as renewable sources. Urbanization could be a key driver, especially in the ASEAN economy. Therefore, on the ground of current literature and the importance of urbanization in ASEAN nations, our study is warranted to conduct and examine both the short and long run effects of urbanization on renewable energy consumption. Besides, the causal relationship between urbanization and renewable energy consumption has also been discussed.

3. Data and methodology

3.1. Data sources

In this paper, we analyze the relationship between urbanization on for renewable energy consumption, which is proxied by consumption of hydroelectric power, in ASEAN-5 nations, covering Indonesia, Malaysia, the Philippines, Thailand, and Vietnam. We employ two sources of the database. First, data of renewable energy consumption is reported in the Statistical Review of World Energy, which is published by the British Petro (BP) statistics [51]. The PB statistics report adequate data about hydroelectric consumption for all the above five ASEAN nations. We focus on hydroelectric consumption, because data on other renewable energy consumption, such as solar, wind, and biofuel, is unavailable or has an inefficient number of observations for conducting time-series analysis in this study.

Second, other macroeconomic indicators used in our analysis are extracted from the World Development Indicators (WDI) database from the World Bank Database [52]. It is worth noting that the Covid-19 pandemic has put heavy pressure on the global economy since 2020. On the one hand, the Covid-19 pandemic can potentially change energy consumption patterns, especially hydroelectric consumption [53,54]. As such, we include the effects of Covid-19 in the model. On the other hand, the currently available data is updated to 2021. Thus, the pandemic is only available for two years during this research period. A dummy variable representing Covid-19 is not sufficient for time-series analysis. As such, we remove 2020 and 2021 from the sample. Table 2 presents data availability for each variable used in this paper. Table 3 describes variable measurements and data sources.

3.2. Methodology

Based on significant efforts from previous research, urbanization as a factor of modernization potentially affects energy consumption by enhancing energy use efficiency [38,39]. On the one hand, urbanization demands a huge supply of energy for infrastructure development, transportation, residential construction, residential daily activities, and many others [38,39]. On the other hand, the enormous demand for energy in urban areas leads to tremendous pressure on the surrounding environmental quality [38,39]. Therefore, the government in developing countries where the speed of urbanization is relatively high tries to encourage the application and use of renewable energies, such as hydroelectric, solar, and wind power. Besides, during the modernizing process, improvements in individual income and living standards foster the use of environmentally friendly energy to maintain environmental quality in urban areas [55,56]. Therefore, urbanization in developing countries can employ more fossil energies because of the affordability and availability of fossil sources or enhance the use of renewable energies to raise awareness of environmental issues [24]. implied that urbanization has inconsistent effects on fossil energy consumption in ASEAN-5 nations. Thus, in the current paper, we particularly focus on the impact of urbanization on renewable energy demand.

Besides, in developing countries, economic growth has a dual role of fostering the consumption of energy [57] and enhancing the ability to transit energy consumption structure toward better quality sources [58]. From other aspects, industrialization in developing countries also changes the energy consumption structure depending on the level of technology in each nation's key industrial and manufacturing sectors. Therefore, we consider the contribution of the industrial and manufacturing sectors to GDP to explain our paper's use of renewable energy.

Furthermore, we utilize the advantages of time-series regression to observe and compare the relationship between urbanization and the consumption hydroelectric power among five ASEAN nations. Besides, conducting a time-series analysis for each of these five nations helps solve different measurement problems across nations.

In conclusion, in our model, the growth rate of urbanization represents the proxy for urbanizing; the share of industry in GDP and the share of manufacturing in GDP are used as a proxy for industrialization; GDP is used to control for economic growth in the model; and the consumption of hydroelectric consumption represents for renewable energy consumption. The model can be illustrated as follows:

$$Hydro_t^j = f\left(GDP_t^j, URB_t^j, IND_t^j, MAN_t^j\right)$$

Where: *Hydro* represents hydroelectric consumption. Hydroelectric consumption is calculated to be equivalent to a million tons of oil consumption. *GDP* is Gross Domestic Products. *URB* is the growth rate of urban population. *IND* and *MAN* are contribution in total GDP of industry and manufacturing, respectively. Subscript "t" and "j" stand for years and countries, respectively.

In the current literature, common time-series techniques which are applied in macroeconomic analysis are the Vector

Table 2
Data availability of variables.

	Indonesia	Malaysia	The Philippines	Thailand	Vietnam
Hydroelectric consumption	1965–2021	1965–2021	1965–2021	1965–2021	1965–2021
Urbanization population	1960–2021	1960–2021	1960–2021	1960–2021	1960–2021
GDP	1967–2021	1960–2021	1960–2021	1960–2021	1985–2021
Share of Industry	1983–2021	1960–2021	1960–2021	1960–2021	1985–2021
Share of Manufacture	1983–2021	1960–2021	1960–2021	1960–2021	1985–2021

Table 3
Descriptions of the variables.

Variable	Proxy	Measurement	Data source	From	To
Renewable energy consumption	Hydroelectric consumption	Tons of oil equivalent	BP Statistical Review of World Energy database	1985	2019
Urbanization	Urbanization growth	%	World Development Indicators database	1985	2019
Economic growth	GDP	Million USD	World Development Indicators database	1985	2019
Contribution of Industry	Share of Industry	%	World Development Indicators database	1985	2019
Contribution of Manufacture	Share of Manufacture	%	World Development Indicators database	1985	2019

Autoregressive (VAR) or the Autoregressive Distributed Lags (ARDL) regressions. The VAR model has several advantages. First, VAR can overcome the endogenous problem which can potentially occur in most of the models. The VAR is a kind of simultaneous regression model in which each variable will be treated as a dependence. Second, the VAR is proposed as an appropriate framework for time analysis with a large sample. Last but not least, the Johansen co-integration test based on VAR can report the co-integration relationship between variables in the model. However, VAR is limited by sample size and consistent order of stationarity among variables. A small sample size or when all variables are not stationary in the same order, I(0) or I(1) is not sufficient to apply VAR [59].

Then, in the occasion of small time-series sample, and inconsistent order of stationarity, the ARDL model is a reasonable solution. ARDL model can perform well in these two scenarios that VAR cannot [59–62]. Furthermore, the “bounds test” in ARDL package in Stata software can also identify the existence of co-integration in the model. Moreover, the ARDL can report robust long-run estimation and provide valid test statistics to ensure the robustness of results [63]. Thus, ARDL gains three advantages over VAR. *First*, ARDL performs well with a small time-series sample. *Second*, ARDL can produce robust results with the mixed order of integration. *Finally*, ARDL can reveal the regressors' short-term and long-term effects on the dependent variable. Therefore, we propose using the ARDL technique in the current study. Empirical models that used ARDL are expressed as follows.

$$\Delta Hydro_t^j = \sum_{i=0}^{r_1-1} \alpha_1 \Delta Hydro_{t-i}^j + \sum_{i=0}^{r_2-1} \alpha_2 \Delta URB_{t-i}^j + \sum_{i=0}^{r_3-1} \alpha_3 \Delta GDP_{t-i}^j + \sum_{i=0}^{r_4-1} \alpha_4 \Delta IND_{t-i}^j + \sum_{i=0}^{r_5-1} \alpha_5 \Delta MAN_{t-i}^j + \delta^j \left[Hydro_{t-1}^j - \left(b_1 URB_{t-r}^j + b_2 GDP_{t-r}^j + b_3 IND_{t-r}^j + b_4 MAN_{t-r}^j\right)\right] + \pi^j$$

Where: α_i $(i = 1, 5)$ denotes the short-term estimated coefficients; β_i $(i = 1, 4)$ represents the long-term effects; δ is the error correction, and π is the error term; the upper script "j" means each of the five ASEAN nations.

Several tests must be satisfied to ensure valid estimations, such as unit-root test, structural break identification and other diagnostic tests. In the ARDL model, all variables are required to be stationarity at the level or the first difference. We employ two stationarity tests namely the Augmented Dicky – Fuller (ADF) test and Zivot and Andrews (ZA) test for the unit-root test with a structural break. The null hypothesis of ADF is that the series does not contain a unit root, while Zivot and Andrews test null hypothesis is that there is a unit root in the time series with a structural break. All tests must reject the null hypothesis of either ADF or the Zivot and Andrews test to perform the next step of the co-integration test. The ADF test results are presented in Table 4 and Table 5. The Zivot and Andrews test for stationarity with the presence of structural break is provided in the appendices.

To identify long-term relationship, we need to test for the presence of cointegration relationship between variables. We use the Gregory - Hansen and ARDL bound tests to conduct a co-integration test. The Gregory - Hansen test can produce a co-integration test and identify a structural break that can appear in the time-series. Besides, the bound test option in ARDL package can report the co-integration test based on ARDL regression.

Several robustness tests, such as auto-correlation, homoskedasticity, and heteroskedasticity, are conducted as a final step. The Durbin-Watson statistic and LM test for autoregressive conditional heteroskedasticity (ARCH effect) are employed to test auto-correlation in the disturbance. For homoskedasticity and heteroscedasticity, White's test for homoscedasticity is used.

Besides the ARDL estimation, we also employ the Granger causality test to identify the causal direction between pairs of variables in

Table 4
Unit-root test results at the level (I(0)).

Variable	Indonesia	Malaysia	The Philippines	Thailand	Vietnam
Panel A: ADF unit-root test					
Hydroelectric consumption	−4.02***	−1.22	−2.52	−3.59**	−1.73
Urbanization growth	−1.97	−1.72	−1.72	−1.77	−2.79
Log of GDP	−2.17	−2.52	−2.01	−2.31	−4.02***
Industrial contribution to GDP	−1.61	−1.25	−1.46	−0.89	−1.59
Manufactural contribution to GDP	−1.23	−1.28	−1.36	−0.80	−2.67
Panel B: ZA unit-root test					
Hydroelectric consumption	−5.82**	−4.51**	−4.12	−4.64**	−3.81
Urbanization growth	−4.01	−3.20	−3.53	−4.29	−7.14**
Log of GDP	−3.45	−4.52**	−5.67**	−3.20	−2.92
Industrial contribution to GDP	−5.9**	−3.25	−4.35	−4.10	−4.67**
Manufactural contribution to GDP	−11.68**	−4.57**	−9.5**	−5.95**	−4.97**

Note: *, **, and *** are 10 per cent, 5 per cent, and 1 per cent significant levels, respectively; the ZA test is performed at only a 95 per cent confidence level.

Table 5
Empirical results from the unit-root test at the first differences.

Variable	Indonesia	Malaysia	The Philippines	Thailand	Vietnam
Panel A: ADF unit-root test					
Hydroelectric consumption	−7.7***	−3.88***	−5.34***	−5.32***	−3.09*
Urbanization growth	−4.09***	−3.51**	−3.99***	−3.64**	−3.99***
Log of GDP	−4.43***	−3.8***	−3.34**	−3.45**	−4.48***
Industrial contribution to GDP	−5.47***	−4.03***	−3.61**	−3.4**	−3.5**
Manufactural contribution to GDP	−5.3***	−3.89***	−3.46**	−3.3**	−3.31**
Panel B: ZA unit-root test					
Hydroelectric consumption	−8.76**	−4.67**	−4.67**	−4.67**	−4.67**
Urbanization growth	−5.98**	−5.98**	−5.98**	−4.9**	−6.26**
Log of GDP	−4.67**	−4.67**	−9.18**	−5.98**	−5.98**
Industrial contribution to GDP	−6.26**	−6.26**	−6.26**	−6.84**	−5.45**
Manufactural contribution to GDP	−5.45**	−5.45**	−5.45**	−5.45**	−9.48**

Note: *, **, and *** are 10 per cent, 5 per cent, and 1 per cent significant levels, respectively; the ZA test is performed at only a 95 per cent confidence level.

our model. A causality test is a time-series test to confirm whether a significant directional causality exist in a pair of variables. The causality test can provide a robustness check and a different angle to discuss the empirical results. The original Granger causality test requires the consistence of stationarity order as same as a based restriction in VAR. However, the Granger causality test based on the Toda – Yamamoto approach relaxes the assumption of the same order of stationarity of all variables [64]. The Toda – Yamamoto Granger causality test includes the maximal order of integration (d_{max}) in the k-lags VAR regression. Then, we will have a ($k + d_{max}$) th-order VAR model. We treat the coefficients matrix of d_{max} lagged vectors as a vector of exogenous variables in the VAR estimation. They are then excluded from the Granger causality test.

4. Results

Table 4 presents the results from ADF (Panel A). Again, most variables are not stationary at this level, except hydroelectric consumption in Indonesia and Thailand and GDP in Vietnam. In Panel B of Table 4, the Zivot and Andrews unit-root test confirms that only *the contribution of manufacturing to GDP* is integrated at I(0) for all five ASEAN countries.

Table 5 presents that all variables are station in the first difference order (I(1)) by both ADF and the Zivot and Andrews tests. These results confirm the appropriateness of the ARDL model compared with VAR.

Table 6 presents the co-integration test by Gregory-Hansen test to identify the structural break. The Gregory-Hansen test confirms a long-run relationship between variables in Indonesia, Malaysia, and Vietnam but not in the Philippines and Thailand. Based on the structural break identified by the Gregory-Hansen test, we produce the bound tests of ADRDL with and without these breaks. The results are presented in Table 7. The ARDL bound tests confirm a long-term relationship between variables in Malaysia, The Philippines, Thailand, and Vietnam. Their results are inconsistent because the Gregory-Hansen test and ARDL bound test have different procedures. Therefore, we argue that the co-integration relationship among variables is confirmed if it passes one of the tests, regardless of the Gregory-Hansen or ARDL bound test. Then, the co-integration is found in all five ASEAN nations in this study.

Table 8 presents urbanization's long-run and short-run effects on renewable energy consumption using the ARDL regression. *Hydroelectric consumption* is dependent on various factors. About the long-run effect, a significant effect of *urbanization* on *hydroelectric consumption* is found in Malaysia, the Philippines, Thailand, and Vietnam. *Urbanization* and *economic growth* increase the consumption of hydroelectric power in the Philippines, Thailand, and Vietnam but not in Malaysia. For Malaysia, the contribution from the *industrial* and *manufacturing sectors* inversely affects *hydroelectric consumption*. Particularly, *industrial contribution to GDP* decreases *hydroelectric consumption*, while the *contribution of manufacturing to GDP* increases it. In the Philippines and Thailand, *manufacturing* and *industry* positively affect *hydroelectric consumption*. We note that the *contributions of manufacturing* and *industry to GDP* have no long-term effects on Vietnam's *hydroelectric consumption*.

About the short-term results presented in Table 8, *urbanization* significantly positively affects *hydroelectric consumption* in Malaysia and the Philippines. However, it is negative in Indonesia, Thailand, and Vietnam. Besides, the significantly negative effects of ec*onomic growth* on *hydroelectricity* consumption have been confirmed in Malaysia, the Philippines, Thailand, and Vietnam. From other aspects, the *industrial contribution to GDP* has a significantly negative and positive impact on *hydroelectric consumption* in Indonesia and

Table 6
Co-integration test by Gregory - Hansen test.

Dependent variable	Indonesia		Malaysia		The Philippines		Thailand		Vietnam	
	T-statistic	Break year	T-statistic	Break year	T-statistic	Break year	T-statistic	Break year	T-statistic	Break year
Hydroelectric consumption	−6.55***	1995	−5.86*	2012	−5.25	2011	−5.57	2013	−5.70*	2003

*, **, and *** are 10 per cent, 5 per cent and 1 per cent significant levels, respectively.

Table 7
Co-integration test by ARDL Bound-test ***with*** and ***without*** breaks from the Gregory - Hansen test.

Country	Indonesia	Malaysia	The Philippines	Thailand	Vietnam
*Penal A: ARDL Bound-test **with** a structural break from the Gregory - Hansen test*					
Hydroelectric consumption	2.74	8.12***	7.86***	4.15**	8.94***
*Penal B: ARDL Bound-test **without** a structural break from the Gregory - Hansen test*					
Hydroelectric consumption	1.92	5.29***	2.69	7.01***	6.05***

and * are 5 per cent and 1 per cent significant levels, respectively.

Table 8
Empirical results from the ARDL results do not include breaks confirmed by the Gregory – Hansen co-integration test.

Country	Indonesia	Malaysia	The Philippines	Thailand	Vietnam
Error Correction Term	−0.355	−0.245***	−3.514***	−1.158***	−0.419***
	(0.321)	(0.0640)	(0.695)	(0.270)	(0.138)
Long-run results					
Urbanization growth	−0.549	−3.280***	0.103**	0.196**	9.672**
	(0.560)	(0.699)	(0.034)	(0.091)	(4.229)
GDP (Log)	−0.374	0.973	1.105***	0.154*	7.107***
	(1.110)	(0.662)	(0.115)	(0.086)	(1.098)
Industrial contribution to GDP	0.270	−0.548**	0.035	0.150*	0.359
	(0.383)	(0.200)	(0.065)	(0.078)	(0.530)
Manufactural contribution to GDP	−0.381	0.947***	0.230**	−0.108	−1.069
	(0.436)	(0.269)	(0.079)	(0.102)	(0.926)
Short-run results					
Urbanization growth	−0.860*	0.877***	0.197*	−0.263*	−4.666**
	(0.443)	(0.273)	(0.0965)	(0.138)	(2.166)
Hydroelectric consumption (1-year lagged)	−0.450*	–	2.027***	0.664**	−0.847***
	(0.242)	–	(0.464)	(0.244)	(0.256)
GDP (Log)	–	−0.685*	−1.480**	−1.471**	−4.278***
	–	(0.390)	(0.582)	(0.671)	(1.309)
Industrial contribution to GDP	−0.111**	–	−0.033	–	0.511***
	(0.045)	–	(0.233)	–	(0.130)
Manufactural contribution to GDP	–	0.117**	−0.416	–	–
	–	(0.049)	(0.284)	–	–
Constant	4.342	−2.775	−116.2***	−6.532*	−80.27***
	(7.628)	(4.390)	(22.590)	(3.553)	(26.220)
Observations	31	31	31	31	31
R-squared	0.683	0.821	0.948	0.666	0.736
Robustness test					
Durbin's alternative test for autocorrelation	0.501	0.216	2.059	0.487	2.711
	[0.487]	[0.649]	[0.194]	[0.494]	[0.118]
LM test for autoregressive conditional heteroskedasticity (ARCH)	1.743	0.022	0.032	0.022	2.544
	[0.187]	[0.882]	[0.859]	[0.883]	[0.111]
White's test for homoskedasticity	40.81	45.210	47.340	43.300	50.410
	[0.435]	[0.463]	[0.693]	[0.373]	[0.204]

Note: hydroelectric consumption is the dependent variable; Standard error in parentheses; p-value in squared brackets; and ***, **, * are statistically significant at 1, 5, and 10 per cent, respectively.

Vietnam, respectively. Meanwhile, the *contribution of manufacturing to GDP* only presents a significantly positive effect on *hydroelectricity* consumption in Malaysia. Industry and manufacturing have no significant impacts on *hydroelectric consumption* in the Philippines.

Table 9 presents results of ARDL regression with the structural breaks found by the Gregory–Hansen test (in Table 5). In the long run, while considering the presence of structural breaks, only Thailand reveals a significant relationship between *growth rate of urban population* and *consumption of hydroelectric power*. In the short run, the significant relation is found in Indonesia, Malaysia, and Thailand. However, the effects are different. While *urbanization* positively affects *hydroelectric consumption* in Malaysia, the negative impact is found in Indonesia and Thailand.

In Table 9, while considering the presence of the structural breaks, only Thailand reveals significant effects of *economic growth* on *hydroelectricity* consumption, in both the long run and the short run, with positive and negative influences, respectively. Besides, in the short term, *industry* and *manufactur*ing positively affect *hydroelectric consumption* in Vietnam and Malaysia, respectively.

Fig. 1 presents the results of the Granger causality test based on the Toda – Yamamoto approach. Urbanization is found to Granger cause hydroelectric consumption in Thailand, whereas the reversed Granger causality is found in Indonesia and the Philippines. Besides, a bidirectional causality between urbanization and renewable energy consumption presents in Malaysia, whereas no causal relationship is found in Vietnam. Besides, GDP has a unidirectional causality to the hydropower consumption in Indonesia, the Philippines, Malaysia, and Vietnam, whereas the reversed causality is found in Thailand. On the other hand, industrialization and

Table 9
Empirical results from the ARDL results include breaks confirmed by the Gregory – Hansen co-integration test.

Country	Indonesia	Malaysia	The Philippines	Thailand	Vietnam
Error Correction Term	−1.045**	−0.470*	−3.123	−1.599***	−0.162
	(0.494)	(0.217)	(1.557)	(0.247)	(0.271)
Long-run results					
Urbanization growth	2.274	−1.377	0.081	0.149***	23.360
	(2.049)	(0.783)	(0.235)	(0.051)	(33.370)
GDP (Log)	1.402	0.616	0.939	0.251***	30.830
	(2.782)	(0.375)	(0.971)	(0.057)	(42.980)
Industrial contribution to GDP	0.152	−0.239	0.141	0.008	−4.645
	(0.177)	(0.147)	(0.505)	(0.052)	(7.575)
Manufactural contribution to GDP	−0.128	0.422	0.107	−0.022	6.350
	(0.413)	(0.239)	(0.596)	(0.059)	(10.890)
Short-run results					
Urbanization growth	−0.881*	0.611*	0.093	−0.372***	−1.845
	(0.467)	(0.306)	(0.499)	(0.101)	(2.440)
Hydroelectric consumption (1-year lagged)	0.008	–	1.746	0.868***	−0.751*
	(0.354)	–	(1.024)	(0.198)	(0.364)
GDP (Log)	–	0.587	−0.441	−1.800***	−1.709
	–	(0.380)	(3.039)	(0.428)	(2.324)
Industrial contribution to GDP	−0.066	–	0.007	–	0.357**
	(0.055)	–	(1.135)	–	(0.149)
Manufactural contribution to GDP	–	0.109**	−0.686	–	–
	–	(0.0482)	(0.971)	–	–
Constant	−50.860	−4.535	−92.310	−8.263***	−123.800*
	(78.720)	(4.398)	(77.140)	(2.304)	(57.820)
Observations	32	31	31	32	31
R-squared	0.752	0.891	0.969	0.870	0.838
Robustness test					
Durbin's alternative test for autocorrelation	1.083	0.479	0.833	0.207	2.201
	[0.313]	[0.505]	[0.458]	[0.655]	[0.164]
LM test for autoregressive conditional heteroskedasticity (ARCH)	4.211	0.654	0.591	0.013	8.968
	[0.040]	[0.419]	[0.441]	[0.909]	[0.028]
White's test for homoskedasticity	43.600	46.500	60.250	41.530	47.000
	[0.573]	[0.614]	[0.394]	[0.698]	[0.514]

Note: hydroelectric consumption denotes the dependent variable; Standard error in parentheses; p-value in squared brackets; and ***, **, * are statistically significant at 1, 5, and 10 per cent, respectively.

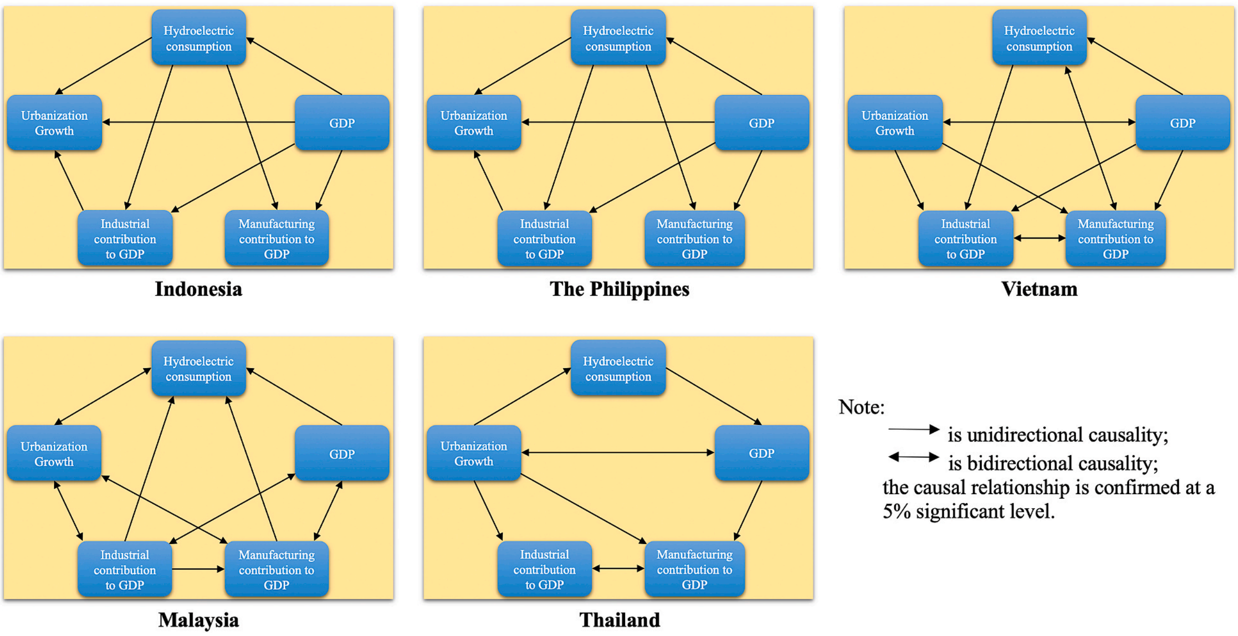

Fig. 1. Granger causality test based on Toda – Yamamoto approach for ASEAN-5 countries.

modernization led to hydroelectric consumption in Malaysia. The opposite causality is confirmed in Indonesia, the Philippines, and Thailand. In Vietnam, hydropower consumption Granger causes industrialization but has bidirectional Granger causality with manufacture. Our Granger causality results are similar to findings from Ref. [65], which confirmed causal relationships between population growth and renewable energy consumption in the ASEAN region.

Fig. 1 presents a unidirectional Granger causality between economic growth (GDP) and urbanization in Indonesia and the Philippines. In contrast, a bidirectional causality is found in Thailand and Vietnam. Our results also confirm no causality in Malaysia. Industrialization Granger causes urbanization in Indonesia and the Philippines, and the reverse is found in Thailand and Vietnam. Besides, a bidirectional Granger causality between industrialization and urbanization is found in Malaysia.

5. Discussion

Based on our empirical evidence, we find some long-term effects of urbanization on renewable energy consumption. A positive relationship between urbanization and renewable energy consumption is confirmed in the Philippines, Thailand, and Vietnam. Compared with [24], the Philippines, Thailand, and Vietnam revealed that urbanization reduces the use of fossil energy sources in the long term. This evidence implies a positive change in energy consumption structure in these ASEAN nations toward using more environmentally friendly energy sources. Therefore, Indonesia, Thailand, and Vietnam reveal a tendency of energy transformation toward renewable sources for their modernization process in the long term.

Results from the Granger causality test exhibit different angles of the relationship between urbanization and renewable energy consumption. For Indonesia, since the 2010s, it has faced challenges of a high degree of urbanization with an exhausted infrastructure, leading to inequality and social instability [66,67]. As such, Indonesia announced a National Urban Development Project to plan and prioritize its capital investments for transportation, housing, economic strategies, and the environment in 2021. Before the project, the development of infrastructure, in which renewable energy is the primary power source for economic strategy and environmental goals, might influence the speed of urbanization in Indonesia. In addition [68], argued that energy consumption tends to enhance the urbanizing process in the Philippines. In addition [69], reported that Thailand improves urbanization in small cities to utilize sustainable economic benefits from urbanization in various regions instead of focusing on its current economic and social hub – Bangkok. Therefore, urbanization in Thailand intensely puts pressure on power demand. For Malaysia, while the country has promised potential sources of hydropower [70], it has also asserted that it will pursue an environmentally friendly economy while focusing on urbanization to encourage social and business innovations [71]. As such, Malaysia's bidirectional causality between urbanization and hydroelectric consumption is reasonable.

Regarding empirical results, in the case of Malaysia, urbanization in this country consumes less hydroelectricity and fossil power in the long term as in Ref. [24]. Meanwhile, in the short-term, urbanization in Malaysia has a tremendous demand for power, including hydroelectricity, as our findings, and coal and gas sources [24]. There is a particular case in Malaysia in which the inverse effects of urbanization on hydroelectric consumption in the long- and short-run are confirmed. At first, the geographical characteristics of Malaysia facilitate the development of small hydropower [72]. Besides, small hydropower development in Malaysia has several challenges, such as financial support, floods, and overflow caused by heavy rainfall. Thus, the growth rate of urbanization could be beyond the capacity of hydroelectric production in Malaysia in the long term.

To compare with previous findings, our results are similar to Ref. [73], at which urbanization and economic growth foster renewable energy consumption. However, our results conflict with [74] about the effect of economic growth on renewable energy consumption. Notably, our findings indicate that economic growth reduces the use of renewable energy in the short term. At the same time [74], confirmed a positive effect of economic growth on renewable energy consumption in middle-income countries. Our results are reasonable as developing ASEAN nations prioritize the growth target in the short run by using more affordable power sources instead of renewable energy.

In conclusion, our findings indicate that ASEAN countries are pursuing a more sustainable energy structure by switching from fossil sources to environmentally friendly sources toward their modernization and industrialization. Although Indonesia, Malaysia, the Philippines, Thailand, and Vietnam need time to achieve their long-term sustainable goals, they are exhibiting their commitments to the Sustainable Development Agenda from the United Nations, particularly the seventh and the thirteenth goals – Affordable and Clean Energy and Climate Action. While Affordable and Clean Energy ensures access to clean and affordable energy, Climate Action aims to reduce and prevent climate changes and their harmful impacts on the global environment. Changes from using fossil energy sources to environmentally friendly sources can be a promising dual solution for ASEAN nations and other countries worldwide.

6. Conclusions and policy recommendation

Most energy–growth studies have focused on industrialized countries [22,23] and large manufactured nations [18–21,34]. Studies for the ASEAN region, a new economic force in the Asia-Pacific region, have largely been ignored, especially the relationship between urbanization and renewable energy. Regardless of some recent efforts investigating this gap [48,75], we further examine the impact of urbanization on renewable energy consumption in the ASEAN emerging markets in the short and long run.

Results from co-integration tests confirm the long-run relationship between urbanization, renewable consumption, economic growth, industrialization, and manufacturing in five ASEAN nations. Empirically, based on the ARDL regression, urbanization in Indonesia, the Philippines, Thailand, and Vietnam significantly enhances the demand for hydroelectricity. Particularly, an increase in the speed of urbanization in Malaysia reduces hydroelectric consumption in the long run. In the short run, the negative effect of urbanization on hydroelectric consumption can be found in Indonesia, Thailand, and Vietnam, whereas Malaysia and the Philippines reveal the inversed results.

Policy implications have emerged based on these essential findings for these five emerging ASEAN markets: Indonesia, Malaysia, the Philippines, Thailand, and Vietnam. Results are relatively similar for Vietnam and Thailand. The short-term negative impacts and the long-term positive effects of urbanization on hydroelectric consumption in Thailand and Vietnam support the transition of energy structure toward renewable energy sources in these countries. Thus, the two nations should develop and encourage investment in renewable energy, especially hydropower, to support sustainable economic growth and development. In Thailand, the unidirectional Granger causality from urbanization to hydroelectric consumption and economic growth implies a potential contribution of urbanization for sustainable economic growth. As such, the Thai government may pursue urbanization to support economic growth and reduce urbanization's negative impacts on environmental quality using renewable energy. A unidirectional causality from economic growth to (hydroelectric) renewable consumption and a bidirectional causality between economic growth and urbanization are confirmed in Vietnam. Furthermore, these links demonstrate an indirect effect of urbanization on renewable energy consumption via economic growth. Urbanization supports economic growth in Vietnam, which then encourages renewable energy usage.

For the Philippines, the positive effect of urbanization on renewable consumption is confirmed in both the short- and long-run. These findings demonstrate the extended usage of environmentally friendly energy in the urban area of the country. As such, the Philippines' government may need to focus on hydropower development in its energy policy. Besides, a unidirectional causality from renewable consumption to urbanization in the Philippines encourages the country to foster hydroelectricity technology to support urbanization. For Indonesia, our empirical results indicate the short-term adverse effects of urbanization on hydroelectric consumption. In addition, economic growth, renewable consumption, and industrialization have unidirectional causality to urbanization. Thus, urbanization is a consequence of economic growth in Indonesia. As such, urbanization may not be a good starting point for developing renewable energy in Indonesia.

In the case of Malaysia, the long-term negative impact of urbanization on renewable indicates two potential scenarios. At first, the worst case is that there is a transformation of energy consumption toward non-renewable sources in Malaysia's urban areas. The second scenario is that the Malaysian government directs its modernizing process toward energy efficiency to mitigate the increase in total energy consumption. On the other hand, bidirectional causalities among three pairs (i) urbanization and hydroelectric consumption, (ii) urbanization and industrialization, and (iii) urbanization and manufacturing imply that urbanization plays a key role in Malaysia. Then, the country might pay more attention to urbanizing policies to approach a dual development goal: (i) economic growth and (ii) environmental security.

Finally, this study aims to examine the link between urbanization and renewable energy consumption in ASEAN countries. Besides our findings, there are some potential contributions for future research. First, employing the ARDL technique with limited time-series observations restricts us from considering further control variables. Therefore, it could be a potential issue of omitted variables, even though they are control variables. At this point, further research can investigate other methods to enhance the robustness of results. Second, we need more data on other kinds of renewable energy to dig into more specific characteristics of energy structure among these ASEAN nations. Therefore, future research can investigate advanced econometric techniques or more specific data on renewable energy sources to contribute to the literature on the relationship between urbanization and renewable energy consumption in developing nations.

Data availability statement

Data is publicly available from World Development Indicators and British Petro Statistics.

CRediT authorship contribution statement

Duc Hong Vo: Writing – review & editing, Writing – original draft, Validation, Supervision, Formal analysis, Conceptualization. **Anh The Vo:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation. **Chi Minh Ho:** Writing – review & editing, Writing – original draft, Validation, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] J. Duan, Y. Yan, B. Zheng, J. Zhao, Analysis of the relationship between urbanisation and energy consumption in China, Int. J. Sustain. Dev. World Ecol. 15 (2008) 309–317, https://doi.org/10.3843/SusDev.15.4:4a.

[2] K. Li, L. Fang, L. He, How urbanization affects China's energy efficiency: a spatial econometric analysis, J. Clean. Prod. 200 (2018) 1130–1141, https://doi.org/10.1016/j.jclepro.2018.07.234.

[3] Z. Mrabet, M. Alsamara, A.S. Saleh, S. Anwar, Urbanization and non-renewable energy demand: a comparison of developed and emerging countries, Energy 170 (2019) 832–839, https://doi.org/10.1016/j.energy.2018.12.198.

[4] P. Poumanyvong, S. Kaneko, Does urbanization lead to less energy use and lower CO2 emissions? A cross-country analysis, Ecol. Econ. 70 (2010) 434–444, https://doi.org/10.1016/j.ecolecon.2010.09.029.

[5] ASEAN Sustainable Urbanisation Forum, 2021. https://connectivity.asean.org/asuf/. (Accessed 16 November 2022).

[6] ACE, The 7th ASEAN energy outlook, ASEAN Cent. Energy (2022). https://aseanenergy.org/the-7th-asean-energy-outlook/. (Accessed 16 November 2022).

[7] IEA, World Energy Balances - Data Product, IEA, 2022. https://www.iea.org/data-and-statistics/data-product/world-energy-balances. (Accessed 16 November 2022).
[8] J. Verriere, Powering ASEAN's future: energy transition challenges and opportunities. https://www.enerdata.net/publications/executive-briefing/asean-energy-connectivity.html, 2023. (Accessed 25 February 2024).
[9] D.H. 1 1 H.C.M.C.O.U. Vo, Sustainable agriculture & energy in the U.s.: a link between ethanol production and the acreage for corn, 259–268, https://doi.org/10.14254/2071-789X.2020/13-3/16, 2020.
[10] T.N. Vu, C.M. Ho, T.C. Nguyen, D.H. Vo, The determinants of risk transmission between oil and agricultural prices: an IPVAR approach, Agriculture 10 (2020) 120, https://doi.org/10.3390/agriculture10040120.
[11] The British Petro Statistics, Statistical review of World energy, bp glob. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/year-in-review.html, 2019. (Accessed 13 October 2020).
[12] P. Benoit, Energy and development in a changing World: a framework for the 21st century, Cent. Glob. Energy Policy Columbia Univ. SIPA CGEP (2019). https://www.energypolicy.columbia.edu/publications/energy-and-development-changing-world-framework-21st-century/. (Accessed 27 February 2024).
[13] IEA, Energy Consumers of Tomorrow – World Energy Outlook 2021 – Analysis, IEA, 2021. https://www.iea.org/reports/world-energy-outlook-2021/energy-consumers-of-tomorrow. (Accessed 27 February 2024).
[14] U. Al-mulali, C.N. Binti Che Sab, H.G. Fereidouni, Exploring the bi-directional long run relationship between urbanization, energy consumption, and carbon dioxide emission, Energy 46 (2012) 156–167, https://doi.org/10.1016/j.energy.2012.08.043.
[15] U. Al-mulali, H.G. Fereidouni, J.Y.M. Lee, C.N.B.C. Sab, Exploring the relationship between urbanization, energy consumption, and CO2 emission in MENA countries, Renew. Sustain. Energy Rev. 23 (2013) 107–112, https://doi.org/10.1016/j.rser.2013.02.041.
[16] U. Al-Mulali, I. Ozturk, The effect of energy consumption, urbanization, trade openness, industrial output, and the political stability on the environmental degradation in the MENA (Middle East and North African) region, Energy 84 (2015) 382–389, https://doi.org/10.1016/j.energy.2015.03.004.
[17] K. Li, B. Lin, Impacts of urbanization and industrialization on energy consumption/CO2 emissions: does the level of development matter? Renew. Sustain. Energy Rev. 52 (2015) 1107–1122, https://doi.org/10.1016/j.rser.2015.07.185.
[18] Q. Wang, S. Wu, Y. Zeng, B. Wu, Exploring the relationship between urbanization, energy consumption, and CO2 emissions in different provinces of China, Renew. Sustain. Energy Rev. 54 (2016) 1563–1579, https://doi.org/10.1016/j.rser.2015.10.090.
[19] C. Zhang, Y. Lin, Panel estimation for urbanization, energy consumption and CO2 emissions: a regional analysis in China, Energy Pol. 49 (2012) 488–498, https://doi.org/10.1016/j.enpol.2012.06.048.
[20] M. Shahbaz, M. Shafiullah, V.G. Papavassiliou, S. Hammoudeh, The CO2–growth nexus revisited: a nonparametric analysis for the G7 economies over nearly two centuries, Energy Econ. 65 (2017) 183–193, https://doi.org/10.1016/j.eneco.2017.05.007.
[21] S. Wang, C. Fang, X. Guan, B. Pang, H. Ma, Urbanisation, energy consumption, and carbon dioxide emissions in China: a panel data analysis of China's provinces, Appl. Energy 136 (2014) 738–749, https://doi.org/10.1016/j.apenergy.2014.09.059.
[22] J. Chontanawat, L.C. Hunt, R. Pierse, Does energy consumption cause economic growth?: evidence from a systematic study of over 100 countries, J. Pol. Model. 30 (2008) 209–220, https://doi.org/10.1016/j.jpolmod.2006.10.003.
[23] A. Kasman, Y.S. Duman, CO2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: a panel data analysis, Econ. Modell. 44 (2015) 97–103, https://doi.org/10.1016/j.econmod.2014.10.022.
[24] C.M. Ho, L.T. Nguyen, A.T. Vo, D.H. Vo, Urbanization and the consumption of fossil energy sources in the emerging southeast Asian countries, Environ. Urban. ASIA 12 (2021) 90–103, https://doi.org/10.1177/0975425321990378.
[25] FEBIS, The environmental problems facing Southeast Asia, Fed. Bus. Inf. Serv. http://www.febis.org/2023/07/26/the-environmental-problems-facing-southeast-asia/, 2023. (Accessed 27 February 2024).
[26] S.Y.L. Tan, H. Kamaruddin, Environmental challenges within ASEAN: contemporary legal issues and future considerations, in: A. Idris, N. Kamaruddin (Eds.), ASEAN Post-50 Emerg. Issues Chall, Springer, Singapore, 2019, pp. 155–176, https://doi.org/10.1007/978-981-13-8043-3_8.
[27] ASEAN, ASEAN joint statement on climate change to the 28th session of the conference of the parties to the united nations framework, Convention on Climate Change (UNFCCC COP-28), ASEAN Main Portal (2023). https://asean.org/asean-joint-statement-on-climate-change-to-the-28th-session-of-the-conference-of-the-parties-to-the-united-nations-framework-convention-on-climate-change-unfccc-cop-28/ (accessed February 27, 2024).
[28] A. Aslan, N. Apergis, S. Yildirim, Causality between energy consumption and GDP in the U.S.: evidence from wavelet analysis, Front. Energy 8 (2014) 1–8, https://doi.org/10.1007/s11708-013-0290-6.
[29] M. Bartleet, R. Gounder, Energy consumption and economic growth in New Zealand: results of trivariate and multivariate models, Energy Pol. 38 (2010) 3508–3517, https://doi.org/10.1016/j.enpol.2010.02.025.
[30] A. Belke, F. Dobnik, C. Dreger, Energy consumption and economic growth: new insights into the cointegration relationship, Energy Econ. 33 (2011) 782–789, https://doi.org/10.1016/j.eneco.2011.02.005.
[31] P.K. Narayan, S. Narayan, S. Popp, A note on the long-run elasticities from the energy consumption–GDP relationship, Appl. Energy 87 (2010) 1054–1057, https://doi.org/10.1016/j.apenergy.2009.08.037.
[32] N.S. Ouedraogo, Energy consumption and economic growth: evidence from the economic community of West African States (ECOWAS), Energy Econ. 36 (2013) 637–647, https://doi.org/10.1016/j.eneco.2012.11.011.
[33] I. Ozturk, A. Acaravci, The causal relationship between energy consumption and GDP in Albania, Bulgaria, Hungary and Romania: evidence from ARDL bound testing approach, Appl. Energy 87 (2010) 1938–1943, https://doi.org/10.1016/j.apenergy.2009.10.010.
[34] B. Li, N. Haneklaus, The role of renewable energy, fossil fuel consumption, urbanization and economic growth on CO2 emissions in China, Energy Rep. 7 (2021) 783–791, https://doi.org/10.1016/j.egyr.2021.09.194.
[35] N.A. Burney, Socioeconomic development and electricity consumption A cross-country analysis using the random coefficient method, Energy Econ. 17 (1995) 185–195, https://doi.org/10.1016/0140-9883(95)00012-J.
[36] C. Dahl, M. Erdogan, Oil demand in the developing World: lessons from the 1980s applied to the 1990s, Energy J. 15 (1994), https://doi.org/10.5547/ISSN0195-6574-EJ-Vol15-NoSI-5.
[37] M. Lenzen, M. Wier, C. Cohen, H. Hayami, S. Pachauri, R. Schaeffer, A comparative multivariate analysis of household energy requirements in Australia, Brazil, Denmark, India and Japan, Energy 31 (2006) 181–207, https://doi.org/10.1016/j.energy.2005.01.009.
[38] I. Larivière, G. Lafrance, Modelling the electricity consumption of cities: effect of urban density, Energy Econ. 21 (1999) 53–66, https://doi.org/10.1016/S0140-9883(98)00007-3.
[39] Y. Liu, Exploring the relationship between urbanization and energy consumption in China using ARDL (autoregressive distributed lag) and FDM (factor decomposition model), Energy 34 (2009) 1846–1854, https://doi.org/10.1016/j.energy.2009.07.029.
[40] R. Madlener, Y. Sunak, Impacts of urbanization on urban structures and energy demand: what can we learn for urban energy planning and urbanization management? Sustain. Cities Soc. 1 (2011) 45–53, https://doi.org/10.1016/j.scs.2010.08.006.
[41] M. Aguirre, G. Ibikunle, Determinants of renewable energy growth: a global sample analysis, Energy Pol. 69 (2014) 374–384, https://doi.org/10.1016/j.enpol.2014.02.036.
[42] B. Quito, M. de la C. del Río-Rama, J. Álvarez- García, F.V. Bekun, Spatiotemporal influencing factors of energy efficiency in 43 european countries: a spatial econometric analysis, Renew. Sustain. Energy Rev. 182 (2023) 113340, https://doi.org/10.1016/j.rser.2023.113340.
[43] R.A. Salim, S. Shafiei, Urbanization and renewable and non-renewable energy consumption in OECD countries: an empirical analysis, Econ. Modell. 38 (2014) 581–591, https://doi.org/10.1016/j.econmod.2014.02.008.
[44] J. Yang, W. Zhang, Z. Zhang, Impacts of urbanization on renewable energy consumption in China, J. Clean. Prod. 114 (2016) 443–451, https://doi.org/10.1016/j.jclepro.2015.07.158.
[45] Y. Chen, Factors influencing renewable energy consumption in China: an empirical analysis based on provincial panel data, J. Clean. Prod. 174 (2018) 605–615, https://doi.org/10.1016/j.jclepro.2017.11.011.

[46] F.V. Bekun, Mitigating emissions in India: accounting for the role of real income, renewable energy consumption and investment in energy, Int. J. Energy Econ. Pol. 12 (2022) 188–192, https://doi.org/10.32479/ijeep.12652.
[47] S. Nathaniel, S.A.R. Khan, The nexus between urbanization, renewable energy, trade, and ecological footprint in ASEAN countries, J. Clean. Prod. 272 (2020) 122709, https://doi.org/10.1016/j.jclepro.2020.122709.
[48] T. Tran, Q. Tran, N.T. Vu, D.H. Vo, Renewable energy, urbanization, financial development and environmental degradation in the ASEAN countries, Environ. Urban. ASIA 14 (2023) 10–23, https://doi.org/10.1177/09754253221151102.
[49] S.-Z. Huang, M. Sadiq, F. Chien, Dynamic nexus between transportation, urbanization, economic growth and environmental pollution in ASEAN countries: does environmental regulations matter? Environ. Sci. Pollut. Res. 30 (2023) 42813–42828, https://doi.org/10.1007/s11356-021-17533-z.
[50] M. Salman, D. Zha, G. Wang, Interplay between urbanization and ecological footprints: differential roles of indigenous and foreign innovations in ASEAN-4, Environ. Sci. Pol. 127 (2022) 161–180, https://doi.org/10.1016/j.envsci.2021.10.016.
[51] British Petro Statistics, Energy economics | Home, Bp Glob. (n.d.). https://www.bp.com/en/global/corporate/energy-economics.html (accessed February 27, 2024)..
[52] WDI, World Development Indicators | Data Catalog, (n.d.). https://datacatalog.worldbank.org/search/dataset/0037712/World-Development-Indicators (accessed February 27, 2024)..
[53] P. Jiang, Y.V. Fan, J.J. Klemeš, Impacts of COVID-19 on energy demand and consumption: challenges, lessons and emerging opportunities, Appl. Energy 285 (2021) 116441, https://doi.org/10.1016/j.apenergy.2021.116441.
[54] M. Krarti, M. Aldubyan, Review analysis of COVID-19 impact on electricity demand for residential buildings, Renew. Sustain. Energy Rev. 143 (2021) 110888, https://doi.org/10.1016/j.rser.2021.110888.
[55] J.P. Painuly, Barriers to renewable energy penetration; a framework for analysis, Renew. Energy 24 (2001) 73–89, https://doi.org/10.1016/S0960-1481(00)00186-5.
[56] P. Hartmann, V. Apaolaza-Ibáñez, Consumer attitude and purchase intention toward green energy brands: the roles of psychological benefits and environmental concern, J. Bus. Res. 65 (2012) 1254–1263, https://doi.org/10.1016/j.jbusres.2011.11.001.
[57] M. del P. Pablo-Romero, J. De Jesús, Economic growth and energy consumption: the energy-environmental Kuznets Curve for Latin America and the Caribbean, Renew. Sustain. Energy Rev. 60 (2016) 1343–1350, https://doi.org/10.1016/j.rser.2016.03.029.
[58] S.J. Ergun, P.A. Owusu, M.F. Rivas, Determinants of renewable energy consumption in Africa, Environ. Sci. Pollut. Res. 26 (2019) 15390–15405, https://doi.org/10.1007/s11356-019-04567-7.
[59] M.B. Shrestha, G.R. Bhatta, Selecting appropriate methodological framework for time series data analysis, J. Finance Data Sci. 4 (2018) 71–89, https://doi.org/10.1016/j.jfds.2017.11.001.
[60] M.A. Danish, S. Suad Baloch, Modeling the impact of transport energy consumption on CO2 emission in Pakistan: evidence from ARDL approach, Environ. Sci. Pollut. Res. 25 (2018) 9461–9473, https://doi.org/10.1007/s11356-018-1230-0.
[61] N.M. Odhiambo, Energy consumption and economic growth nexus in Tanzania: an ARDL bounds testing approach, Energy Pol. 37 (2009) 617–622, https://doi.org/10.1016/j.enpol.2008.09.077.
[62] R. Sari, B.T. Ewing, U. Soytas, The relationship between disaggregate energy consumption and industrial production in the United States: an ARDL approach, Energy Econ. 30 (2008) 2302–2313, https://doi.org/10.1016/j.eneco.2007.10.002.
[63] R. Harris, R. Sollis, Applied Time Series Modelling and Forecasting, first ed., Wiley, New Jersey, 2003. https://www.wiley.com/en-us/Applied+Time+Series+Modelling+and+Forecasting-p-9780470844434. (Accessed 24 March 2023).
[64] H.Y. Toda, T. Yamamoto, Statistical inference in vector autoregressions with possibly integrated processes, J. Econom. 66 (1995) 225–250, https://doi.org/10.1016/0304-4076(94)01616-8.
[65] D.H. Vo, A.T. Vo, Renewable energy and population growth for sustainable development in the Southeast Asian countries, Energy Sustain. Soc. 11 (2021) 30, https://doi.org/10.1186/s13705-021-00304-6.
[66] World Bank, Indonesia's Urban Story, World Bank, 2016. https://www.worldbank.org/en/news/feature/2016/06/14/indonesia-urban-story. (Accessed 26 February 2024).
[67] L. Boediono, N. Keyes, Indonesia: Integrated Development to Improve Lives of Growing Urban Population, World Bank (n.d.). https://www.worldbank.org/en/news/press-release/2019/06/11/indonesia-integrated-development-to-improve-lives-of-growing-urban-population (accessed February 26, 2024)..
[68] A. Raihan, The dynamic nexus between economic growth, renewable energy use, urbanization, industrialization, tourism, agricultural productivity, forest area, and carbon dioxide emissions in the Philippines, Energy Nexus 9 (2023) 100180, https://doi.org/10.1016/j.nexus.2023.100180.
[69] K. Kongrukgreatiyos, Thailand's smaller cities can help drive economic growth and reduce inequality. https://www.worldbank.org/en/news/press-release/2023/09/01/thailand-s-smaller-cities-can-help-drive-economic-growth-and-reduce-inequality, 2023. (Accessed 27 February 2024).
[70] International Water Power & Dam Construction, Harnessing Hydropower in Malaysia - International Water Power, 2020. https://www.waterpowermagazine.com/features/featureharnessing-hydropower-in-malaysia-8396270/. (Accessed 27 February 2024).
[71] C.H. Seng, Urbanization in Malaysia and potential of social innovation business : Hitachi review. https://www.hitachi.com/rev/archive/2018/r2018_04/gir/index.html, 2018. (Accessed 27 February 2024).
[72] S. Abdullah, E.A. Azrulhisham, M.J.M. Basri, J. Othman, Exploring Malaysia's small Hydro potential, Hydro Rev. (2016). https://www.hydroreview.com/business-finance/exploring-malaysia-s-small-hydro-potential/. (Accessed 17 November 2022).
[73] S. Nathaniel, O. Anyanwu, M. Shah, Renewable energy, urbanization, and ecological footprint in the Middle East and North Africa region, Environ. Sci. Pollut. Res. 27 (2020) 14601–14613, https://doi.org/10.1007/s11356-020-08017-7.
[74] A. Omri, D.K. Nguyen, On the determinants of renewable energy consumption: international evidence, Energy 72 (2014) 554–560, https://doi.org/10.1016/j.energy.2014.05.081.
[75] A. Awan, M. Kocoglu, A. Bandyopadhyay, S. Rej, M. Altuntaş, A quantile-based analysis of the nexus between hydropower generation, trade and urbanization for China utilizing the EKC hypothesis, Environ. Model. Assess. 28 (2023) 843–857, https://doi.org/10.1007/s10666-023-09889-y.