Comparative Analysis of Energy Efficiency Programs in Large ASEAN Industries with Sustainable Energy Indicators

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Abstract. Reducing energy demand through energy efficiency (EE) policies is a key strategy in dealing with climate change and the energy needs of Southeast Asian countries (ASEAN). The industrial sector is the largest energy user sector and has significant energy-saving potential through good and sustainable energy management. This research is intended to analyze the progress of energy-saving programs in several ASEAN countries through policies that have been made with a focus on large industries. Five steps will be carried out, namely: searching for data on total population, GDP and total final energy consumption; conducting analysis with indicators of energy intensity, per capita energy consumption and GDP productivity; comparing the EE programs of ASEAN countries; designing savings strategies; and determine sustainable energy indicators. As a result, the energy consumption of ASEAN countries during the 2016 to 2020 time period has mostly increased. The policies that have been taken have similarities such as the implementation of energy audit and management, the application of minimum equipment performance standards, and the funding of the EE program. ASEAN countries need cooperation and coordination to ensure readiness in welcoming the energy transition.

Keywords: Energy audit, energy conservation, energy program, green industry.

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1 Introduction

ASEAN as a highly diverse and dynamic region [1], with a cumulative Gross Domestic Product (GDP) of USD 2.5×10^{12}, is one of the largest economic coalitions. ASEAN economic growth has increased energy demand by 70 % compared to 2 000 and contributed 5 % of total global energy demand. Economic growth is the main driver of emissions growth, while population growth has only a small impact on emissions growth [2]. Indonesia is the largest country in ASEAN, and a 1 % increase in the use of fossil energy will increase CO_2 emissions by 0.67 % [3]. Coal and natural gas have dominated the ASEAN electricity sector with a contribution of 77 % [4]. ASEAN countries plan to reduce regional energy intensity by 30 % by 2025 through energy efficiency. ASEAN's energy intensity is expected to increase from 2013 to 2035 as its energy demand is expected to increase only 2.7 times while GDP grows 3.7 times [5]. Final energy consumption has increased quite rapidly over the last two decades, with the industrial and transportation sectors being the largest contributors. The industrial sector experienced the largest increase in energy use of any sector. In the industrial sector, the shift from coal to gas and oil to gas plays an important role in reducing emissions from this sector by 2030.

As the largest energy consumer, the industrial sector has the potential to save energy through proper and sustainable energy management. This industrial sector consumes more than 29 % of the final energy consumption [6]. Energy management aims to improve energy efficiency. This minimizes energy wastage, cuts energy costs and helps companies reduce their profits. In the industrial sector, energy consumption will increase by almost 40 % in 2030 and 80 % in 2050, mainly driven by the light manufacturing sector such as cars and increased production of steel and chemicals [7]. Most countries in the region have set energy efficiency targets. Some of the targets are reducing energy consumption (Brunei, Laos, Myanmar, Vietnam), and reducing energy intensity at the economic level or in certain end-user sectors (Malaysia, Singapore, Thailand), while others specify both (Indonesia, Philippines) [6].

Energy efficiency improvement and renewable energy projects in ASEAN face several obstacles that limit the scope and speed of renewable energy projects, developers face financial, macroeconomic and regulatory challenges [6]. Energy efficiency makes the second largest contribution to lowering CO_2 emissions in the Net Zero Emissions (NZE) scenario over the next decade – a cumulative reduction of 13 Gt that is only surpassed by solar and wind photovoltaic (PV) impacts [8]. Energy efficiency measures can reduce fuel demand while maintaining the same energy levels [9]. Improving industrial energy efficiency often results in high capital costs [10]. Opportunities for energy savings can be realized by overcoming energy waste, controlling energy consumption and utilizing renewable energy technologies [11]. In the automotive component manufacturing industry, the utilization of wasted hot air is one of the steps that can be taken to energy saving and efficiency [12]. In industry, cost remains a significant barrier to adopting more energy-efficient equipment, such as boilers, chillers, motors and transformers [9]. Industry compliance with energy efficiency programs has not been maximized, for example, in Indonesia, it has only reached 10.25 % [13]. The development of an energy management control system can provide an overview of energy-saving opportunities [14].

So far, research related to the efficiency programs of ASEAN countries is more general with various sectors and scopes in each country. More specific discussions related to energy efficiency programs in the industrial sector have not been found. From this research, we will obtain trends in the progress of energy-saving programs in several ASEAN countries through policies that have been made and implemented with a focus on large industries that consume a lot of energy. Furthermore, a comparison will be made with what Indonesia has achieved with the same program for the big industry (consumption of 6 000 toes yr^{-1}). In the end, it is

hoped that this will provide input on what else Indonesia should do to make this energy-saving program with a focus on large industries so that it becomes even more successful.

2 Methods

The methodology used in this study includes three steps. First, look for data in the form of the total population, GDP and total final energy consumption of ASEAN countries for the 2016 to 2020 period from various sources, both papers, journals and reports from international institutions, government and non-government.

Second, processing and analyzing the data with several important indicators:

(i) Energy intensity is defined as the amount of energy consumed per unit of GDP. This indicator is effective for measuring how effectively a country uses energy, measured as the ratio of energy supplied to GDP and calculated by Equation (1)

$$\mathrm{IE} = \frac{\mathrm{EC}}{\mathrm{GDP}} \tag{1}$$

Where IE is the energy intensity, EC is the amount of energy consumed and GDP is the gross domestic product.

(ii) Energy consumption per capita is a cost indicator and can be calculated by Equation (2)

$$\mathrm{ECpc} = \frac{\mathrm{EC}}{\mathrm{P}} \tag{2}$$

Where is EC_{pc} is energy consumption per capita, EC is energy consumption and P is population.

(iii) GDP productivity is the energy efficiency level of GDP, calculated by Equation (3)

$$\mathrm{EE} = \frac{\mathrm{GDP}}{\mathrm{EC}} \tag{3}$$

Third, comparing energy efficiency programs between ASEAN countries, including policies and their follow-up/implementation design a savings strategy as well as determine sustainable energy indicators related to energy efficiency in the industrial sector.

3 Results and discussion

Among ASEAN countries, Cambodia, Laos, Malaysia, Philippines have slightly higher population growth rates than the rest of the ASEAN. In 2021, Cambodia and Laos have a population growth rate of ± 1.4 %, while Malaysia and the Philippines are ± 1.3 %. Population growth is an important indicator of future economic growth and energy demand. From 2016 to 2020, the combined real GDP growth of ASEAN countries shows a positive trend as shown in Table 1. Almost all ASEAN countries experienced a decline in GDP in 2020 due to the emergence of the covid 19 outbreak, except for Vietnam which is consistent with its GDP growth. In terms of energy consumption during the 2016 to 2020 time period, most ASEAN countries have experienced an increase from year to year. Malaysia has shown a downward trend in the last three years of 6.5 %. Energy efficiency measures can help reduce carbon emissions that cause global warming. As shown, in the total energy consumption of all ASEAN countries, Indonesia has the highest energy consumption of 241 044 ktoe, while Laos has the lowest energy consumption of 5 657 ktoe. Indonesia is the largest energy consumer in the ASEAN region with a share of 36 % of the total area's final consumption [15].

Table 1. GDP and total energy consumption of ASEAN countries.

Country	GDP (US$ million) (1)					Total final energy consumption (ktoe) (2)				
	2020	2019	2018	2017	2016	2020	2019	2018	2017	2016
Brunei	12 016	13 469	13 567	12 128	11 401	N/A	N/A	N/A	917 (3)	851 (3)
Philippines	361 489	376 823	346 842	328 481	318 627	56 358	61 621	60 928	59 002	55 904
Indonesia	1 058 424	1 119 091	1 042 272	1 015 619	931 877	216 090	241 044	231 641	221 182	209 697
Cambodia	25 291	27 089	24 572	22 177	20 017	8 182	8 080	7 436	6 902	6 662
Laos	19 136	18 246	17 954	16 853	15 806	6 136	5 657	5 744	5 698	5 210
Malaysia	336 664	364 681	358 715	319 112	301 255	87 886	92 461	94 012	92 239	88 356
Myanmar	76 186	79 844	68 698	67 145	61 449	24 273	23 518	22 686	22 494	19 602
Singapore	339 998	374 386	375 982	343 338	318 764	33 086	34 427	33 249	35 817	32 474
Thailand	501 795	544 264	506 611	456 357	413 366	128 096	138 604	135 146	137 997	138 713
Vietnam	271 158	261 921	245 214	223 780	205 276	90 975	91 195	82 008	70 808	68 572

Sources: (1) CompareEconomy.com; (2) Enerdata.net; (3) eria.org

The energy efficiency trend of ASEAN countries is increasing due to economic and population growth as shown in Table 2. The highest electrical energy intensity score was obtained by Singapore with an average score of 2.50 kWh, while the Philippines had the lowest average score of 0.59 kWh. Energy intensity indicates the energy inefficiency of an economy and is measured as energy use per unit of GDP.

Table 2. Electrical energy intensity of ASEAN countries (kWh).

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018
Philippines	0.61	0.59	0.57	0.57	0.57	0.59	0.60	0.62	0.60
Indonesia	0.88	0.88	0.86	0.78	0.75	0.73	0.71	0.70	0.74
Cambodia	0.65	0.65	0.67	0.66	0.68	0.73	0.85	0.84	0.99
Laos	1.12	1.35	1.30	1.42	1.35	1.48	2.92	2.76	2.71
Malaysia	1.81	1.74	1.80	1.80	1.72	1.66	1.68	1.61	1.56
Myanmar	0.36	0.38	0.42	0.45	0.49	0.42	0.46	0.57	0.58
Singapore	2.65	2.56	2.48	2.41	2.40	2.50	2.54	2.52	2.44
Thailand	1.40	1.43	1.43	1.40	1.43	1.42	1.40	1.37	1.36
Vietnam	1.32	1.38	1.37	1.38	1.44	1.53	1.56	1.57	1.64

From the data in Table 1 using Equation 1, the energy intensity of ASEAN countries for the period 2016 to 2020 is obtained, the calculation results are shown in Table 3. Vietnam, Myanmar, Laos and Cambodia have energy intensity above 0.3 while Singapore is a country that has the lowest energy intensity value followed by the Philippines, Indonesia, Malaysia and Thailand. Especially for Brunei, the intensity value is quite low, but the data is not representative of the period studied.

Table 3. Energy intensity of ASEAN countries (ktoe per US$ million).

Country	2020	2019	2018	2017	2016
Brunei	N/A	N/A	N/A	0.08	0.07
Philippines	0.16	0.16	0.18	0.18	0.18
Indonesia	0.20	0.22	0.22	0.22	0.23
Cambodia	0.32	0.30	0.30	0.31	0.33
Laos	0.32	0.31	0.32	0.34	0.33
Malaysia	0.26	0.25	0.26	0.29	0.29
Myanmar	0.32	0.29	0.33	0.34	0.32
Singapore	0.10	0.09	0.09	0.10	0.10
Thailand	0.26	0.25	0.27	0.30	0.34
Vietnam	0.34	0.35	0.33	0.32	0.33

Furthermore, by using Equation 2, the per capita energy consumption of ASEAN countries is obtained. As shown in Table 4, the trend has increased from year to year. Singapore is the country with the highest level of energy consumption capita^{-1} with an average of 5.88 toe capita^{-1}, followed by Malaysia with an average of 2.89 toe capita^{-1}. For ASEAN itself, the average energy consumption level during the 2016 to 2020 period is 1.65 toe capita^{-1}.

Table 4. Energy consumption per capita in ASEAN countries (toe per person).

Country	2020	2019	2018	2017	2016
Brunei	N/A	N/A	N/A	2.16	2.03
Philippines	0.51	0.57	0.57	0.56	0.54
Indonesia	0.79	0.89	0.87	0.84	0.80
Cambodia	0.49	0.49	0.46	0.43	0.42
Laos	0.84	0.79	0.81	0.82	0.76
Malaysia	2.72	2.89	2.98	2.97	2.88
Myanmar	0.45	0.44	0.42	0.42	0.37
Singapore	5.66	5.93	5.77	6.27	5.74
Thailand	1.84	1.99	1.95	1.99	2.01
Vietnam	0.93	0.95	0.86	0.75	0.73

The productivity of GDP to energy is the inverse of energy intensity, calculated using Equation 2. The calculation results for ASEAN countries are summarized in Table 5. Singapore has the highest productivity in 2020 of 10 276 US$ toe^{-1} and increasing from year to year. Indonesia with the largest population is above most ASEAN countries except Singapore, the Philippines and Brunei Darussalam.

Table 5. GDP productivity of ASEAN countries (US$ per toe).

Country	2020	2019	2018	2017	2016
Brunei	N/A	N/A	N/A	13 226	13 397
Philippines	6 414	6 115	5 693	5 567	5 700
Indonesia	4 898	4,643	4 500	4 592	4 444
Cambodia	3 091	3,353	3 304	3 213	3 005
Laos	3 119	3,225	3 126	2 958	3 034
Malaysia	3 831	3,944	3 816	3 460	3 410
Myanmar	3 139	3,395	3 028	2 985	3 135
Singapore	10 276	10,875	11 308	9 586	9 816
Thailand	3 917	3,927	3 749	3 307	2 980
Vietnam	2 981	2,872	2 990	3 160	2 994

ASEAN countries' targets regarding energy efficiency before the implementation of the renewable energy concept are shown in Table 6. In terms of energy conservation, the most optimal target is shown by Brunei with a 63 % reduction in energy consumption by 2035, with Malaysia and Myanmar only targeting a reduction in electricity consumption. Meanwhile, Indonesia, Singapore and Thailand did not set energy conservation targets. The Philippines will reduce energy intensity by 40 % by 2040, Singapore by 35 % by 2030 and Thailand by 30 % by 2036. ASEAN itself is targeting a reduction of energy intensity by 45 % by 2050 [16].

Table 6. Energy efficiency targets of ASEAN countries [9, 17].

Country	Reduction targets			Document
	Final energy consumption	Energy intensity	Year	
Brunei	63 %	45 %	2035	Energy white paper 2014
Cambodia	20 %	N/A	2035	Cambodia energy efficiency plan
Indonesia	17 % (industry), 20 % (transportation), 15 % (households and commercial buildings)	1 % per yr	2025	PP No. 79/2014 concerning national energy policy
Laos	10 %	N/A	2030	National energy efficiency policy 2016
Malaysia	8 % (electricity consumption)	N/A	2025	National energy efficiency action plan
Myanmar	20 % (electricity consumption)	N/A	2030	National energy efficiency & conservation policy strategy & roadmap
Philippines	1 % per annum	40 %	2040	Energy efficiency roadmap for the Philippines, 2017 to 2020
Singapore	35 %	N/A	2030	Singapore sustainable blueprint 2009
Thailand	N/A	30 %	2036	Thailand EE policy 2015
Vietnam	5 % to 7 %, 8 % to 10 %	10 %	2025, 2030	National target program for EE and conservation

The Malaysian government revived the National Energy Efficiency Action Plan (NEEAP) for the period 2016 to 2025. The aim is to promote energy efficiency by ensuring the productive use of energy and minimizing waste. In the field of law, the government established the 2008 Electric Energy Efficient Management Regulation (EMEER) to regulate large energy users to improve energy management practices, especially large factories or industries whose total electricity consumption equals or exceeds 3 000 000 kWh. The Malaysian government's energy efficiency target is 10 % by 2025 and 15 % by 2030 [1].

To achieve the energy efficiency target, the ASEAN countries created a program and no follow-up as shown in Table 7. In general, EE programs that run are almost the same, only differ in terms of the systems and schemes used. The Indonesian government through the energy conservation partnership program provided energy audit services to 647 industries and buildings during 2003 to 2011, issued Indonesian National Work Competency Standards (SKKNI/*Standar Kompetensi Kerja Nasional Indonesia*) for energy managers and Indonesian National Work Competency Standards Draft (RSKKNI/*Rancangan Standar Kompetensi Kerja Nasional Indonesia*) for industrial and building sector auditors.

Singapore through its Minimum Energy Performance Standards (MEPS) program phased out low-efficiency equipment, introduced MEPS to three-phase induction motors in 2018 and gradually expanded its coverage to other industrial equipment. Every year the energy manager submits plans to increase saving energy and monitors and reports energy usage. The government maintains an EE promotion centre which provides information on EE measures, available incentives and EE training.

In terms of EE funding, Malaysia uses the Green Technology Financing Scheme (GTFS) and Green Investment Tax Allowance (GITA) schemes, Singapore provides training grants for certified energy managers and energy resource efficiency, Thailand provides 4 % low-interest financing, the Philippines provides fiscal financing and non-fiscal.

Table 7. Programs and follow-up of ASEAN countries [18–23].

Program and follow up	BN	PH	ID	CD	LA	MY	MM	SG	TH	VN
Application of minimum energy perf. std. (MEPS)	●	●		●		●		●		
Energy management & audit services (AME)	●	●	●	●		●		●		
Promotion of cognation						●				
Promotion of EE and conservation					●	●				
Energy-efficient building design/technology	●					●				
ESCO funding, fiscal/non-fiscal/other incentives	●	●	●	●	●	●	●	●	●	●
Standardization & labelling of energy-saving levels	●	●	●	●		●		●	●	●
Energy efficiency & conservation training			●					●		
Provision of energy eff. promotion centre (EEPC)								●		
Energy Mgr & Energy Auditor officer certification		●	●					●		
Certification of energy supply companies		●								
Efficient power generation & energy conv. tech.			●							

BN: Brunei; PH: Philippines; ID: Indonesia; CD: Cambodia; LA: Laos; MY: Malaysia; MM: Myanmar; SG: Singapore; TH: Thailand; VN: Vietnam

Design savings strategies based on short-term, medium-term and long-term programs.

(i) Short-term. First, designing an industrial park as an eco-industrial park by utilizing the maximum potential of energy wastage in the area. Second, implement consistent and reliable Energy Management and Information Systems (EMIS). Third, gather information on losses in the area of operations and seek best practice information from around the world regarding solutions to repair these losses.

(ii) Medium-term. First, develop energy efficiency codes for the industry as input for the development of energy audit and reporting guidelines. Second, create a motor rewinding centre in one of the industries that can repair, test and certify motors so that efficiency can be increased.

(iii) Long-term. First, industry certification for energy management systems and standards after information systems are implemented. Second, take energy-saving measures on equipment. Third, replace the chiller with the right size and optimize the chiller operation. Fourth, reducing the energy consumption of pumps and cooling towers through the use of Variable Speed Drives (VSD) to control flow rates. Fifth, replacing metal halide and fluorescent lamps with energy-efficient LED and induction lamps. Sixth, retrofit air compressors with efficient models and repair compressed air leaks.

Improving energy efficiency and reducing energy intensity in industrial processes is a sustainable development goal. Improvements in the efficiency of energy supply systems translate into more effective utilization of energy resources and reduce negative environmental impacts. Intensity provides information on relative energy use per unit of output. This tool is used to analyze trends in energy efficiency and changes in product composition and fuel mixtures as they affect industry, branch and product intensity. In addition, this set of indicators can be used to evaluate trends in technology improvement and

changes in the structure of industry sectors and subsectors. Referring to the energy indicators for sustainable development used by the UN commission, indicators for sustainable energy in the industrial sector are made as in Table 8.

Table 8. Industrial sector sustainable energy indicators [24].

Theme	Sub-themes	Energy indicator	Component
Patterns of use and production	Use	Energy use per capita	• Total final energy consumption • Total population
	Productivity	Energy use per unit of GDP	• Total final energy consumption • GDP
	Efficiency	Energy conversion and distribution efficiency	Losses in electricity generation, transmission and distribution
	End-use	Industrial energy intensity	Energy use in the industrial sector
	Diversification	The share of renewable energy in energy and electricity	Primary energy supply, final consumption and electricity generation and generation capacity with renewable energy

Referring to the results above, two points can be discussed. First, the energy intensity of GDP in Southeast Asia will fall by an average of 1.7 % annually between 2020 and 2050. Energy efficiency policies and measures keep energy consumption around 10 % lower in 2030 and around 12 % lower by 2050. However, despite these improvements, Southeast Asia's total per capita primary energy demand will grow by more than 50 % over the period up to 2050. There is untapped potential to further reduce energy demand through efficiency.

Second, energy policies in each ASEAN country have many similarities, so they have room to further develop regional cooperation in managing energy aspects. The future of the energy transition depends heavily on technological advances, improved governance, efficiency and connectivity between countries. Strengthening cooperation and coordination must be a key strategy for ASEAN countries to ensure readiness in welcoming the energy transition towards environmentally friendly future energy. The ASEAN Action Plan on Energy Cooperation (APAEC) Phase II: 2021 to 2025 sets out the goal of achieving a target of reducing energy intensity by 32 % by 2025 based on 2005 levels. Improving the region's energy efficiency will require financial drivers. Financial incentives in the form of tax breaks, subsidies, grants and loans are considered effective in encouraging technology users, such as tax holidays and exemption from component producer duties. The establishment of public-private partnerships, such as Energy Services Companies (ESCOs) to promote commercial and industrial facility solutions should be given the opportunity. This policy has proven effective in several member countries and can be replicated in other countries that wish to establish energy efficiency financing policies.

4 Conclusion

The energy consumption of most ASEAN countries during the 2016 to 2020 time period has increased. Composite real GDP growth also shows a positive trend. Among ASEAN countries, Indonesia is the largest energy consumer with a share of 36 % of total final consumption. Singapore recorded the lowest energy intensity followed by the Philippines, Indonesia, Malaysia and Thailand. Singapore is the country with the highest level of energy consumption per capita with an average of 5.88 toe per person, followed by Malaysia with an average of 2.89 toe per person, while ASEAN is 1.65 toe per person. The GDP productivity of ASEAN countries has been stable in the last 5 yr and tends to decline. In terms of energy conservation, the most optimal target is shown by Brunei Darussalam with a reduction in energy consumption of 63 % in 2035. In general, EE programs that run are

almost the same, only differ in terms of the systems and schemes used. The Indonesian government through the energy conservation partnership program, and Singapore and Malaysia through the MEPS program.

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