

8th ASEAN ENERGY OUTLOOK

2023 - 2050



One Community
for Sustainable
Energy



EXECUTIVE SUMMARY

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The ASEAN Energy Outlook



Since its inception in 2006, AEO has emerged as a cornerstone document supporting ASEAN’s energy policy and planning. Guided by the ASEAN Plan of Action for Energy Cooperation (APAEC), especially the Regional Energy Policy and Planning (REPP) programme area, the AEO series has consistently provided valuable insights into energy trends and projections across the ASEAN region. It provides regular updates on regional energy trends and delivers strategic reports on essential topics, such as energy access, affordability, efficiency, security, and environmental sustainability. The AEO evaluates whether national and regional energy goals can be achieved and identifies the necessary policies, measures, and technologies.

The AEO stands out from other energy outlooks because it is grounded in rigorous data and modeling, developed through a close partnership between the ASEAN Centre for Energy (ACE) and the ten ASEAN Member States (AMS). The AMS contribute much of the data used in the AEO, and they thoroughly validate the modeling results in each workshop conducted over the years of 2023-2024 to ensure they represent current conditions and align with regional development plans. This cooperative approach promotes a sense of ownership and enhances the relevance and application of the findings for all countries involved further embodying the spirit of “from ASEAN, by ASEAN, for ASEAN”.

The 8th ASEAN Energy Outlook (AEO8) also becomes more important as the findings of this outlook will influence ASEAN energy policymakers gearing up towards its final year of APAEC Phase II: 2021 – 2025. The next cycle of APAEC 2026-2030 is expected to align with the directives of the new ASEAN Community Vision 2045 and the 5-year timeframe of ASEAN Economic Community Strategic Plans, promoting a more integrated and comprehensive approach.

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AEO8 is poised to serve not only as a guiding compass but also as a catalyst for the formulation of visionary regional targets and driving strategic energy policy development for the APAEC 2026-2030 and also for a coming transformative decade.

”



Report Framework

CHAPTER 1 INTRODUCTION



The overview of ASEAN energy landscape based on economic growth, aiming to maintain the energy security and resilience in the region. This content overview explores the key drivers behind the growth in ASEAN Member States (AMS)'s energy consumption, focusing on essential aspects such as safeguarding energy security and resilience, pursuing a just energy transition, and achieving carbon neutrality. It also delves into the critical issue of financing low-carbon energy systems and the importance of regional cooperation. Looking ahead, the discussion will outline the vision for a post-2025 blueprint that aims to address these challenges and harness opportunities for sustainable development.

CHAPTER 2 UNDERSTANDING THE OUTLOOK



This section presents a comprehensive overview of the various scenarios and methodologies utilised to forecast and analyse future energy landscapes within the ASEAN region. It begins with a detailed examination of multiple scenarios, including the Baseline Scenario (BAS), AMS Targets Scenario (ATS), Regional Aspiration Scenario (RAS), and Carbon Neutrality Scenario (CNS). The discussion transitions to the methodologies employed in modelling these scenarios and the steps involved in data processing.

CHAPTER 3 CHARTING MULTIPLE PATHWAYS



This section offers a comprehensive analysis of ASEAN's energy sector, detailing energy demand across industry, transport, commercial, and residential sectors. It explores energy supply, including primary sources, renewable energy, energy intensity, and trade. The review covers electricity aspects such as installed capacity, generation, investment, the ASEAN Power Grid, and storage technologies. Additionally, it addresses energy access, greenhouse gas emissions, employment impacts, and land use for renewables, providing a broad overview of current and future energy dynamics in the region.

CHAPTER 4 A STRATEGIC APPROACH TO ENERGY REGIONAL BLUEPRINT



Multilateral
Power Grid



ASEAN
Gas
Infrastructure



CO₂
Carbon
Capture
Storage



Smart
Demand
Response



Variable
Renewable
Energy



Carbon
Pricing



Emerging
Technologies

This chapter elaborates on seven emphasised energy sectors considered essential to attaining secure and reliable energy amidst transition.

CHAPTER 5 RECOMMENDATIONS AND IMPROVEMENTS



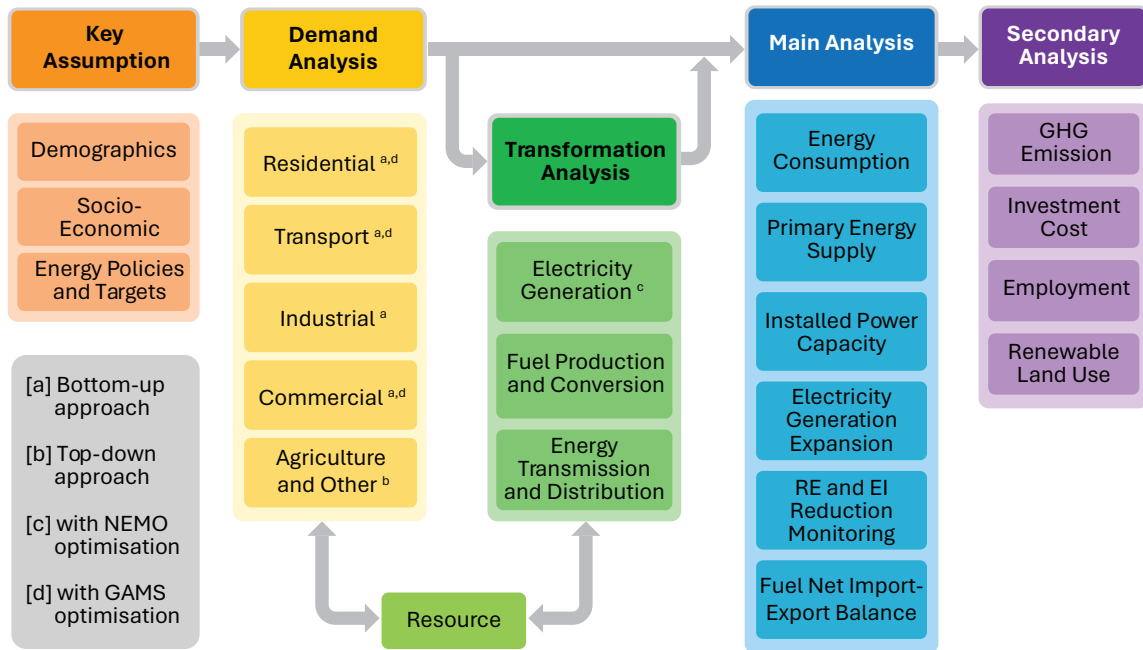
This concluding chapter offers key energy policy proposals and strategic steps to address barriers in utilising resources to meet the demand of AMS from end-use and power sectors, and aligning them with the regional targets, in conjunction with institutional, data, and model improvement prospects for the subsequent editions of the ASEAN Energy Outlook.

Modelling Structure

Recent editions of the AEO have adopted a new, bottom-up modelling approach, better suited for examining the implications of national and regional policies and providing a technology-rich picture of how ASEAN's energy systems will grow and change in the coming decades.

Figure 1.

AEO8 Modelling Structure




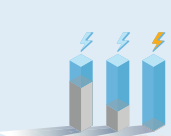


The AEO8 builds on its bottom-up modelling approach with more detailed analyses for the commercial and industrial sectors, providing deeper insights into how national and regional targets can be achieved while taking into account the unique characteristics of each Member State. The main AEO model incorporates resource use and conversion flows from the Energy Balance Table (EBT).

For AEO8, the Low Emissions Analysis Platform (LEAP) and the Next Energy Modelling System for Optimisation (NEMO) were employed. LEAP is a scenario-based, demand-driven tool capable of tracking energy consumption, production, and resource extraction across economic sectors, while NEMO optimises the supply side, particularly electricity generation, through mixed-integer linear optimisation. Furthermore, optimisation for the demand side is carried out outside LEAP using the General Algebraic Modelling System (GAMS), a high-level tool designed to solve linear, nonlinear, and mixed-integer optimisation problems. In addition, secondary analysis for emissions is inherited from the LEAP, whereas the energy employment and land use of renewables were calculated separately.

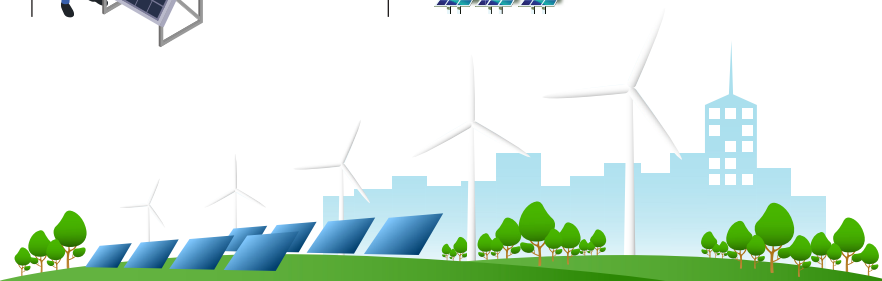
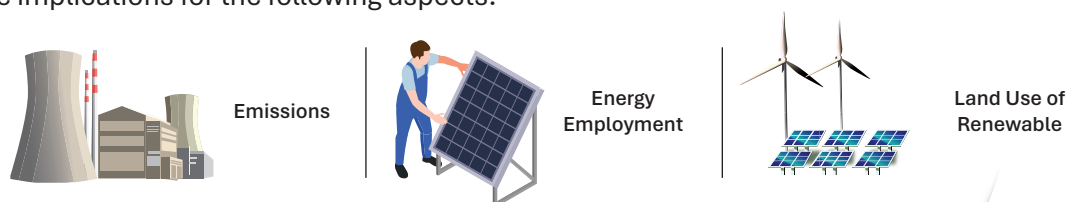


Scenarios






Scenario	Least-Cost Optimisation	Energy Efficiency (EE)	Renewable Energy (RE)	Power Generation Capacity	Energy Targets and Measures in NDCs
Baseline Scenario (BAS) 	NO	Constant at the level of the last historical year	Preserving growth rate from the previous historical year	No installed capacities from the national PDP	Not considered in the projection
AMS Targets Scenario (ATS) 	NO	Based on individual Member States' Targets	Based on individual Member States' Targets	Consistent with PDP, prioritising RE and more efficient technologies when adding new capacity	Energy-related items in NDCs (unconditional), including EE, RE, and energy access targets
Regional Aspiration Scenario (RAS) 	YES	Raise individual Member States' targets with the assumption to reach the 2025 regional targets and aspiration standards, and scale up	Raise individual Member States' targets and scale up where possible based on accelerated policies	PDP capacities included with accelerated deployment of RE capacity based on each country's potential	Energy-related items in NDCs (conditional), including EE, RE and energy access targets, but scaled up where possible
Carbon Neutrality Scenario (CNS) 	YES	Accelerate individual Member states' EE development based on their potential with the assumption of achieving their respective pledge to carbon neutrality, implementing new net zero measures if possible to further increase EE	Accelerate individual Member states' RE development based on their potential with the assumption of achieving their respective pledge to carbon neutrality	The PDP capacity additions are included and the model is allowed to build additional plants and prioritise dispatch of RE, retirement assumptions for both coal and gas technologies without CCS to achieve the lowest carbon emission	Energy-related items in NDCs (conditional), including EE, RE and energy access targets and dispatch emerging technologies to reduce emissions

AEO8 projection illustrates four scenarios for 2023 – 2050 based on the historical data from 2005 to 2022. The degree of ambition escalates from the first to the last scenario. The Baseline Scenario (BAS) follows the historical trend without any policy intervention, whilst the AMS Targets Scenario (ATS) considers the energy policies of each AMS, such as power development plans, renewable energy (RE), and energy efficiency and conservation (EE&C). Keeping the 2025 APAEC targets, the Regional Aspiration Scenario (RAS) uses least-cost optimisation (LCO) in the power sector with accelerated targets of each AMS, whilst the Carbon Neutrality Scenario (CNS) serves as an alternative scenario that considers enhanced decarbonisation efforts using the LCO of net-zero technologies.

AEO8 explains the implications for the following aspects:



Overview of ASEAN Member States Energy and Related Policies

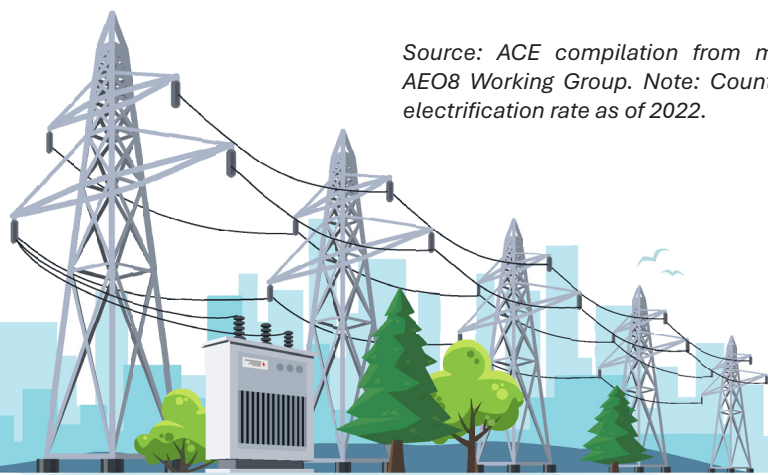
Country	Sector	Official Target
Brunei Darussalam 	Demand	<ul style="list-style-type: none"> Increase the total share of EVs to 60% of total annual vehicle sales by 2035
	Supply	<ul style="list-style-type: none"> Increase the total share of RE to at least 30% of total capacity in the power generation mix by 2035 200 MW target for solar capacity by 2025 and more than 600 MW by 2035
Cambodia 	Access	<ul style="list-style-type: none"> Fully electrified by 2030
	Demand	<ul style="list-style-type: none"> Reduce energy consumption—thermal and electrical—by 19% by 2030 to a BAU trajectory¹ Public transport will have a 30% share in urban areas by 2050 Moderate penetration for EVs: 70% for motorcycles, and 40% for cars and urban buses by 2050 Compressed natural gas (CNG) penetration of 80% for interregional buses and 80% for trucks until 2050
	Supply	<ul style="list-style-type: none"> Aiming to achieve a minimum of 70% renewable energy capacity by 2030
Indonesia 	Access	<ul style="list-style-type: none"> Reach 100% electrification rate by 2025
	Demand	<ul style="list-style-type: none"> Reduce energy intensity (TPES per GDP) by 1%/year through 2025 Achieve 2 million units of electric cars and 13 million units of electric motorbikes by 2030
	Supply	<ul style="list-style-type: none"> Increase RE share to 19% in TPES by 2025 and 25% by 2033 Biodiesel blending ratio targets 30% by 2025 and 50% by 2050; Bioethanol blending ratio of 20% by 2025 and 50% by 2050 The nuclear power plant is scheduled to commence operations in 2032 with a capacity of 250 MW, gradually increasing to 9 GW by 2060
Lao PDR 	Access	<ul style="list-style-type: none"> Increase the electricity access rate to 98% of total households by 2025
	Demand	<ul style="list-style-type: none"> Reduce TFEC by 10% by 2030 and 20% by 2040 as compared to the Baseline¹ Introduction of 50,000 energy-efficient cook stoves by 2030 (energy-efficient gasifier cookstoves using biomass pellets)
	Supply	<ul style="list-style-type: none"> 30% share of RE in total energy consumption by 2025, including 20% renewable electricity share (excluding large-scale hydro) and 10% biofuel share (blending ratio 5%-10%) 13 GW total hydropower capacity (domestic and export use) in the country by 2030
Malaysia 	Demand	<ul style="list-style-type: none"> By 2040, achieve energy savings of 21% compared to the BAU scenario Elevate the public transport modal share to reach 40% by 2040 and 60% by 2050 Accelerate the penetration of xEV (4W) share of the vehicle fleet to 80% Accelerate the penetration of electric two-wheelers' (E2W) share of the vehicle fleet to 80% Maintain the pathway towards achieving a 5% share of rail freight modal utilisation by the year 2030 5% of heavy vehicles utilise hydrogen by 2050
	Supply	<ul style="list-style-type: none"> Increase the RE share to 31% in the power capacity mix by 2030 and 40% by 2035 Increase biodiesel blending targets to 30% (B30) by 2030 Up to 47% sustainable aviation fuel (SAF) blending mandate by 2050



Myanmar 	Access	<ul style="list-style-type: none"> Increase electricity access rate to 100% by 2030
	Demand	<ul style="list-style-type: none"> Transport: Reduce consumption by 20% by 2030 (raise fuel efficiency and EV share) Industrial: reduce consumption by 3.6% by 2020, 5% by 2025, 6.6% by 2030 Commercial/Residential: reduce consumption by 7.4% by 2020, 10% by 2025, 12% by 2030 5% reduction by 2025 and 7% by 2030 in traditional biomass use, relative to 2012 levels, via the promotion of energy-efficient cooking stoves
	Supply	<ul style="list-style-type: none"> Increase the RE share to 39% in electricity generation by 2030 (28% hydro and 11% other RE)
Philippines 	Access	<ul style="list-style-type: none"> Achieve a 100% household electrification rate by 2028
	Demand	<ul style="list-style-type: none"> Total energy saving by 2040: Transport 25%, Industry 15%, Residential 20%, Commercial 25%, Agricultural 10% Reach at least a 10% EV share for road transportation (including motorcycles, cars, jeepneys) by 2040
	Supply	<ul style="list-style-type: none"> Aim for at least 35% RE share in the power generation mix by 2030, 50% share by 2040, and more than 50% by 2050 1,200 MW Nuclear Energy by 2032, 2,400 MW by 2035, and at least 4,800 MW by 2050
Singapore 	Demand	<ul style="list-style-type: none"> Reduce energy consumption in residential (existing HDB towns) by 15% Implement green buildings to see an 80% improvement in energy efficiency (over 2005 levels) by 2030 Achieve 100% cleaner-energy public bus fleet and taxis by 2040 (electric or hybrid vehicles)
	Supply	<ul style="list-style-type: none"> Increase solar energy deployment to at least 1.5 GWp by 2025 and 2 GWp in 2030 200 MW of deployed energy storage systems beyond 2025
Thailand 	Demand	<ul style="list-style-type: none"> Decrease energy intensity by 30% of the base year in TFEC compared to 2010 level by 2037 Achieve 30% EVs manufactured and sales by 2030
	Supply	<ul style="list-style-type: none"> Increase the RE share to 30% in TFEC by 2037, which equates to 26.26% renewable electricity in total electricity generation; 39.32% of consumed heating from renewables in total heat consumption; 11.74% consumed biofuel in total oil fuel consumption in the transport sector
Vietnam 	Demand	<ul style="list-style-type: none"> By 2025, reduce energy intensity in TFEC by 5%-7% and keep power losses under 6.5% By 2030, reduce energy intensity in TFEC by 8%-10%, keep power losses under 6%, and reduce fuel and oil consumption by 5% in transportation Energy saving to 10% in 2030 and 20% by 2050
	Supply	<ul style="list-style-type: none"> The proportion of RE in the TPES will be 15%-20% by 2030 Green hydrogen production will reach between 100,000 and 200,000 tonnes annually by 2030 Renewables are to account for about 30.9-39.2% of Vietnam's electricity supply by 2030 By 2030, electricity exports should be scaled-up to about 5,000 to 10,000 MW Increase the absorption area of solar hot water rigs in commercial, service, civil, and industrial production, providing about 3.1 Mtoe by 2030 Total RE sources for heat production and co-generation of thermal power in 2030 will be about 8 to 9 Mtoe Biogas is expected to be about 60 million m³ by 2030

Source: ACE compilation from multiple official documents and consultation with AMS AEO8 Working Group. Note: Countries without 'Access' information have achieved a 100% electrification rate as of 2022.

¹ Refer to its national energy outlook BAU scenario

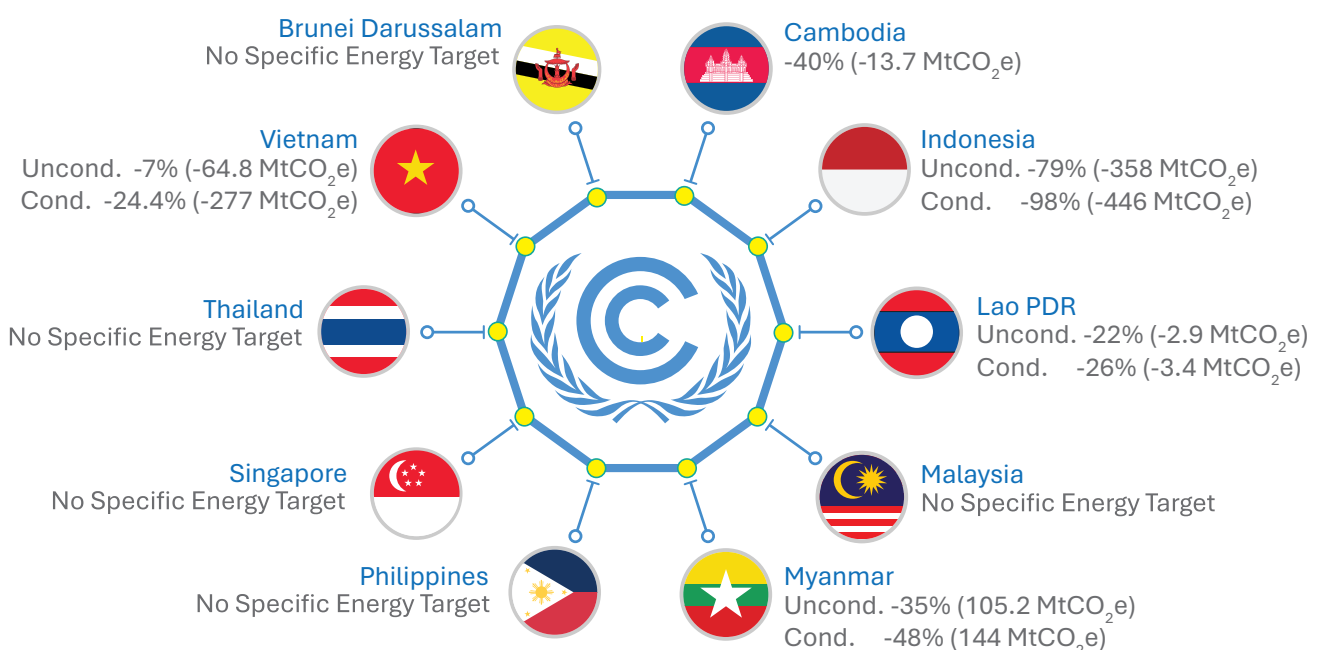


AMS Net Zero and NDC Targets in Mitigating Greenhouse Gas Emissions

Country	Net Zero/Carbon Neutrality Target	NDC Target (Reduction of GHG Emission)	
		Unconditional	Conditional
Brunei Darussalam	Net Zero by 2050	-20% from 2030 Business-as-Usual (BAU) scenario	-
Cambodia	Net Zero and Carbon Neutrality by 2050	-	-41.7% from 2030 BAU scenario
Indonesia	Net Zero by 2060 or sooner	-31.89% from 2030 BAU scenario	-43.20% from 2030 BAU scenario
Lao PDR	Net Zero by 2050, conditionally	-60% from 2030 BAU scenario	-45.69 MtCO ₂ -eq/yr in 2020-2030
Malaysia	Net Zero by 2050	-45% of carbon intensity from 2005 levels	-
Myanmar	Net Zero from forestry and other land use by 2040	-244.52 MtCO ₂ -eq (sectoral targets)	-414.75 MtCO ₂ -eq (sectoral targets)
Philippines	No specific target	-2.71% from 2020 to 2030 cumulative BAU scenario	-75% from 2020 to 2030 cumulative BAU scenario
Singapore	Net Zero by 2050	Reduce emissions to around 60 MtCO ₂ -eq	-
Thailand	Carbon Neutrality by 2050; Net Zero by 2065	-30% from 2030 BAU scenario	-40% from 2030 BAU scenario
Vietnam	Net Zero by 2050	-15.8% from 2030 BAU scenario	-43.5% from 2030 BAU scenario

Figure 2.

AMS NDC Targets for Emissions Reduction in the Energy Sector by 2030



Energy Demand

National efficiency measures and fuel shifting are projected to reduce the energy demand by 32.7% by 2050 in the ATS, compared to the BAS. By incorporating accelerated national policies, the RAS projects to achieve a 47.9% demand reduction versus the BAS by mid-century, whilst the CNS further boosts this to 36.9% and 18.6% lower than the ATS and RAS, respectively. These savings are accomplished through various strategies, such as enhancing energy efficiency in electric technologies within the residential and commercial sectors (e.g., efficient lighting, cooling systems, and appliances), optimising industrial processes, improving fuel economy, and increasing the use of electric vehicles (EVs) in the transport sector.

Figure 3.
ASEAN Energy Consumption by Sector Across Scenarios

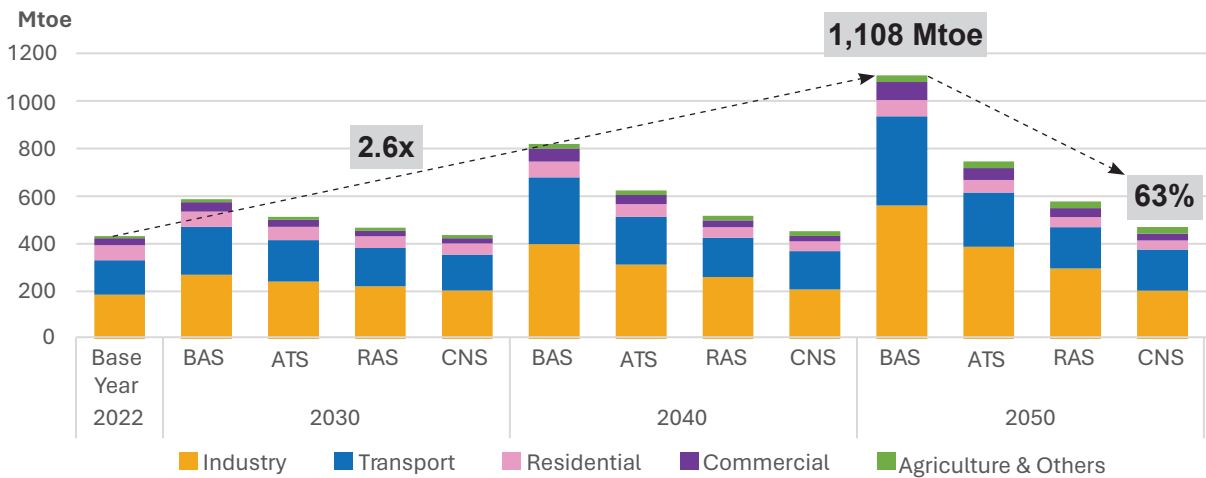
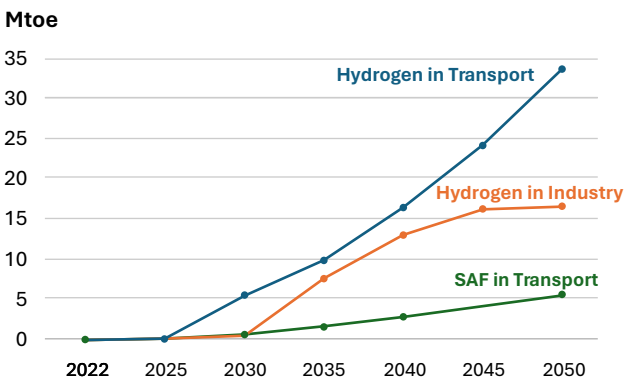


Figure 4.
Projected Emerging Technologies in Demand (CNS)



The industry is among the major energy-consuming sectors that remain highly reliant on coal, electricity, and natural gas. This mix and trends are projected to be the same from 2022 through 2050 in all scenarios. It indicates that coal and natural gas are indispensable for energy requirements in the ASEAN industrial sector. ‘Non-Metallic Minerals’ and ‘Iron and Steel’ consistently emerge as the highest energy-intensive sectors due to their processes, making them the key to decarbonise. While Member States have set targets for reducing energy intensity, achieving these goals will be challenging



To achieve regional targets, a range of demand-driven policy interventions is needed, particularly in the transportation and industrial sectors—the highest energy consumers across all years and scenarios. These measures must accelerate current efforts to make significant progress.

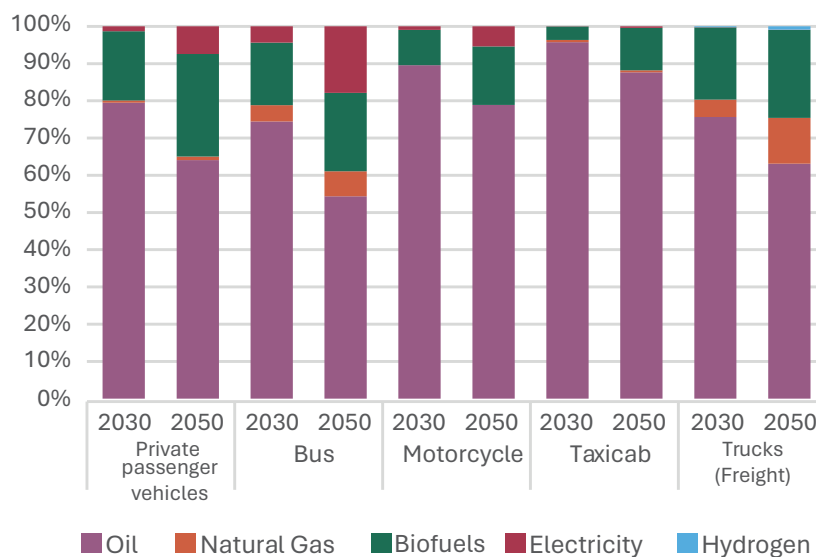


due to the current scarcity of data, which is often proprietary. This lack of accessible information makes accurate accounting difficult, hindering the implementation and monitoring of effective energy-saving programmes. It is essential to intensify efforts to improve data quality to ensure that energy savings can be properly managed and monitored within the sector.

The second highest is the transport sector. In the RAS, the alignment with the accelerated AMS' biofuel blending mandates and EV penetration targets, as well as the ASEAN Fuel Economy Roadmap, will reduce energy demand by 53.8% by 2050, compared to the ATS. The use of hydrogen and Sustainable Aviation Fuel (SAF) as alternative fuels are expected to be introduced as soon as 2023 and 2024, respectively, to further decarbonise aviation and heavy-duty vehicles.

Figure 5.

Fuel Share Consumption per Vehicle Type in Road Transport (ATS)



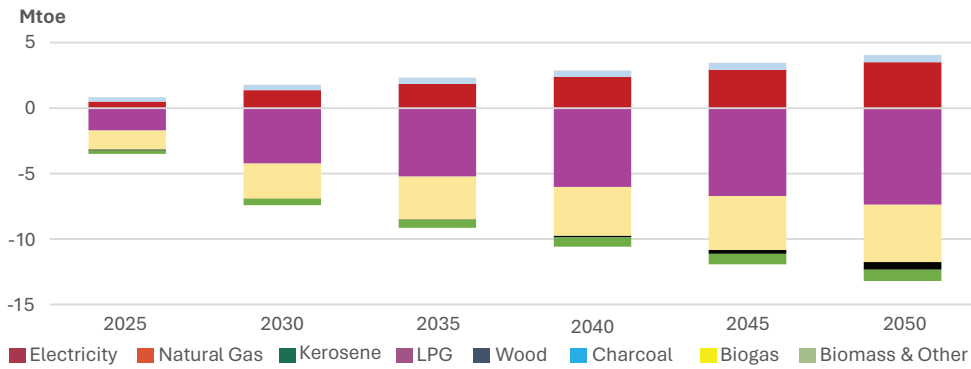
Attainment of EV deployment targets will also be crucial. Although several Member States have set promising strategies for increasing EV uptake, many specify the sales targets rather than penetration, which is more challenging to model in the Outlook. Thus, the scenario with national policies (ATS) is projected to lead to an EV share of only 1.4% of the passenger road transportation fleet by 2030 and 7.4% by 2050 in the ATS. Higher and more specific targets on penetration are required to accelerate EV adoption, coupled with establishing policies in some AMS that have not yet set EV deployment objectives. Despite the low penetration, the deployment of electric passenger vehicles is expected to reduce oil usage, including gasoline and diesel, by 52.1% by 2050 in the ATS, as compared to the BAS.

The residential sector demand is projected to decline due to end-use devices' improved efficiency, by 22.7%, 37.5%, and 44.3% in the ATS, RAS, and CNS, respectively, as compared to the BAS. Generally, the primary contributors to energy consumption in residential are cooking, refrigeration, and air conditioning. With implementing national EE&C efforts, air conditioning and lighting show the highest drops at 38.5% and 33.1%, respectively, as compared to the BAS. Improved policies that promote clean cooking methods and electrification could significantly decrease reliance on traditional fuels, such as wood and charcoal for cooking. Urban households are increasingly switching from LPG stoves to electric alternatives, while rural areas are transitioning from traditional biomass to LPG. These shifts reduce dependence on imported fuels and improve indoor air quality, thereby enhancing residential well-being.



Figure 6.

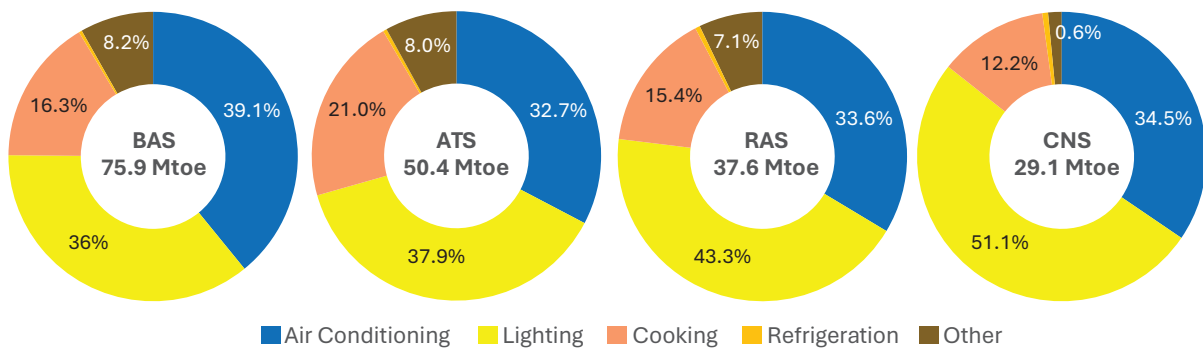
Fuel Shifting due to Clean Cooking (ATS vs BAS)



The commercial sector had various effective policies in place to be enhanced. With the adaption of energy efficiency measures in each of the AMS — including Minimum Energy Performance Standards (MEPS) for appliances, building energy codes, and mandatory energy management systems — the ATS projects overall energy consumption to be reduced by 33.6% to 50.4 Mtoe by 2050, as compared to the BAS. The RAS and CNS predict this sector’s energy demand would be even lower, which are 37.6 Mtoe and 29.1 Mtoe, respectively.

Figure 7.

Share of Commercial Appliances in 2050 Across Scenarios



Note: The percentage of Other is not shown in the figure since the value is very small. End-use details (sectoral demand by appliances) cannot be reported for the historical year (2022). These details only appear at the beginning of the projection year (2023) and thereafter.

Primary Energy Supply

The AEO8 modelling finds that national and regional policies can reduce the overall growth in the total primary energy supply (TPES) and make a series of supply shifts to renewables throughout the projection years. By 2050, the ATS and RAS are projected to reduce the fossil fuels share in the TPES by around 18.6%-points and 25.0%-points, respectively, from the 2022 level. In the more ambitious scenario (CNS), RE supply jumped almost seven times in exchange for 48.6%-points reduction in fossil fuel share, accounting for 697.3 Mtoe for existing types of RE, whilst new RE technology like tidal and wave can potentially generate up to 18.0 Mtoe in 2050.

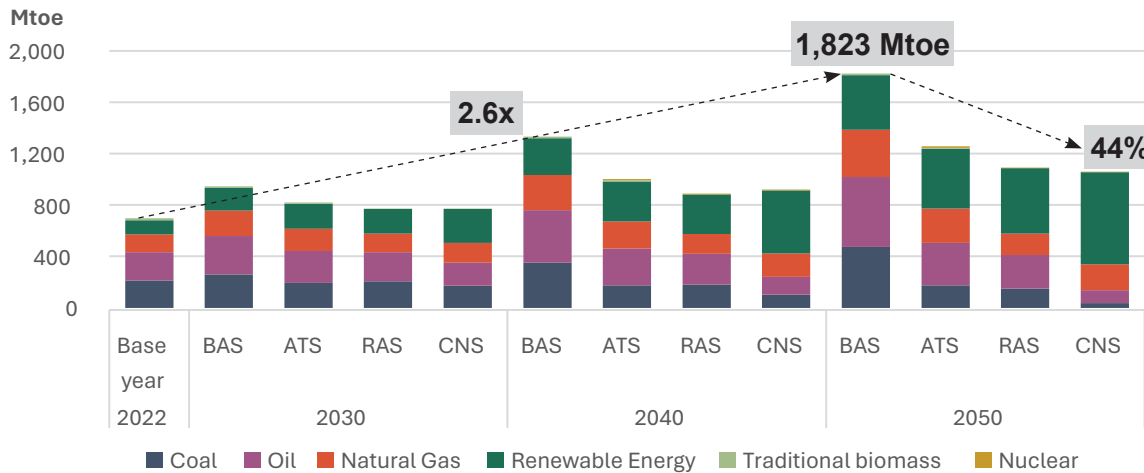


With all national policies implemented, fossil fuel supply requirements are projected to be reduced by 14.4% in 2050 relative to the Baseline Scenario.



Figure 8.

Total Primary Energy Supply Projection Across Scenarios



ASEAN is expected to become a net importer of natural gas by 2027 with no policy intervention. Implemented national and regional policies only serve to delay the date when the region becomes a net importer of natural gas by 3-6 years

Natural gas is expected to play a crucial role as a transitional energy source, especially in the CNS, where its use rises as coal is phased out. Additionally, CNS highlights the growing importance of advanced technologies such as Carbon Capture and Storage (CCS) and the adoption of new renewable sources like tidal and wave energy. Nuclear energy is also projected to contribute to the energy mix from 2035 onwards in all scenarios except the baseline.

Oil supply increased, maintaining the largest total supply addition between 2022 and 2050 at about 321.3 Mtoe. However, oil supply decreased when compared to ATS, RAS, and CNS, which were 39.5%, 51.8%, and 81.8%, respectively. The percentage of fossil fuel used in transportation has decreased as a result of greater biofuel blending requirements in AMS. The adoption of EVs and the development of hydrogen will also reduce the demand for biofuels to replace fossil fuels.

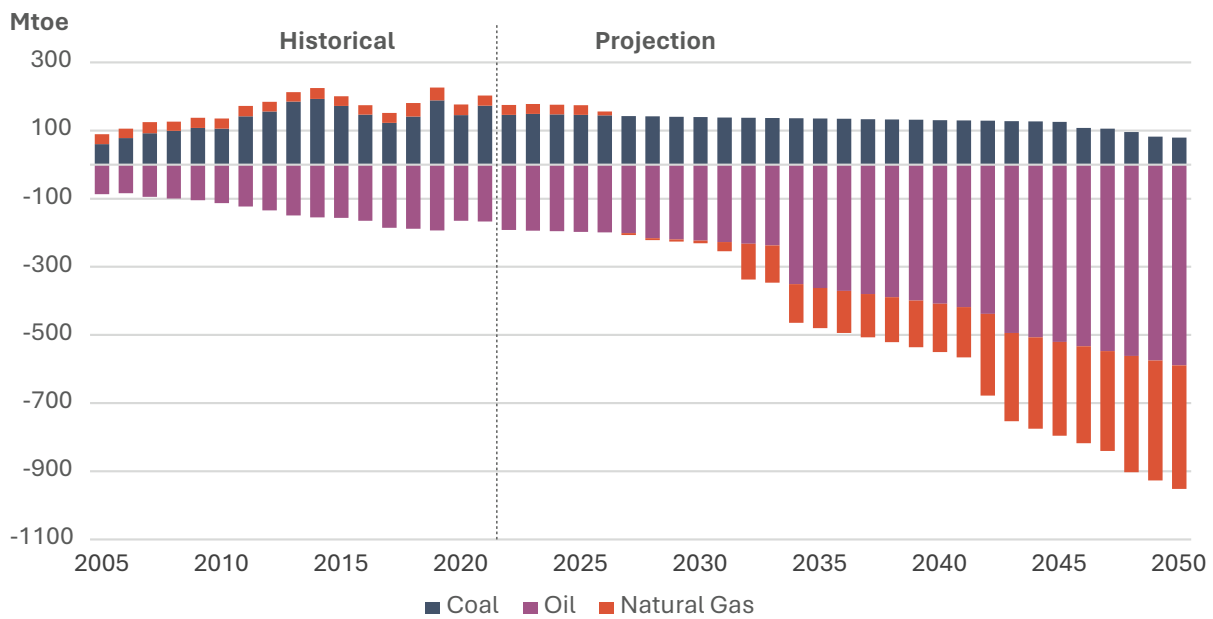
Import Dependence

Under the BAS, ASEAN is projected to become a net importer of natural gas by 2027. This dependency on fossil fuel imports in the future poses severe energy security risks, potentially affecting energy affordability and increasing price volatility. In contrast, coal exports are expected to continue until at least 2050, though its balance is becoming lower. Public opinion in ASEAN countries shows strong support for halting new coal plant construction immediately, with over half of respondents in favour, and nearly two-thirds backing the phase-out of coal consumption by 2030.



Figure 9.

ASEAN Energy Import-Export Balance and Projections



Installed Power Capacity

In 2022, ASEAN's installed power capacity was predominantly reliant on fossil fuels, making up around 66.4% of the energy mix. While fossil fuels will continue to play a significant role without policy interventions, the ATS and RAS are expected to accelerate the shift towards RE, reducing the region's dependency on gas, coal, and oil as electricity demand increases. By 2050, the ATS forecasts a 28.9% decrease in fossil fuel reliance. RE is projected to steadily increase its share in the power capacity across all scenarios, with the most rapid growth in the ATS and RAS, particularly for solar PV and wind energy. Hydro and geothermal energy maintain stable but smaller contributions, while nuclear and other emerging technologies like bioenergy, tidal, and wave remain minor but grow under specific scenarios.

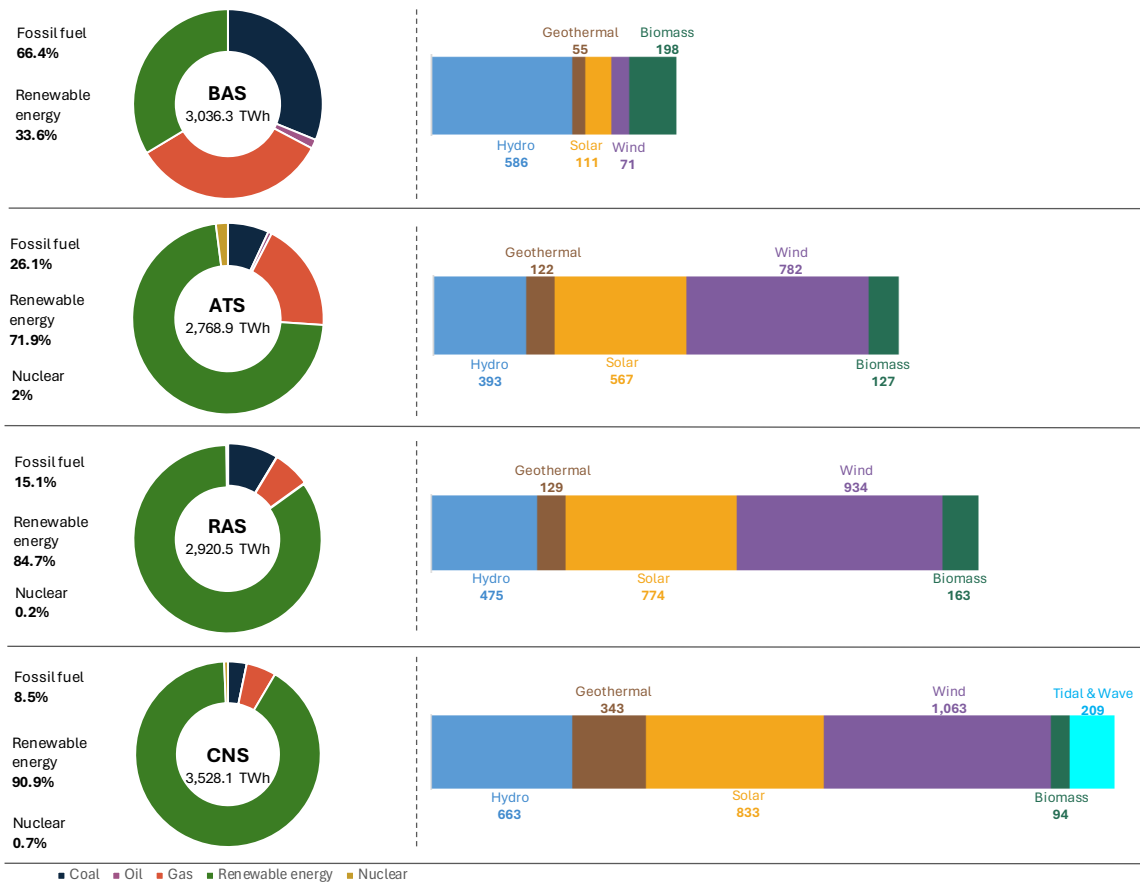
Electricity Generation and Storage

Across all scenarios, there is an expected increase in total power generation in ASEAN by 2050, driven by rising energy demand due to economic and population growth. The projected electricity generation for 2050 is approximately 3,036 TWh under the BAS, 2,769 TWh in the ATS, and 2,920 TWh in the RAS. This growth aligns with the trends in installed capacity, particularly in renewable energy, which is anticipated to play a crucial role in meeting the region's expanding energy needs.

The RAS is projected to exceed the ATS in total power generation by 2050, balancing energy security, affordability, and sustainability through a diverse mix of electricity generation technologies. Most of the member states are projected to increase electricity generation by diversifying energy sources and enhancing energy security. The shift towards a cleaner and more diversified energy mix, especially under RAS, reflects substantial growth in renewable technologies such as solar PV and wind, reducing reliance on non-renewable sources. Natural gas remains a stable transition fuel across scenarios, while hydroelectric power, geothermal, and bioenergy continue to support specific regions, underscoring ASEAN's commitment to balancing economic growth, energy security, and environmental sustainability.

Modelling of the battery and energy storage systems (BESS) were also explored as a part of the RAS and CNS. BESS facilitates the integration of variable RE, especially solar and wind, storing excess electricity during peak hours. This integration is crucial for maintaining grid stability and reliability, especially during peak demand periods or when renewable generation is low.

Figure 10.
ASEAN Power Generation Across Scenarios



Energy Access



As of 2022, an estimated 3.4 million households still lacked access to electricity. By 2040, the ATS projects ASEAN to achieve 100% household electrification.



ATS projects that the region’s electrification rate will reach 99.9% by 2030 and 100% by 2040. The ASEAN region also faces challenges in providing universal electrification due to many remote and hard-to-reach areas. Indonesia is expected to achieve 100% electrification by 2025, followed by the Philippines in 2028 with an annual average growth rate (AAGR) of 0.65% between 2022 and 2028. Both are archipelagic countries. Policy biases towards large projects, lack of integration with rural development efforts, and dependency on donor assistance for off-grid electrification contribute to concerns about the electrification process. Successful electrification cases in Southeast Asia suggest that grid extensions are preferred, and top-down approaches are effective when supported by strong implementation strategies.

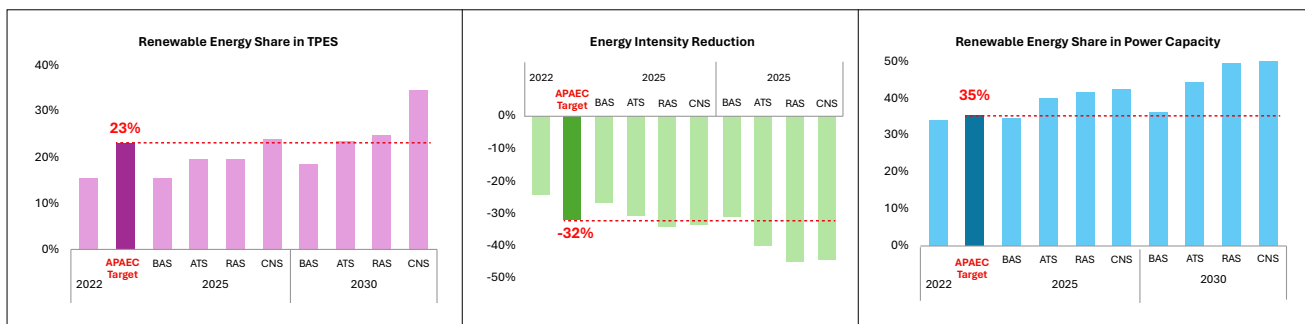
In terms of clean cooking, while ASEAN may not achieve universal access under any of the four scenarios, significant progress is being made. In the ATS, only four out of ten AMS will achieve 100% clean cooking



access by 2030. In the RAS, eight AMS are expected to achieve 100% clean cooking access by 2030. Indonesia and Thailand will achieve this by 2026, while Cambodia and Myanmar will follow in 2028, all ahead of the Sustainable Development Goal 7 (SDG7) target year.

ASEAN 2025 Targets

	Renewable Share in TPES	Renewable Share in Installed Power Capacity	Energy Intensity Reduction from 2005 Level
APAEC Target	23%	35%	32%
Status in ATS 2025	19.6%	39.6%	31%
Status as of 2022	15.6%	33.6%	24.5%



RE is crucial for achieving a sustainable future, with ASEAN targeting a 23% share of renewables in TPES by 2025 under APAEC Phase II. As of 2022, the RE share stood at 15.6%, presenting a challenge to reach the target within three years. While the ATS is projected to meet the target by 2030, and the RAS by 2029, both scenarios show significant increases in RE share by 2050, reaching 38.1% and 50.4%, respectively, driven by supportive policies and technological advancements. ASEAN RE growth is boosted by expanding hydropower, geothermal, and other renewables like solar and wind, particularly under the CNS, where RE share could reach 70.2% by 2050. Despite the progress, ASEAN faces challenges in accelerating the transition away from fossil fuels, balancing ambitious targets with feasibility, and addressing constraints related to biomass reliability and infrastructure investments for emerging technologies.

ASEAN aims for a 35% RE share in installed capacity by 2025. It reached 33.6% in 2022, and the ATS and RAS are on track to surpass this target, reaching 39.6% and 41.3%, respectively, while the BAS is expected to fall short at 34.2%. By 2050, RE shares in the ATS and RAS are projected to rise significantly, reaching 69.4% and 71.7%, driven by strong RE policies and a balanced approach to ambitious targets and cost optimisation.

ASEAN aims for a 32% reduction in energy intensity (EI) by 2025 from the 2005 level under APAEC Phase II. By 2022, a 24.5% reduction was achieved, indicating progress but still short of the target. Projections suggest that the ATS would reach 31% by 2025, slightly missing the target, while the RAS and CNS are on track to meet or exceed it with reductions of 34.2% and 33.7%, respectively. By 2050, the BAS and ATS show substantial gaps, with reductions of 45.0% and 63.2%, respectively, whilst the RAS and CNS project greater reductions of 69.4% and 69.2%, respectively. Achieving further EI reductions will require enhancing national efforts by implementing cost-effective measures in key sectors such as transportation, cooking, and cooling, accelerating the adoption of EVs, improving fuel efficiency, and expanding mass transit. Financial incentives and public-private partnerships should also be leveraged to promote clean technologies and reduce financial risks in energy efficiency projects.

Figure 11.

Renewable Energy Share in TPES Across Scenarios 2005-2050

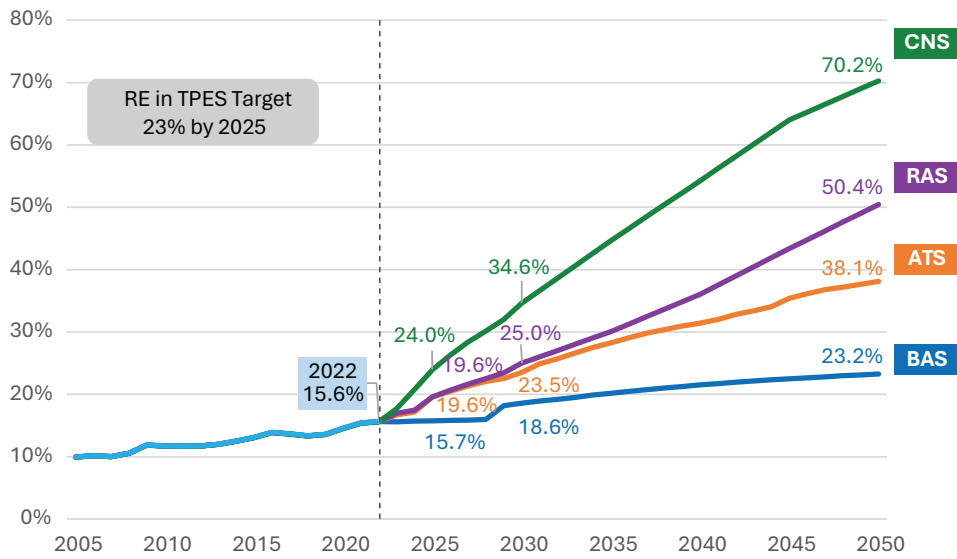


Figure 12.

Renewable Energy Share in Installed Capacity Across Scenarios

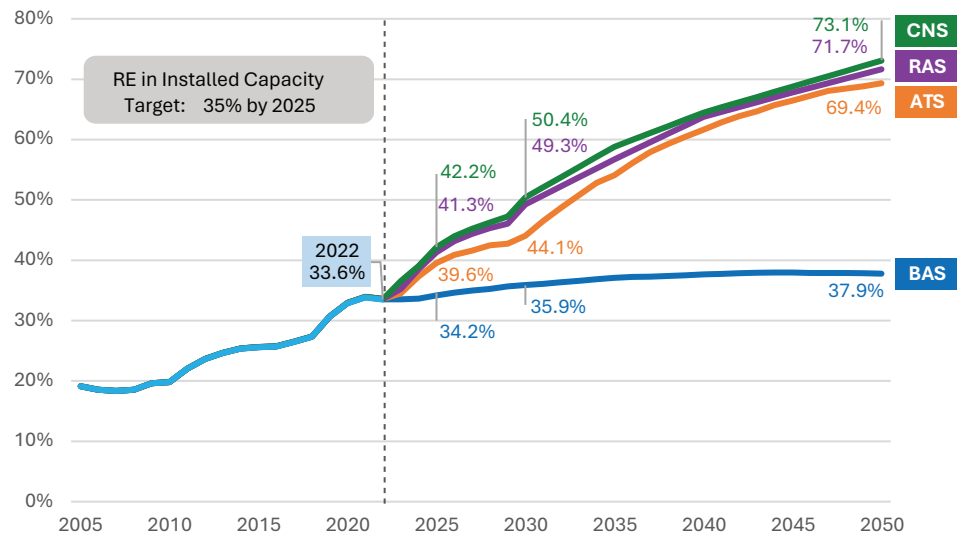
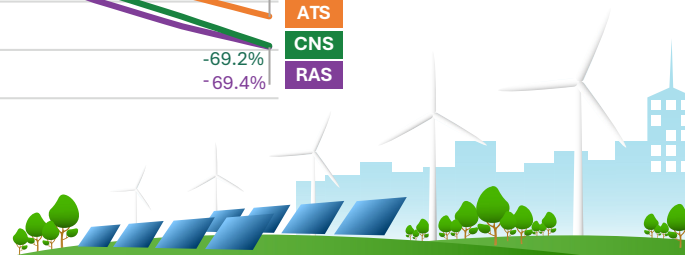
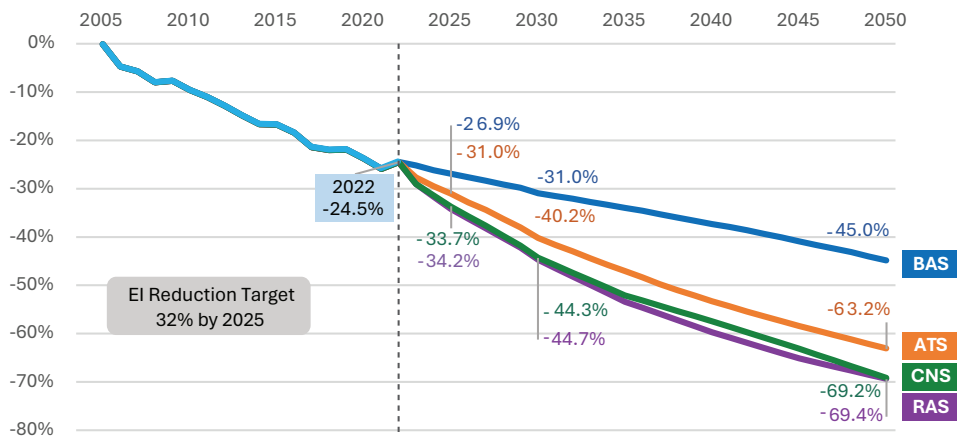


Figure 13.

Primary Energy Intensity Reduction from the 2005 Level Across Scenarios

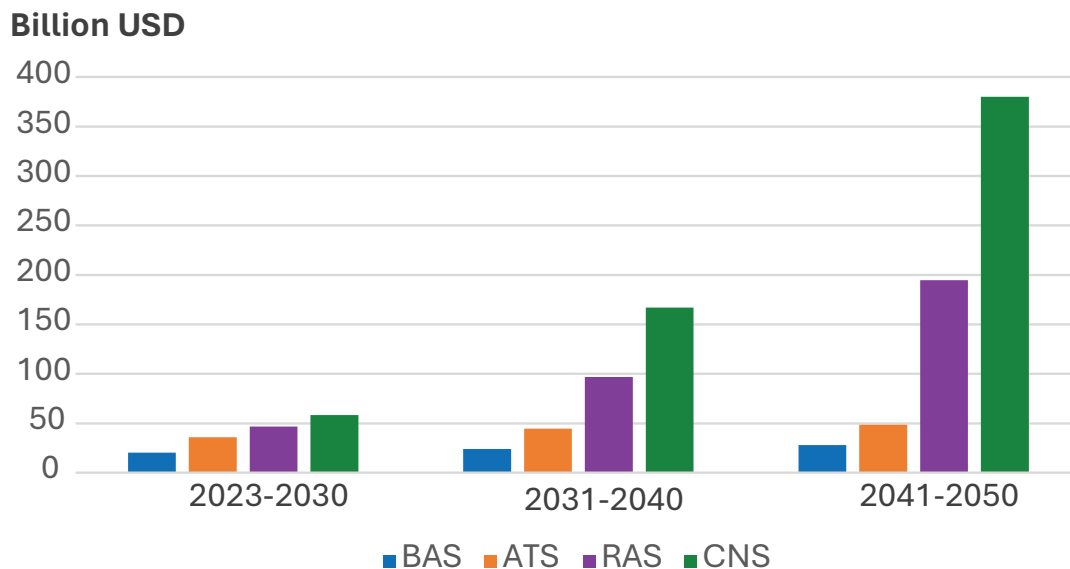


Energy Financing

The high upfront costs and low margins are particularly prominent in the power sector among other sectors since power generation requires significant infrastructure. As the power sector expands across the region, the total financial cost is required to deploy energy generation infrastructure, particularly the implementation of emerging and low-carbon technologies.

Figure 14.

Annual Power Investment Cost Across Scenarios



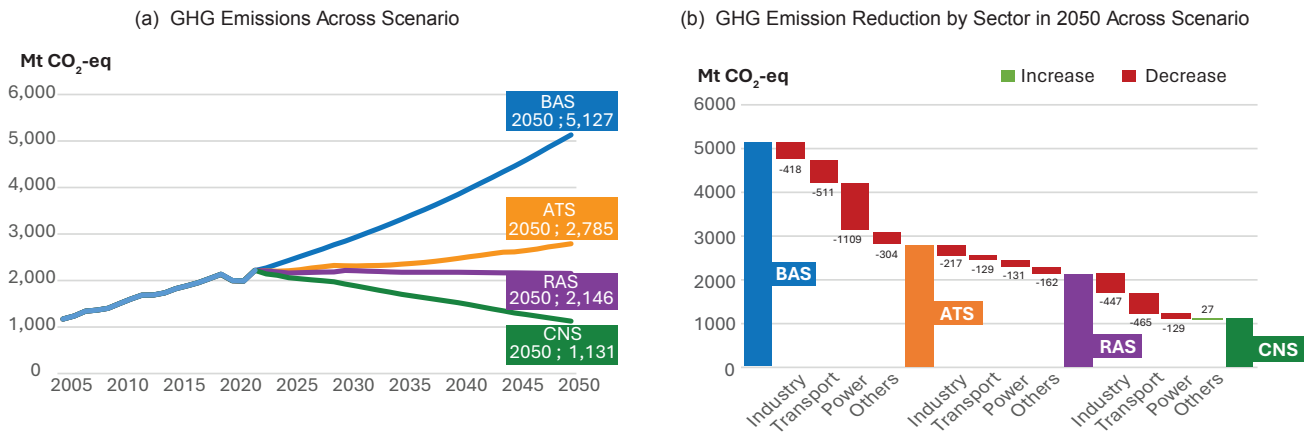
The power investment cost across scenarios shows an upward trend by 2050 as the scale of additional installed capacity is projected to increase. All scenarios follow an increasing trend reaching the highest value for the CNS as it integrates net-zero technologies and associates with capital-intensive projects.

A major effect of the energy diversification policy in ASEAN has been to accelerate the deployment of clean energy technologies. Moreover, the region will experience massive power investment costs in the longer term for additional capacity infrastructure and to meet the electricity demand. In earlier years (2023-2030), the average annual power investment requirement varied from USD 20 billion to USD 56 billion, while the long-term (2041-2050) ranges from USD 28 billion to USD 371 billion. However, the cost of production shows that the BAS would record as the highest in all projection years, having large externality costs.

In contrast, the financing cost of coal power will decrease gradually until 2050 at USD 580 million, reflecting a similar downward trend observed in oil following ongoing fuel costs and O&M expenses. A notable addition to the investment cost is nuclear energy, which may require up to USD 3 billion investment cost in 2050.

Greenhouse Gas Emissions

Figure 15.
GHG Emissions in All Sectors Across Scenarios



The GHG emissions reached 2,215 MtCO₂-eq in 2022, increasing almost two times from 1,175 MtCO₂-eq in 2005, covering demand and power sectors. In the demand sector only, the GHG emissions reached 1,080.7 MtCO₂-eq and will increase to 2,668.2 MtCO₂-eq by 2050 in the BAS. AEO8’s modelled policy measures are projected to slow the rate of increase in emissions significantly. The ATS will reduce the emissions by 45.7% compared to the BAS. The avoided emissions between these two scenarios mostly come from electricity generation, which declines by 74%, due to the shift of power sources from fossil fuels to cleaner energy. The emissions gaps are also supported by fuel shifting and fuel economy in domestic transport, having lower emissions by 49.5% in the ATS.

Given accelerated efforts by each of the AMS in the RAS, the GHG emissions can be further decreased by 23%, as compared to the ATS. This trend can be observed with the contribution of EE&C efforts in the residential sector and cleaner energy sources in electricity generation. In the CNS, putting net-zero measures into effect further can decreased emissions by 4.5 folds in 2050 by figuring out how to make industry operations more effective so that they use less raw materials. Compared to RAS, emission in all sectors is reduced in CNS except in Others (Residential, Commercial, Agriculture, and Other Transformation). One of the reasons is the implementation of emerging technology (hydrogen production), but it’s only small portion, where most of the impact of putting net zero measures to reduce the use of fossil-based power plant is projected to be successful in reducing the emission significantly.

Employment

The energy transition in ASEAN is estimated to have a profound impact on the region’s energy jobs, gradually shifting the workforce from fossil fuels to RE sectors. During the first decade of the projection (2020-2030), job additions across four scenarios remain consistent, with total jobs ranging from eight to ten million. Fossil fuels dominate employment, although RE jobs show growth. By the second decade (2030-2040), a shift towards RE is evident, especially under the RAS and CNS. Fossil fuels job creation will drop sharply after 2030 due to the smaller capacity installations.

Due to the rapid adoption of renewable energy (RE) technology during the last decade of the projection (2040-2050), particularly under the RAS, most employment will be concentrated in construction and installation (C&I) and operation and maintenance (O&M) roles, while fuel-related jobs decline sharply as fossil fuels phase down. In the ATS, RE capacity is projected to be ten times higher than fossil fuel



capacity, leading to the creation of 6.1 million green jobs, surpassing fossil fuel jobs by 1.2 million. In contrast, the installation of 622 GW of new capacity under the BAS scenario will result in 11.8 million jobs, with fossil fuel jobs comprising 73.7% of this total. At the country level, large-scale RE projects in Vietnam, the Philippines, and Indonesia contribute significantly to green job creation, particularly between 2045 and 2050, with a substantial portion tied to O&M roles in the solar and wind sectors.

Figure 16. Job Creations in ASEAN by Category in 2020-2050 (CNS)

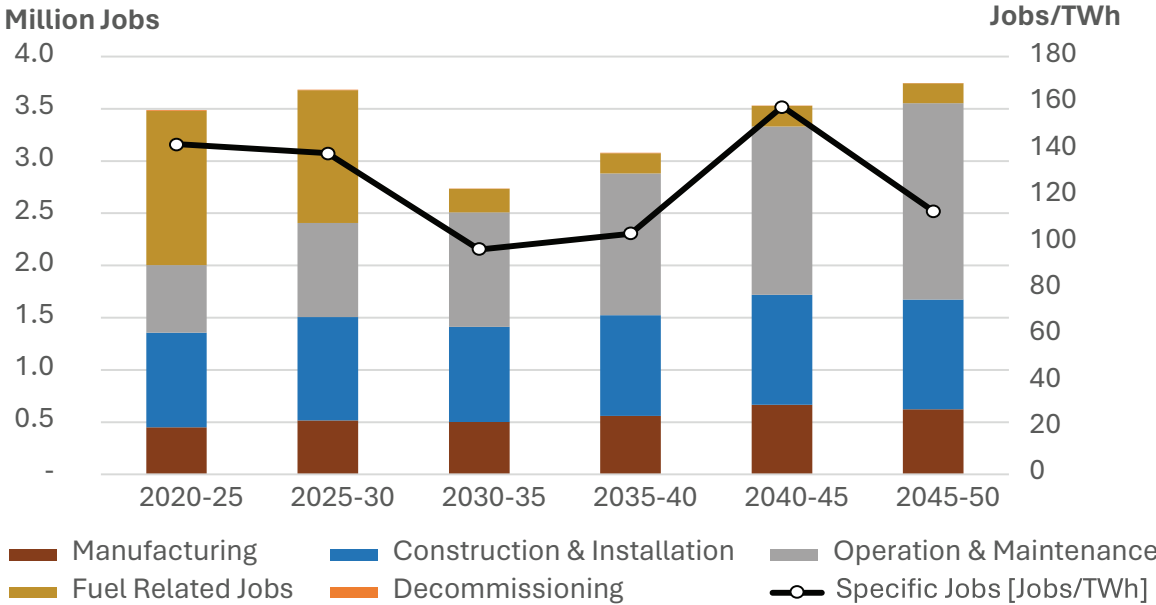
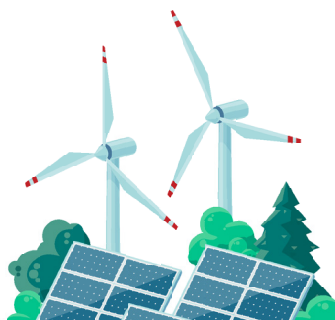
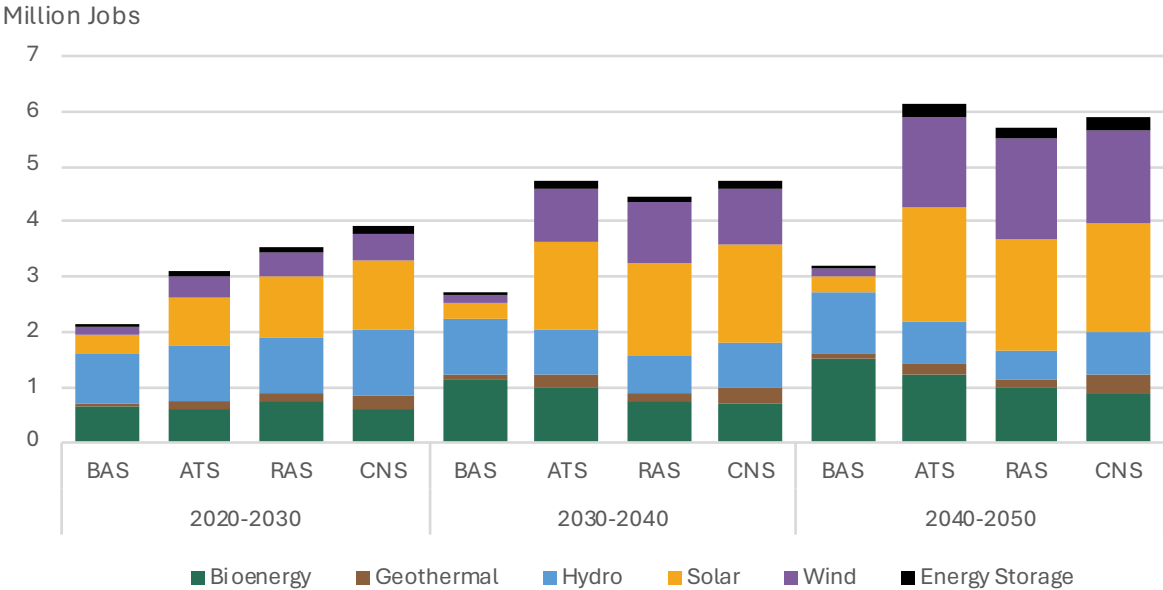


Figure 17. Projected Job Losses in the ASEAN Energy Sector Across Scenarios (2020-2050)



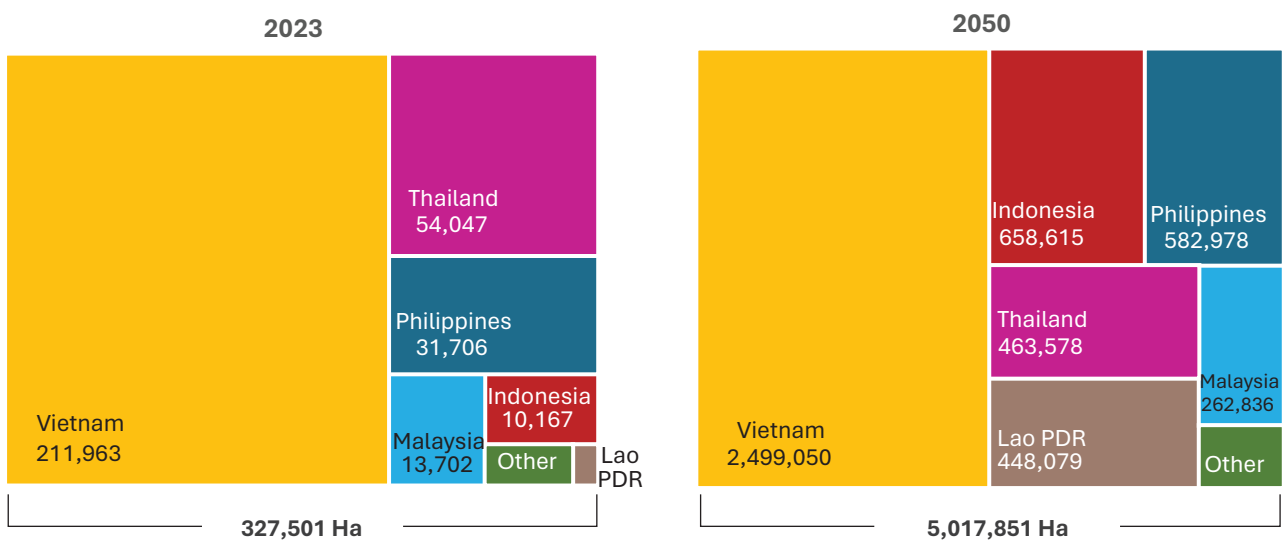
Land Use

A shift towards sustainable energy sources is projected to impact environmental loading, particularly concerning land requirements. Biofuels are increasingly integral to the energy mix of AMS, enhancing energy diversification and facilitating decarbonisation efforts. As countries like Indonesia, Malaysia, the Philippines, and Thailand advance biofuel blending mandates for biodiesel and bioethanol in the transportation sector, the total land requirement for biofuel production is projected to reach approximately 11.1 million hectares by 2050 under the BAS, with a substantial allocation of 8.4 million hectares for biodiesel. However, the CNS suggests a reduction in land use, with an estimation of 2.2 million hectares needed, achieved through optimised power supply and the integration of low-carbon technologies. The implications of these trends necessitate careful consideration of land use policies to balance biofuel production with environmental sustainability.

In parallel, the deployment of solar and wind power is rapidly transforming the energy landscape of the region, with installed capacities expected to grow significantly by 2050. As of 2022, solar and wind made up about 10% of the ASEAN energy mix, but this figure is projected to increase substantially, with land requirements anticipated to rise correspondingly. By 2050, the land allocated for solar and wind projects could occupy as much as 1 million hectares under the absence of energy policy interventions, increasing to 4 million hectares under more aggressive policy frameworks (ATS, RAS, and CNS). Notably, while wind technology demands more land than solar, both energy sources present opportunities to optimise land use. Engaging local communities in decision-making is critical to mitigating socio-ecological impacts, ensuring Free, Prior, and Informed Consent (FPIC), and fostering a sustainable energy transition that respects land rights and local aspirations.

Figure 18.

Land Used for Wind and Solar Projects by ASEAN Countries in 2023 and 2050, RAS



Energy Indicators

The summary table below provides a quick reference to some of AEO8's key assumptions and modelling results, enabling easy comparison amongst the four scenarios.

- Total ASEAN **population** will increase by 6.3% and 15.8% in 2030 and 2050 compared to 2022, respectively. Meanwhile, ASEAN economy is expected to grow fast with an expected average growth rate of 4% between 2023 and 2050. In 2050, the **Gross Domestic Product (GDP)** will rise to almost 3 times based on the 2022 level.
- In **TFEC**, implementing national target and bottom-up EE&C strategies in each AMS (ATS), an overall energy saving of 33% compared to the BAS is projected for ASEAN region by 2050. Although oil demand remains the highest in the ATS and RAS, its usage reduces the highest compared to the BAS, resulting in the increase of bioenergy and electricity shares. The share of electricity in TFEC will increase significantly in the CNS by 24.5% in 2050 compared to 2022.
- In **TPES**, fossil fuels continue to dominate the energy mix in BAS, but under CNS, their share drops significantly to 33.3%, with coal output rapidly declining. It is reduced to 36.8 Mtoe due to tighter emission constraints, an 82.7% drop from 2022 levels. Natural gas grows steadily to 268 Mtoe in ATS and maintaining a 20% share in the CNS by 2050. Oil supply decreases significantly in the ATS, RAS, and CNS with CNS showing an 81.8% reduction by 2050. **Renewable energy (RE) sources in TPES** experience substantial growth across all scenarios, specifically under CNS, increasing 6.6-fold to 715.3 Mtoe by 2050, with solar, wind, geothermal, and emerging technologies like tidal and wave energy contributing to a 70.2% share of the energy mix.
- In 2022, **ASEAN's energy intensity (EI) reduction** was noted at 24.5%. Following historical trend (BAS) and current national policy intervention (ATS) is still insufficient to achieve the regional target in 2025. By scaling up national efforts and optimising the adoption of clean technologies will enable the AMS to meet its 2025 regional target, and even higher in 2030 by reducing EI 44.7% (RAS) and 44.3% (CNS).
- **Installed capacity** is projected to grow by 2.6 times to 821 GW in the BAS by 2050, dominated by natural gas, coal, and hydro. Applying national policies (ATS) is expected to increase installed capacity by 36% compared to the BAS by 2050, with solar and wind expanding 5 and 8 times. Nuclear capacity is introduced starting from 2032, reaching 1,450 MW by 2050. The most substantial expansion occurs in the RAS and CNS, with capacities of 1,436 GW and 1,586 GW by 2050, respectively, as renewable energy accelerates across these scenarios.
- **RE sources in installed capacity** can experience a prominent increase following historical trend, the region could achieve 35.9% renewable energy share by 2030 based on Baseline Scenario. Under ATS and RAS, renewable energy shares will achieve 44.1% and 49.3%, respectively in 2030. From the RAS to CNS, RE sources see strong growth with solar, wind, and geothermal increasing by 80.2 GW and new technologies, such as tidal and wave energy, contributing an additional 25 GW in 2050.
- Throughout all scenarios, there is an increase in **total electricity** generation across the given timeframe, reflecting growing energy demand driven by economic growth and population increases in the region. Electricity generation is reduced from BAS to ATS due to energy efficiency efforts but increases across the remaining scenarios. The CNS estimates the highest level of electricity generation among all scenarios by 2050, reaching approximately 3,528 TWh. By 2050, **RE share in electricity** generation contributes 33.6% by following historical trend (BAS). Under ATS, nuclear energy is introduced by 2032, contributing 0.8% (11.9 TWh) to the electricity generation mix.
- The increase in **GHG emissions in ASEAN** is mostly driven by a combination of rapid economic growth, heavy reliance on fossil fuels, and population growth. In 2050, the ATS will cut emissions by 46% and RAS will further decrease by 23%, compared to BAS. Aligning with CNS will achieve the highest emission reduction at 78% compared to BAS in 2050.



	Historical	Baseline Scenario (BAS)		AMS Targets Scenario (ATS)		Regional Aspiration Scenario (RAS)		Carbon Neutrality Scenario (CNS)	
	2022	2030	2050	2030	2050	2030	2050	2030	2050
Population (million persons) - constant across scenarios	679.7	722.8	787.4	722.8	787.4	722.8	787.4	722.8	787.4
GDP (billion 2017 USD PPP) - constant across scenarios	8,788	12,565	25,952	12,565	25,952	12,565	25,952	12,565	25,952
Total final energy consumption (TFEC, in Mtoe)	432	587	1,108	513	746	467	578	436	465
% Electricity in TFEC	21.7%	20.9%	20.3%	21.3%	23.2%	21.9%	25.9%	27.1%	46.2%
Total primary energy supply (TPES, in Mtoe)	698	947	1,823	820	1,220	758	1,012	764	1,018
% Coal in TPES	30.5%	27.3%	26.0%	23.4%	14.4%	27.1%	14.7%	22.6%	3.6%
% Oil in TPES	31.7%	31.8%	29.8%	30.6%	26.9%	29.8%	25.8%	23.3%	9.7%
% Gas in TPES	19.7%	20.8%	20.3%	21.1%	22.0%	19.4%	16.5%	20.2%	20.0%
% RE in TPES	15.6%	18.6%	23.2%	23.5%	38.1%	25.0%	50.4%	34.6%	70.2%
EI reduction from 2005 level	-24.5%	-31.0%	-45.0%	-40.2%	-63.2%	-44.7%	-69.4%	-44.3%	-69.2%
Installed power capacity (GW)	315	434	818	485	1,115	549	1,436	583	1,586
% RE in installed power capacity	33.6%	35.9%	37.9%	44.1%	69.4%	49.3%	71.7%	50.4%	73.1%
Electricity generation (TWh)	1,270	1,659	3,036	1,472	2,769	1,548	2,920	1,665	3,528
% RE in electricity generation	29.2%	31.2%	33.6%	44.7%	71.9%	50.2%	84.7%	55.2%	90.9%
Energy-related GHG emissions (MtCO ₂ eq)	2,215	2,847	5,127	2,315	2,785	2,211	2,146	1,921	1,131









How Should ASEAN Set Its Future Energy Planning?



“To drive a just and sustainable energy transition in ASEAN, it is essential to enhance energy efficiency, diversify renewable energy sources, and integrate advanced technologies like smart grids and hybrid systems. Regional cooperation, supportive policies, and inclusive stakeholder engagement are crucial to ensuring energy security, affordability, and resilience. A comprehensive approach that involves local communities, fosters innovation, and balances geopolitical considerations will enable ASEAN to meet its ambitious clean energy goals.”



Future energy planning should adopt a multi-faceted approach, prioritising the following key considerations:

 Maximise energy efficiency	 Ensure energy diversification and security	 Promote multistakeholder collaboration
<p>Demand Side</p> <ul style="list-style-type: none"> <input type="checkbox"/> Enhance for buildings, Appliances, and industrial processes <input type="checkbox"/> Invest in efficient technologies to lower energy intensity and operational costs <input type="checkbox"/> Encourage energy diversification for long-term decarbonisation <input type="checkbox"/> Smart demand response through power sector energy use and RE integration for grid efficiency improvement 	<p>Supply Side</p> <ul style="list-style-type: none"> <input type="checkbox"/> Renewable energy sources diversification for greater energy security <input type="checkbox"/> Modernise electrical grids for handling renewable inputs and improving grid reliability <input type="checkbox"/> Balance clean energy with security for a secure energy shift (natural gas and CCS utilisation) <input type="checkbox"/> Ensure community inclusion in renewable energy projects Expand rural electrification efforts to ensure equitable access to energy <input type="checkbox"/> Implement carbon pricing strategies to accelerate decarbonisation 	<p>Regional Cooperation</p> <ul style="list-style-type: none"> <input type="checkbox"/> Promote interconnectivity, including ASEAN Power Grid and cross-border gas pipelines for energy flexibility <input type="checkbox"/> Develop supportive policies including clean energy investment incentives while ensuring energy security and affordability <input type="checkbox"/> Foster international cooperation to accelerate the transition <input type="checkbox"/> Engage with various stakeholders to ensure broad support and address concerns 



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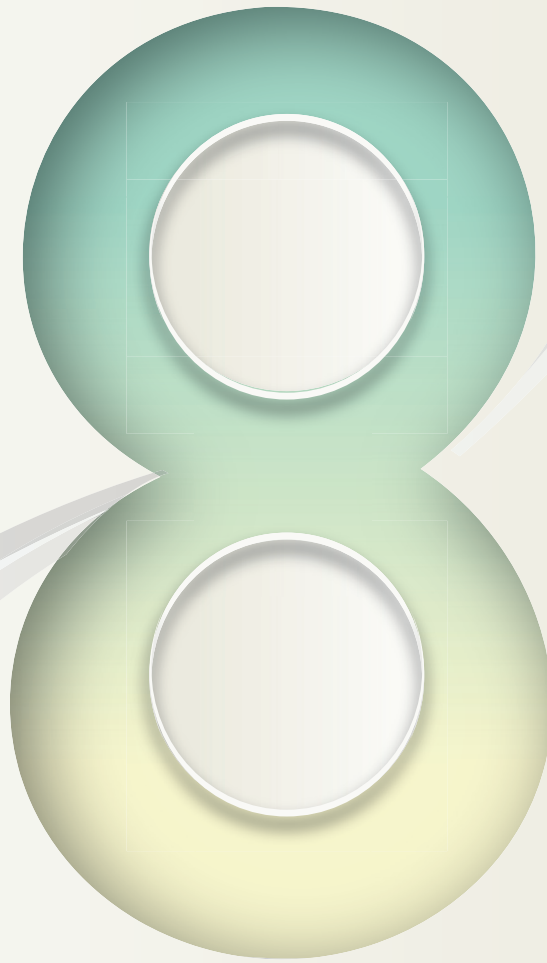
ASEAN Centre for Energy
Soemantri Brodjonegoro II Building, 6th fl.
Directorate General of Electricity
Jl. HR. Rasuna Said Block X-2, Kav. 07-08
Jakarta 12950, Indonesia
Tel: (62-21) 527 9332 | Fax: (62-21) 527 9350
E-mail: secretariat@aseanenergy.org
www.aseanenergy.org


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**ACE (2024). 8th ASEAN Energy Outlook (AEO8). ASEAN Centre for Energy (ACE), Jakarta.
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