# 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 to 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.

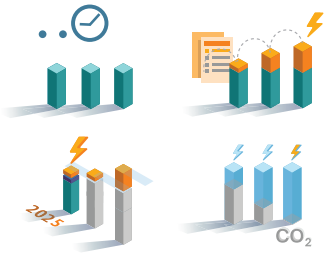
> **AEO8 is poised to serve not only as a guiding compass but also as a catalyst for the formulation of visionary regional targets and driving strategic energy policy development for the APAEC 2026-2030 and also for a coming transformative decade.**

# 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


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

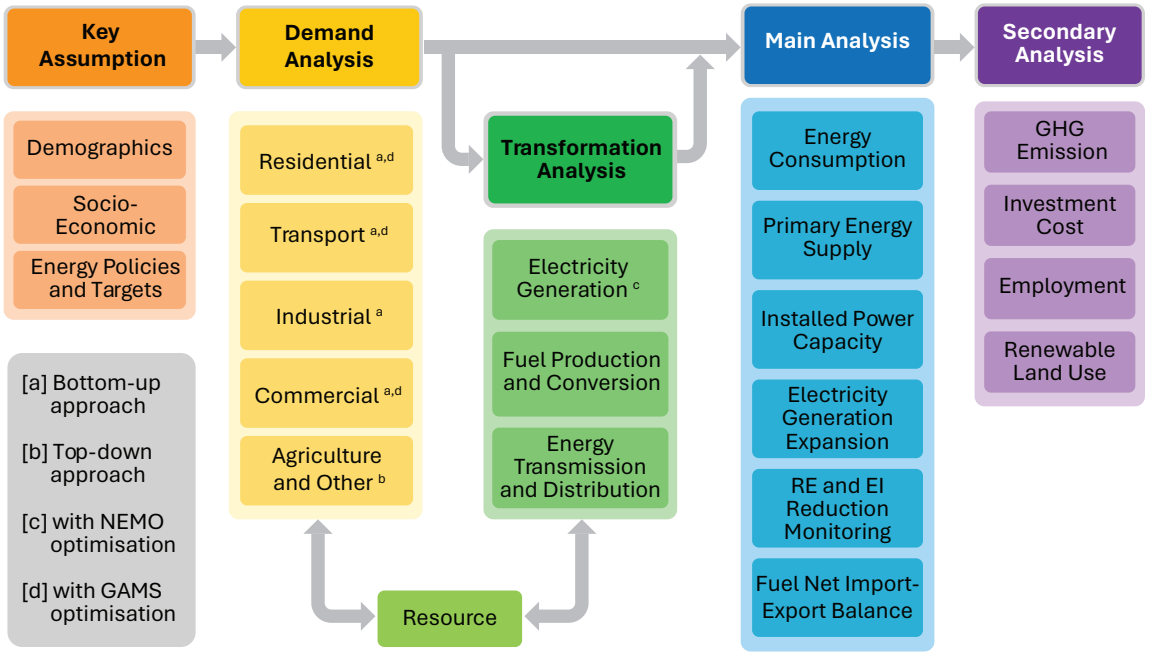
## CHAPTER 5 RECOMMENDATIONS AND IMPROVEMENTS

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.

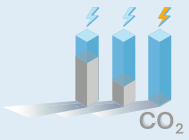
*Figure 1.*
## AEO8 Modelling Structure




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).

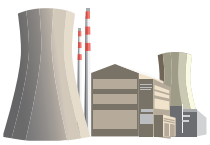
For AEO8, the Low Emissions Analysis Platform (LEAP) and the Next Energy Modelling System for Optimisation (NEMO) were employed. LEAP is a scenario-based, demand-driven tool capable of tracking energy consumption, production, and resource extraction across economic sectors, while NEMO optimises the supply 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 form the previous **historical** year | **No installed capacities from the national PDP** | **Not** conisdered 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 wtih **accelerated depolyment 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 futher 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 technoligies 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:



Emissions

Energy Employment

Land Use of Renewable

# Overview of ASEAN Member States Energy and Related Policies

| Country | Sector | Official Target |
|---|---|---|
| Brunei Darussalam  | Demand | • Increase the total share of EVs to 60% of total annual vehicle sales by 2035 |
| | Supply | • Increase the total share of RE to at least 30% of total capacity in the power generation mix by 2035<br>• 200 MW target for solar capacity by 2025 and more than 600 MW by 2035 |
| Cambodia  | Access | • Fully electrified by 2030 |
| | Demand | • Reduce energy consumption—thermal and electrical—by 19% by 2030 to a BAU trajectory[1]<br>• Public transport will have a 30% share in urban areas by 2050<br>• Moderate penetration for EVs: 70% for motorcycles, and 40% for cars and urban buses by 2050<br>• Compressed natural gas (CNG) penetration of 80% for interregional buses and 80% for trucks until 2050 |
| | Supply | • Aiming to achieve a minimum of 70% renewable energy capacity by 2030 |
| Indonesia  | Access | • Reach 100% electrification rate by 2025 |
| | Demand | • Reduce energy intensity (TPES per GDP) by 1%/year through 2025<br>• Achieve 2 million units of electric cars and 13 million units of electric motorbikes by 2030 |
| | Supply | • Increase RE share to 19% in TPES by 2025 and 25% by 2033<br>• Biodiesel blending ratio targets 30% by 2025 and 50% by 2050; Bioethanol blending ratio of 20% by 2025 and 50% by 2050<br>• 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 | • Increase the electricity access rate to 98% of total households by 2025 |
| | Demand | • Reduce TFEC by 10% by 2030 and 20% by 2040 as compared to the Baseline[2]<br>• Introduction of 50,000 energy-efficient cook stoves by 2030 (energy-efficient gasifier cookstoves using biomass pellets) |
| | Supply | • 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%)<br>• 13 GW total hydropower capacity (domestic and export use) in the country by 2030 |
| Malaysia  | Demand | • By 2040, achieve energy savings of 21% compared to the BAU scenario<br>• Elevate the public transport modal share to reach 40% by 2040 and 60% by 2050<br>• Accelerate the penetration of xEV (4W) share of the vehicle fleet to 80%<br>• Accelerate the penetration of electric two-wheelers' (E2W) share of the vehicle fleet to 80%<br>• Maintain the pathway towards achieving a 5% share of rail freight modal utilisation by the year 2030<br>• 5% of heavy vehicles utilise hydrogen by 2050 |
| | Supply | • Increase the RE share to 31% in the power capacity mix by 2030 and 40% by 2035<br>• Increase biodiesel blending targets to 30% (B30) by 2030<br>• Up to 47% sustainable aviation fuel (SAF) blending mandate by 2050 |

| | | |
|---|---|---|
| Myanmar | Access | • Increase electricity access rate to 100% by 2030 |
| | Demand | • Transport: Reduce consumption by 20% by 2030 (raise fuel efficiency and EV share)<br>• Industrial: reduce consumption by 3.6% by 2020, 5% by 2025, 6.6% by 2030<br>• Commercial/Residential: reduce consumption by 7.4% by 2020, 10% by 2025, 12% by 2030<br>• 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 | • Increase the RE share to 39% in electricity generation by 2030 (28% hydro and 11% other RE) |
| Philippines | Access | • Achieve a 100% household electrification rate by 2028 |
| | Demand | • Total energy saving by 2040: Transport 25%, Industry 15%, Residential 20%, Commercial 25%, Agricultural 10%<br>• Reach at least a 10% EV share for road transportation (including motorcycles, cars, jeepneys) by 2040 |
| | Supply | • Aim for at least 35% RE share in the power generation mix by 2030, 50% share by 2040, and more than 50% by 2050<br>• 1,200 MW Nuclear Energy by 2032, 2,400 MW by 2035, and at least 4,800 MW by 2050 |
| Singapore | Demand | • Reduce energy consumption in residential (existing HDB towns) by 15%<br>• Implement green buildings to see an 80% improvement in energy efficiency (over 2005 levels) by 2030<br>• Achieve 100% cleaner-energy public bus fleet and taxis by 2040 (electric or hybrid vehicles) |
| | Supply | • Increase solar energy deployment to at least 1.5 GWp by 2025 and 2 GWp in 2030<br>• 200 MW of deployed energy storage systems beyond 2025 |
| Thailand | Demand | • Decrease energy intensity by 30% of the base year in TFEC compared to 2010 level by 2037<br>• Achieve 30% EVs manufactured and sales by 2030 |
| | Supply | • 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 | • By 2025, reduce energy intensity in TFEC by 5%-7% and keep power losses under 6.5%<br>• 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<br>• Energy saving to 10% in 2030 and 20% by 2050 |
| | Supply | • The proportion of RE in the TPES will be 15%-20% by 2030<br>• Green hydrogen production will reach between 100,000 and 200,000 tonnes annually by 2030<br>• Renewables are to account for about 30.9-39.2% of Vietnam's electricity supply by 2030<br>• By 2030, electricity exports should be scaled-up to about 5,000 to 10,000 MW<br>• Increase the absorption area of solar hot water rigs in commercial, service, civil, and industrial production, providing about 3.1 Mtoe by 2030<br>• Total RE sources for heat production and co-generation of thermal power in 2030 will be about 8 to 9 Mtoe<br>• Biogas is expected to be about 60 million $m^3$ 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.*

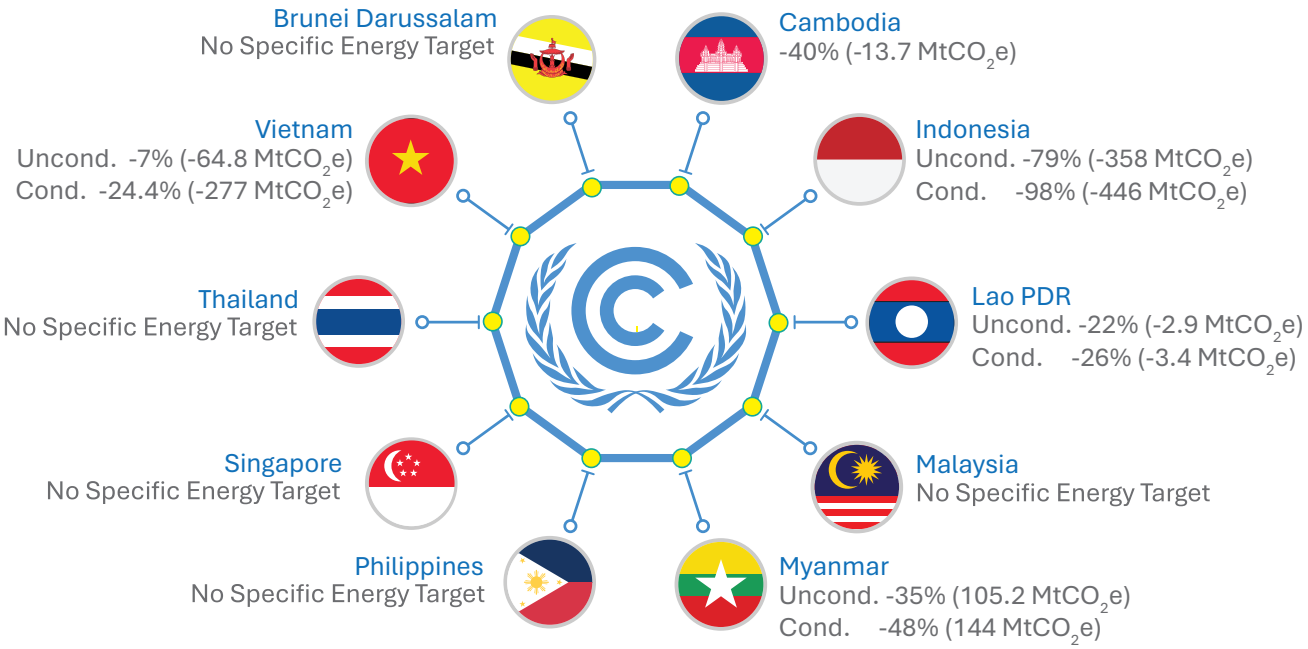
[1] Refer to its national energy outlook BAU scenario
[2] Refer to its national energy outlook BAU scenario

# 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 2030-2030 |
| 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 | Peak absolute emissions at 65 $MtCO_2$-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

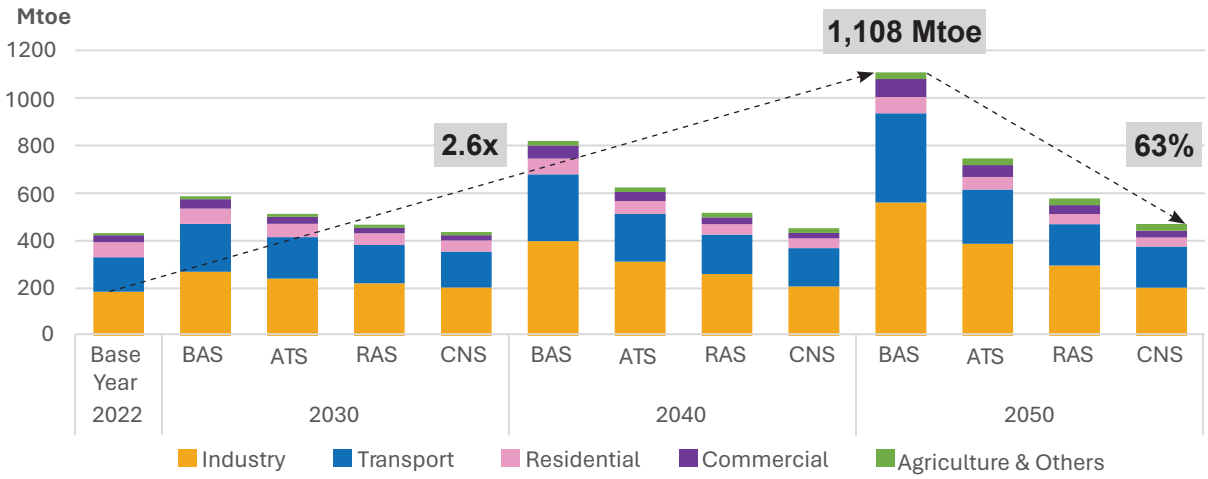
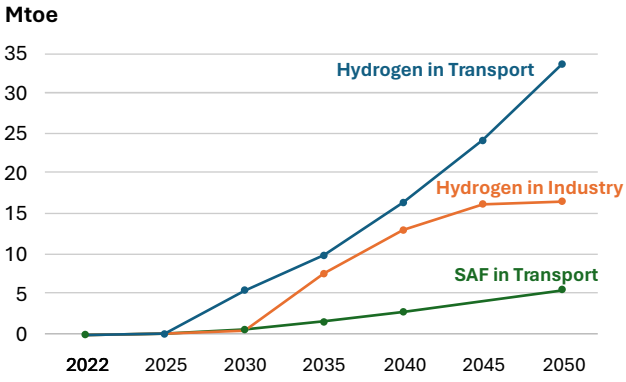



*Figure 4.*

## 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

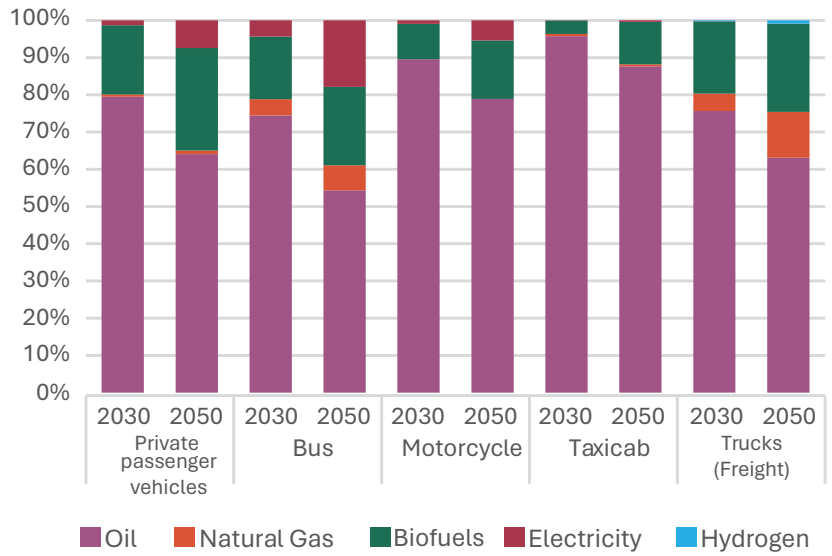
> **To achieve regional targets, a range of demand-driven policy interventions is needed, particularly in the transportation and industrial sectors—the highest energy consumers across all years and scenarios. These measures must accelerate current efforts to make significant progress.**

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)

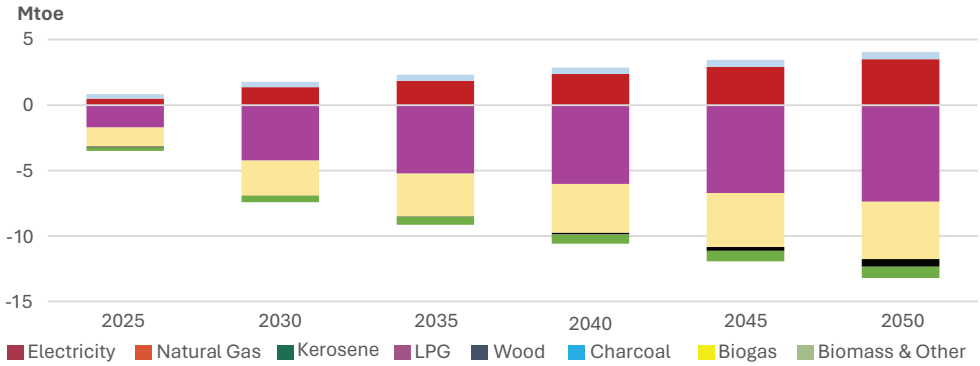



Attainment of EV deployment targets will also be crucial. Although several Member States have set promising strategies for increasing EV uptake, many specify the sales targets rather than penetration, which is more challenging to model in the Outlook. Thus, the scenario with national policies (ATS) is 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.*

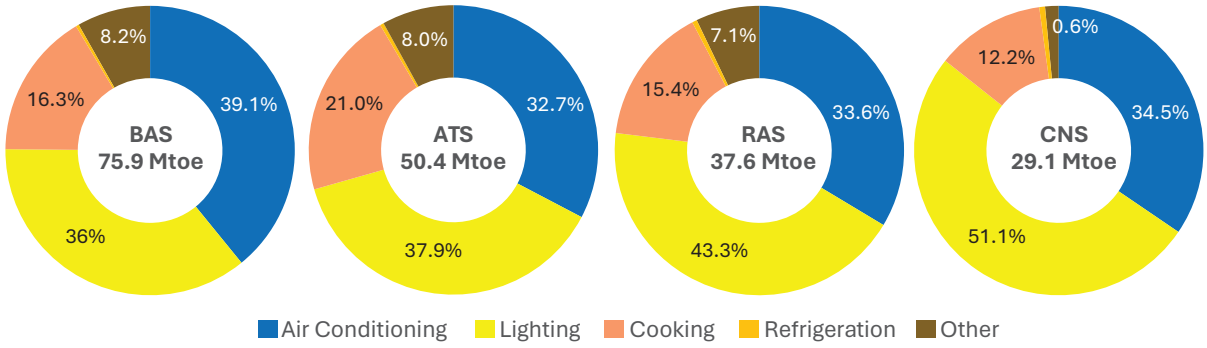
## Fuel Shifting due to Clean Cooking (ATS vs BAS)




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.

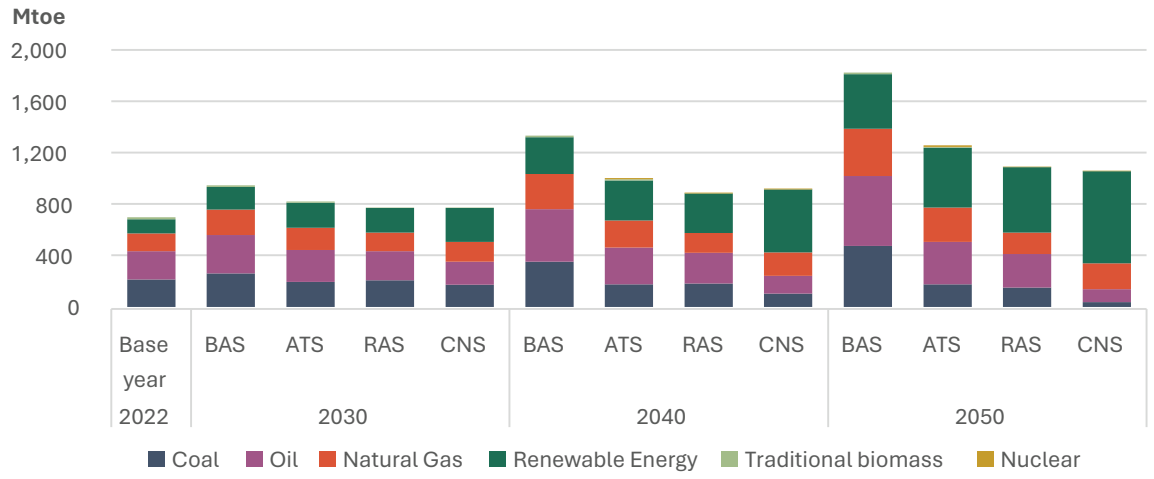
# Primary Energy Supply

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.

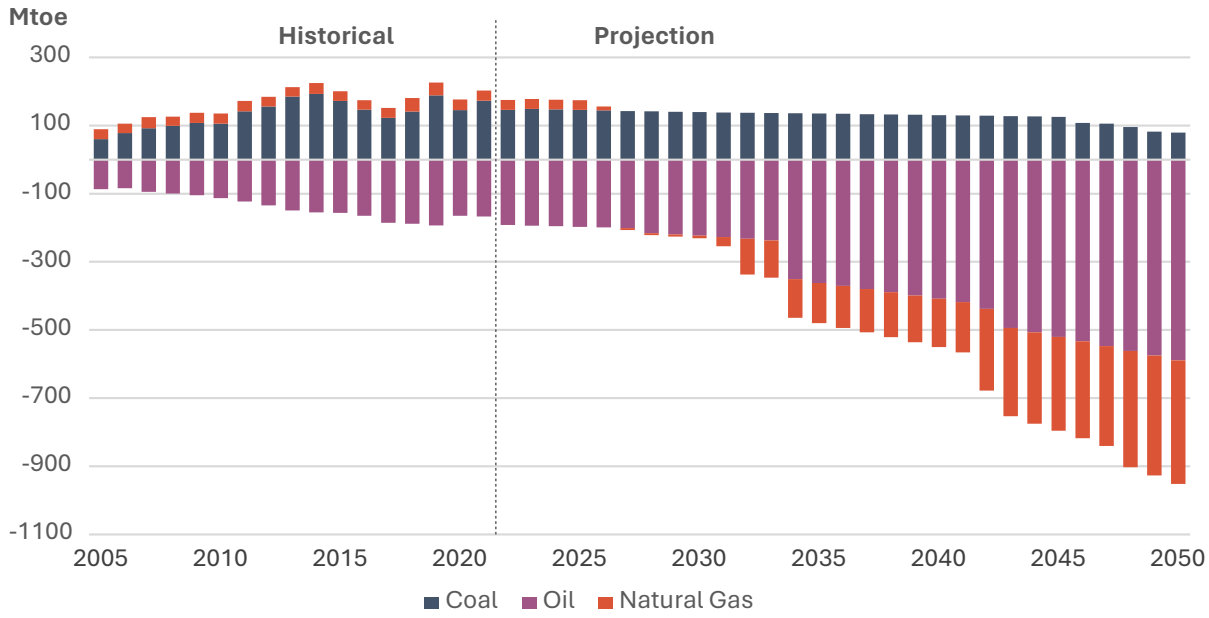
Oil supply increased, maintaining the largest total supply addition between 2022 and 2050 at about 321.3 Mtoe. However, oil supply decreased when compared to ATS, RAS, and CNS, which were 39.5%, 51.8%, and 81.8%, respectively. The percentage of fossil fuel used in transportation has decreased as a result 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

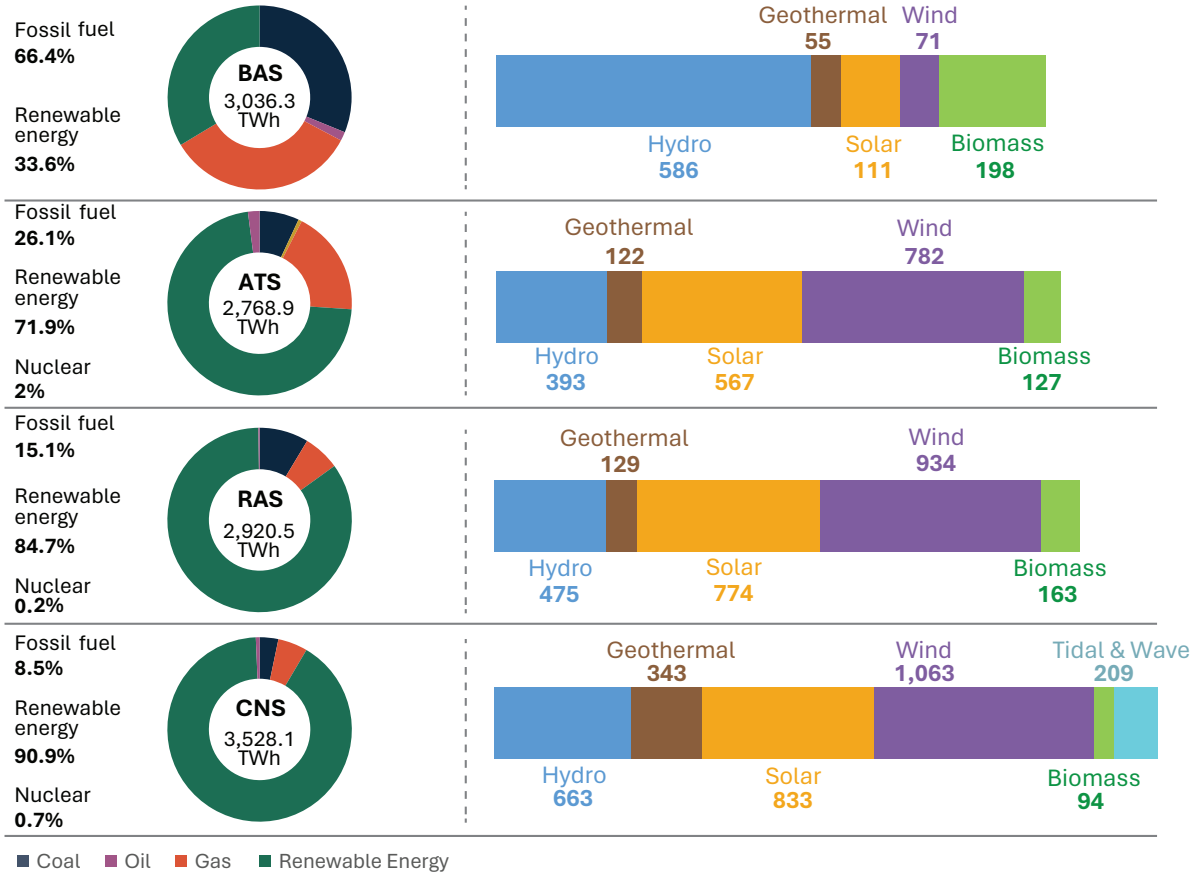
Across all scenarios, there is an expected increase in total power generation in ASEAN by 2050, driven by rising energy demand due to economic and population growth. The projected electricity generation for 2050 is approximately 3,036 TWh under the BAS, 2,769 TWh in the ATS, and 2,920 TWh in the RAS. 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.**

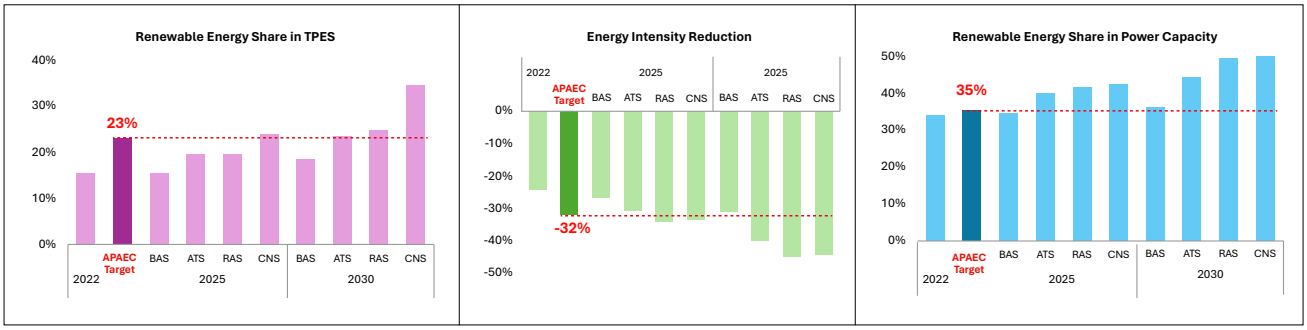
ATS projects that the region's electrification rate will reach 99.9% by 2030 and 100% by 2040. The ASEAN region also faces challenges in providing universal electrification due to many remote and hard-to-reach areas. Indonesia is expected to achieve 100% electrification by 2025, followed by the Philippines 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

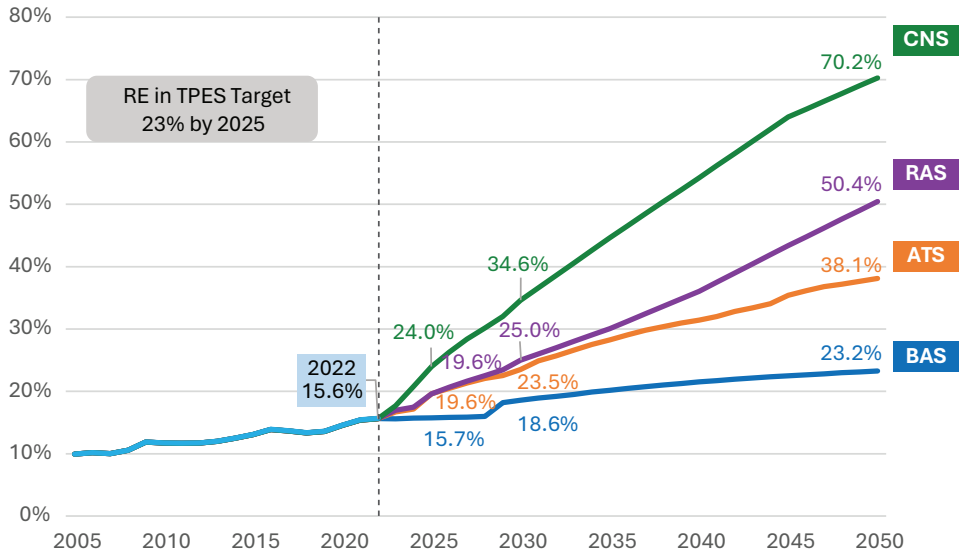



*Figure 12.*

## Renewable Energy Share in Installed Capacity Across Scenarios

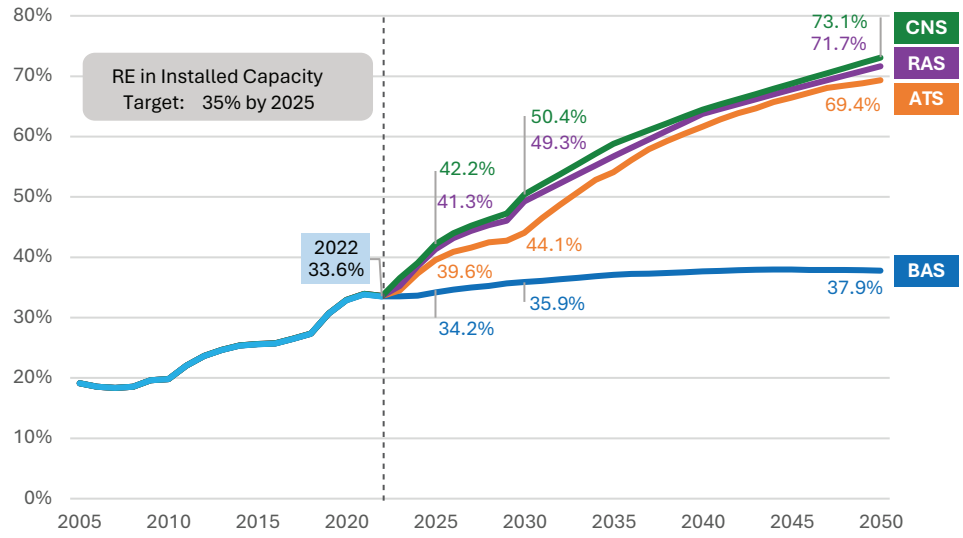
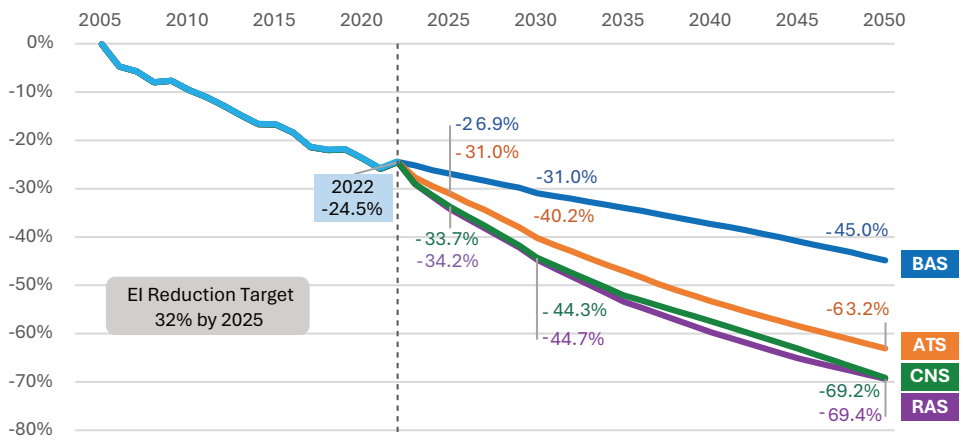



*Figure 13.*

## Primary Energy Intensity Reduction from the 2005 Level Across Scenarios

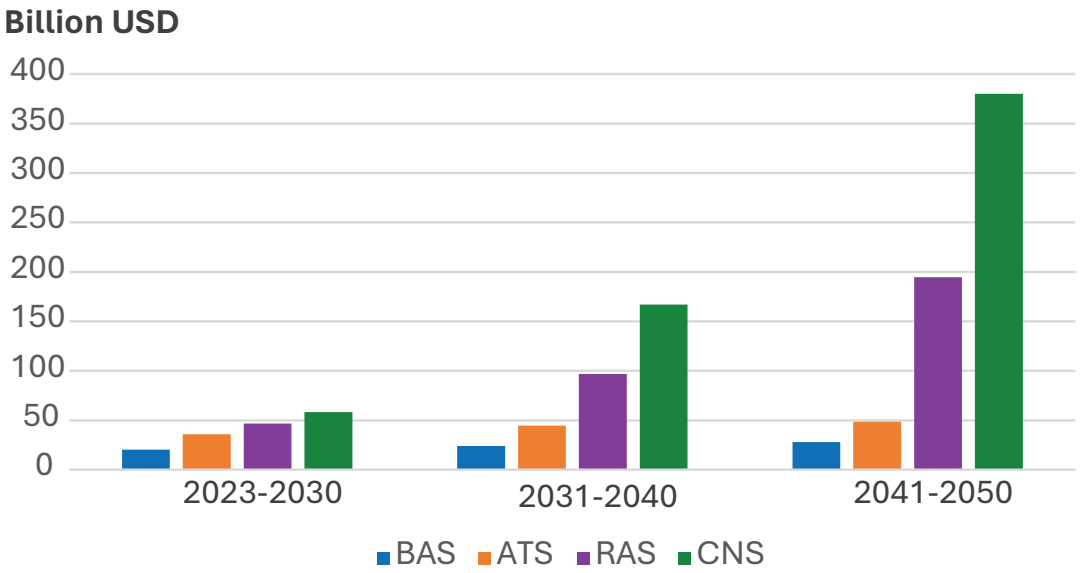


# Energy Financing

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.

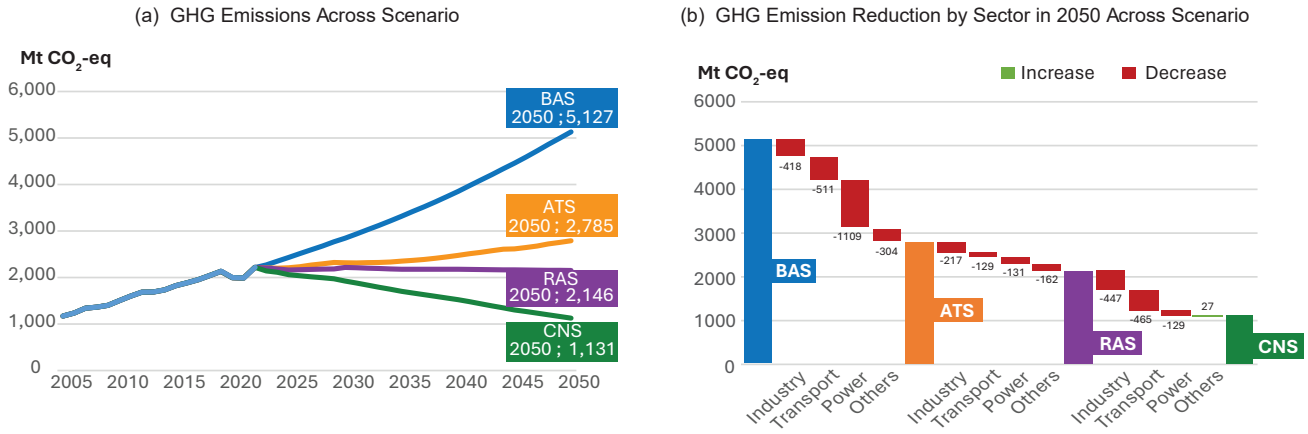
A major effect of the energy diversification policy in ASEAN has been to accelerate the deployment of clean energy technologies. Moreover, the region will experience massive power investment costs in the longer term for additional capacity infrastructure and to meet the electricity demand. In earlier 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 $MtCO_2$-eq in 2022, increasing almost two times from 1,175 $MtCO_2$-eq in 2005, covering demand and power sectors. In the demand sector only, the GHG emissions reached 1,080.7 $MtCO_2$-eq and will increase to 2,668.2 $MtCO_2$-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.

# 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.

Consequently, the bulk of employment will be mainly found in construction and installation (C&I) and operation and maintenance (O&M) jobs, while fuel-related jobs decline sharply as fossil fuels phase out. Between 2040 and 2050, fossil fuels job creation remains significant in the BAS, with over 11.8 million jobs added, comprising 73.7% of total employment, driven by 622 GW of new capacity. In contrast, ATS sees renewable capacity additions ten times higher than fossil fuels, leading to a larger share of RE jobs. Countries such as Vietnam, the Philippines, and Indonesia emerge as major contributors to job creation under the RAS, primarily due to large-scale RE projects. Vietnam is estimated to account for over 1.6 million new jobs between 2045 and 2050, with a significant portion tied to O&M job roles in the solar and wind sectors.

Net employment continues to grow in the BAS, reaching over 6 million jobs by 2045-2050, as fossil fuels remain a dominant energy source. Nevertheless, energy transition leads to considerable job losses in the fossil fuels sector. Total net employment under the RAS and CNS would decline between 2030 and 2040 as fossil fuel jobs rapidly disappear, although RE jobs help stabilise employment by 2050. The CNS projects over 3.2 million job losses by 2050 due to fossil fuel plant decommissioning. These trends highlight the importance of managing workforce transitions through retraining programmes and strategies to support workers affected by the decline of fossil fuels in ASEAN's energy transition.

*Figure 16.*

## Job Creations in ASEAN by Category in 2020-2050 (CNS)

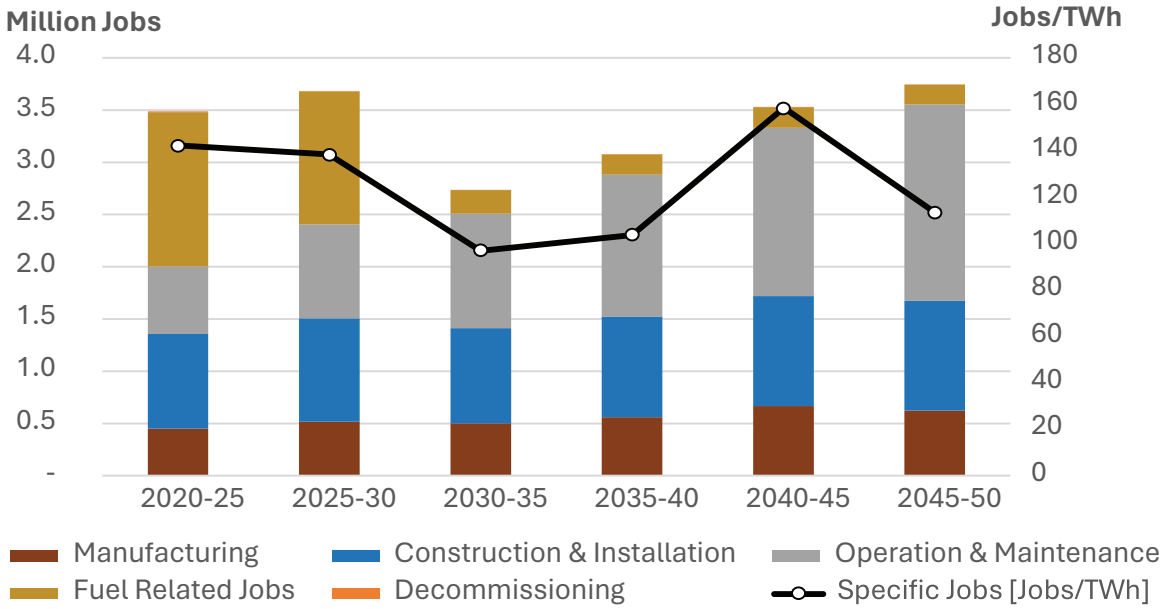
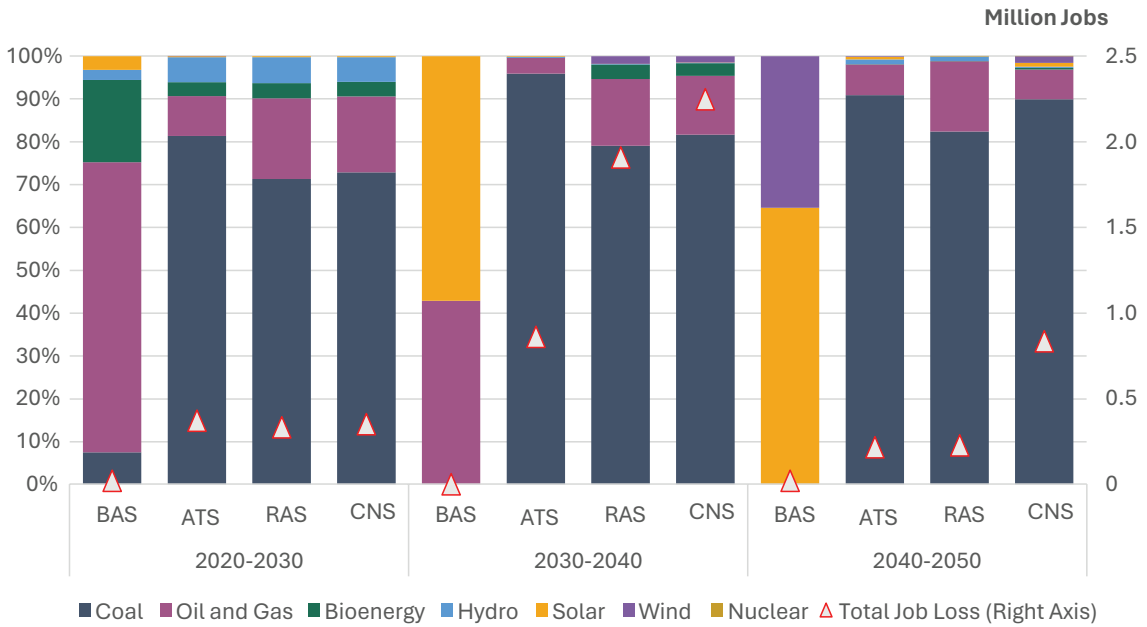



*Figure 17.*

## Projected Job Losses in the ASEAN Energy Sector Across Scenarios (2020-2050)



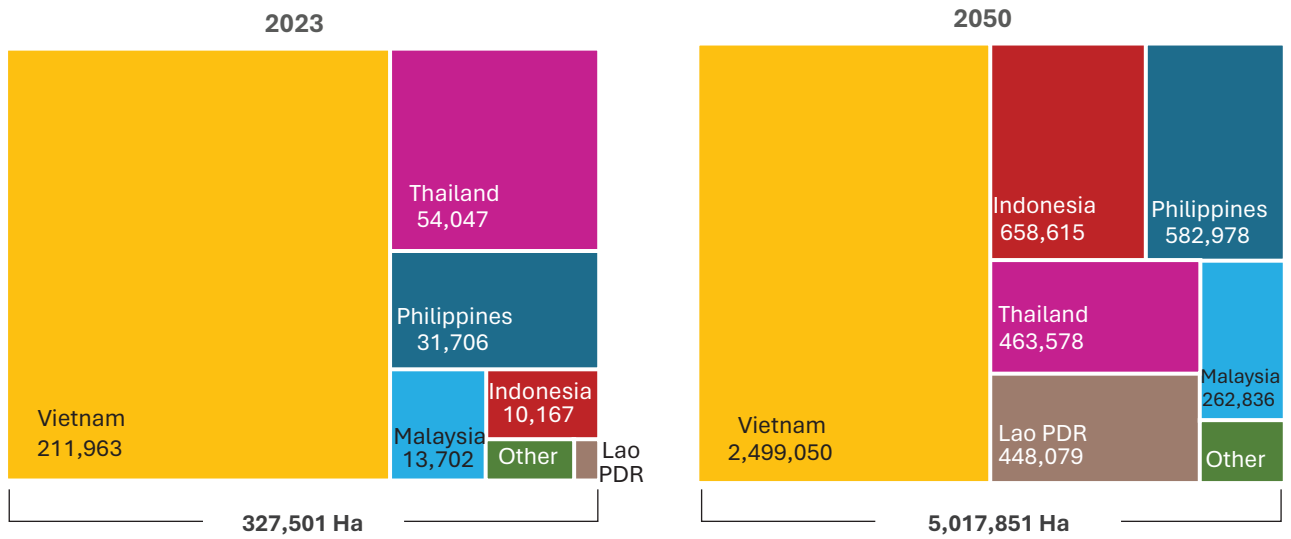

# Land Use

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



# The Key Findings

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.

| | 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 ($MtCO_2eq$) | 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 |
|---|---|---|
| **Demand Side** | **Supply Side** | **Regional Cooperation** |
| ❑ Enhance for buildings, Appliances, and industrial processes<br>❑ Invest in efficient technologies to lower energy intensity and operational costs<br>❑ Encourage energy diversification for long-term decarbonisation<br>❑ Smart demand response through power sector energy use and RE integration for grid efficiency improvement | ❑ Renewable energy sources diversification for greater energy security<br>❑ Modernise electrical grids for handling renewable inputs and improving grid reliability<br>❑ Balance clean energy with security for a secure energy shift (natural gas and CCS utilisation)<br>❑ Ensure community inclusion in renewable energy projects<br>Expand rural electrification efforts to ensure equitable access to energy<br>❑ Implement carbon pricing strategies to accelerate decarbonisation | ❑ Promote interconnectivity, including ASEAN Power Grid and cross-border gas pipelines for energy flexibility<br>❑ Develop supportive policies including clean energy investment incentives while ensuring energy security and affordability<br>❑ Foster international cooperation to accelerate the transition<br>❑ Engage with various stakeholders to ensure broad support and address concerns |

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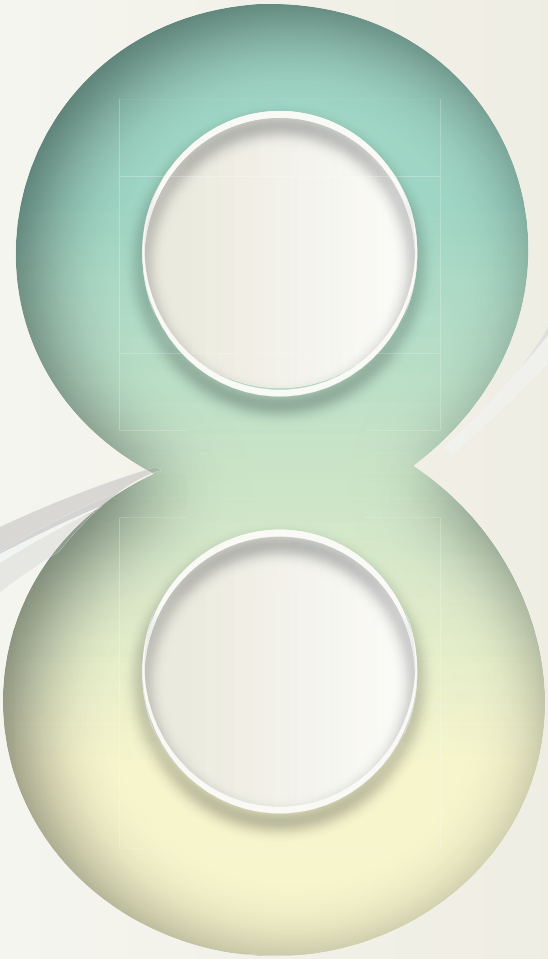

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