The 5th ASEAN ENERGY Outlook 2015 - 2040

One Community
For Sustainable
Energy

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About ACE

One Community For Sustainable Energy

Established on 1 January 1999, the ASEAN Centre for Energy (ACE) is an intergovernmental organisation that independently represents the 10 ASEAN Member States' (AMS) interests in the energy sector. The Centre serves as a catalyst for the economic growth and integration of the ASEAN region by initiating and facilitating multilateral collaborations as well as joint and collective activities on energy. It is guided by a Governing Council composed of Senior Officials on Energy from each AMS and a representative from the ASEAN Secretariat as an *ex-officio* member. Hosted by the Ministry of Energy and Mineral Resources of Indonesia, ACE's office is located in Jakarta.

One of ACE's cooperation is with GIZ on behalf of Federal Ministry for Economic Cooperation and Development (BMZ). The ASEAN-German Energy Programme (AGEP), is a jointly implemented projects by ACE and GIZ. AGEP aims to support the AMS in improving regional coordination for the promotion of renewable energy and energy efficiency towards sustainable energy for all. ACE is grateful to AGEP for its support in the development of AEO5.

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AEO5 was prepared under the overall guidance of Dr. Sanjayan K.V Velautham, Executive Director of ACE, and Maria-José Poddey, Principal Advisor for AGEP, GIZ.

AEO5 development was managed by the *AEO5* Technical Committee: Beni Suryadi (ACE), Badariah Yosiyana (ACE) and Rizky Fauzianto (GIZ).

This Outlook was developed with the assistance of the Fraunhofer Institute for Systems and Innovation Research (ISI): Dr. Wolfgang Eichhammer (team leader), Jose Antonio Ordonez (author and modeller), Dr. Inga Boie (contributing author), and Dr. Martin Pudlik (contributing author).

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Credit: ACE

Forewords

ASEAN Centre for Energy

One Community for Sustainable Energy

The 34th ASEAN Ministers on Energy Meeting (AMEM) held on 21 September 2016 in Nay Pyi Taw, Myanmar endorsed the periodic preparation of the ASEAN Energy Outlook by the ASEAN Centre for Energy (ACE). ACE is therefore pleased to publish t*he 5th ASEAN Energy Outlook (AEO5)*, the result of work between ACE, the members of the ASEAN Energy Outlook Working Group (AEO WG) from the ASEAN Member States (AMS), our partners the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH under the framework of ASEAN-German Energy Programme (AGEP), and with the assistance of the Fraunhofer Institute for Systems and Innovation Research (ISI).

AEO5 reflects the relevance of ACE's effort to fulfil its function as a regional centre of excellence that builds a coherent, coordinated, focused and robust energy policy agenda and strategy for ASEAN. While data collection and its availability in ASEAN is another main priority, which has progressed considerably over recent years. *AEO5* complements and supplements the outcome-based strategies of the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025: Phase 1: 2016-2020.

The findings of *AEO5* highlighted the needed focus for the region in terms of energy security, as energy demand is expected to grow as much as 2.3 times over long-term projections to 2040, in the Business-as-Usual scenario (BAU). At the same time, *AEO5* outlines the feasibility of substantial energy savings through significant energy efficiency (EE) and renewable energy (RE) injection, as demonstrated in the advanced scenarios. However, the energy mix in the region continues to rely heavily on fossil fuel, with coal outstripping natural gas as the main source of fossil fuel to meet the demand in the electricity sector by year 2020, and oil continues as the main source of fuel for the transport sector, accounting for about 45% of total final energy consumption (TFEC) during the projection years.

ASEAN will continue to embrace improvements in technologies whilst capitalising on the global trend of rapidly decreasing costs of variable RE. Nevertheless, robust policies and investments are still very much needed to transform the energy landscape in ASEAN. In this context, we believe that *AEO5* will contribute towards broad appreciation of the challenges of energy security, accessibility and affordability in driving economic prosperity, social development and environment sustainability within the framework of ASEAN Economic Community (AEC), which was launched in December 2015.

We hope that this Outlook with its insights on both the historical trends and future projections will serve as a useful and valuable reference to both AMS and our dialogue partners.

Ir. Dr. Sanjayan Velautham
Executive Director

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

ASEAN, the Association of Southeast Asian Nations, representing ten countries in South East Asia, is home to over 630 million people and has a GDP of almost US$2.4 trillion. The region is an important economic force in Asia and is becoming a driver of global growth. As a result of economic development, it is expected that ASEAN will require more energy, which currently depends on fossil fuels.

However, as highlighted at the Senior Officials Meeting on Energy in Manila in July 2017, and endorsed at the 34th ASEAN Ministers on Energy Meeting in September 2016 in Nay Pyi Taw, ASEAN Member States have again expressed their strong commitment towards renewable energy (RE) and energy efficiency (EE). These commitments are reflected in the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016 – 2025 which aims to achieve a renewable energy target of 23% by 2025 in the ASEAN Total Primary Energy Supply, and to reduce Energy Intensity to 20% by 2020 and 30% by 2025.

To support this action plan and address future energy concerns, the ASEAN-German Energy Programme (AGEP) – a jointly implemented project by ASEAN Centre for Energy (ACE) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) – has developed *the 5th ASEAN Energy Outlook* (*AEO5*).

The *AEO5* addresses key aspects of energy trends, policies, economic development and challenges related to energy systems in the region up to 2040. It aims to give deep and cohesive insights into the trends in energy supply and consumption both at regional and national level, while also providing recommendations to achieve APAEC targets. In 2040 oil is still the largest fuel in the primary energy mix followed by coal. The ASEAN Member States (AMS) have realised that RE and EE represent a central solution to reducing their dependence on fossil fuels and ensure a sustainable energy supply, economic growth and affordability, as well as to diversify the energy matrix. While ASEAN is on track to reduce Energy Intensity, Member States are recommended to show stronger commitment, and develop RE policies beyond the power sector in order to benefit from enhanced cooperation to reach the current APAEC target.

Following *the 4th ASEAN Energy Outlook* (*AEO4*, 2015), the *AEO5* is the second series jointly published by ACE and GIZ, with assistance of Fraunhofer Institute for Systems and Innovation Research (ISI). This publication has required a major joint research and development effort by actors in the region and Germany. Therefore, we would like to thank ACE, the members of the ASEAN Energy Outlook Working Group (AEO WG), as well Fraunhofer ISI, for the fruitful collaboration and continuous support.

We trust that *the 5th ASEAN Energy Outlook* will be of benefit to policy makers and stakeholders in the ASEAN region in the development of policy frameworks to ensure sustainable energy security in the Member States and the region.

Maria-José Poddey
Principal Advisor for AGEP, GIZ

ASEAN is one of the fastest growing regions in the world. Energy as a basic resource will be essential in the path of AMS towards a modern and wealthy community of states. In this path, energy-related and environmental challenges will inevitably emerge for all AMS. *The 5th ASEAN Energy Outlook (AEO5)* highlights how ASEAN can cope with the upcoming challenges up to 2040.

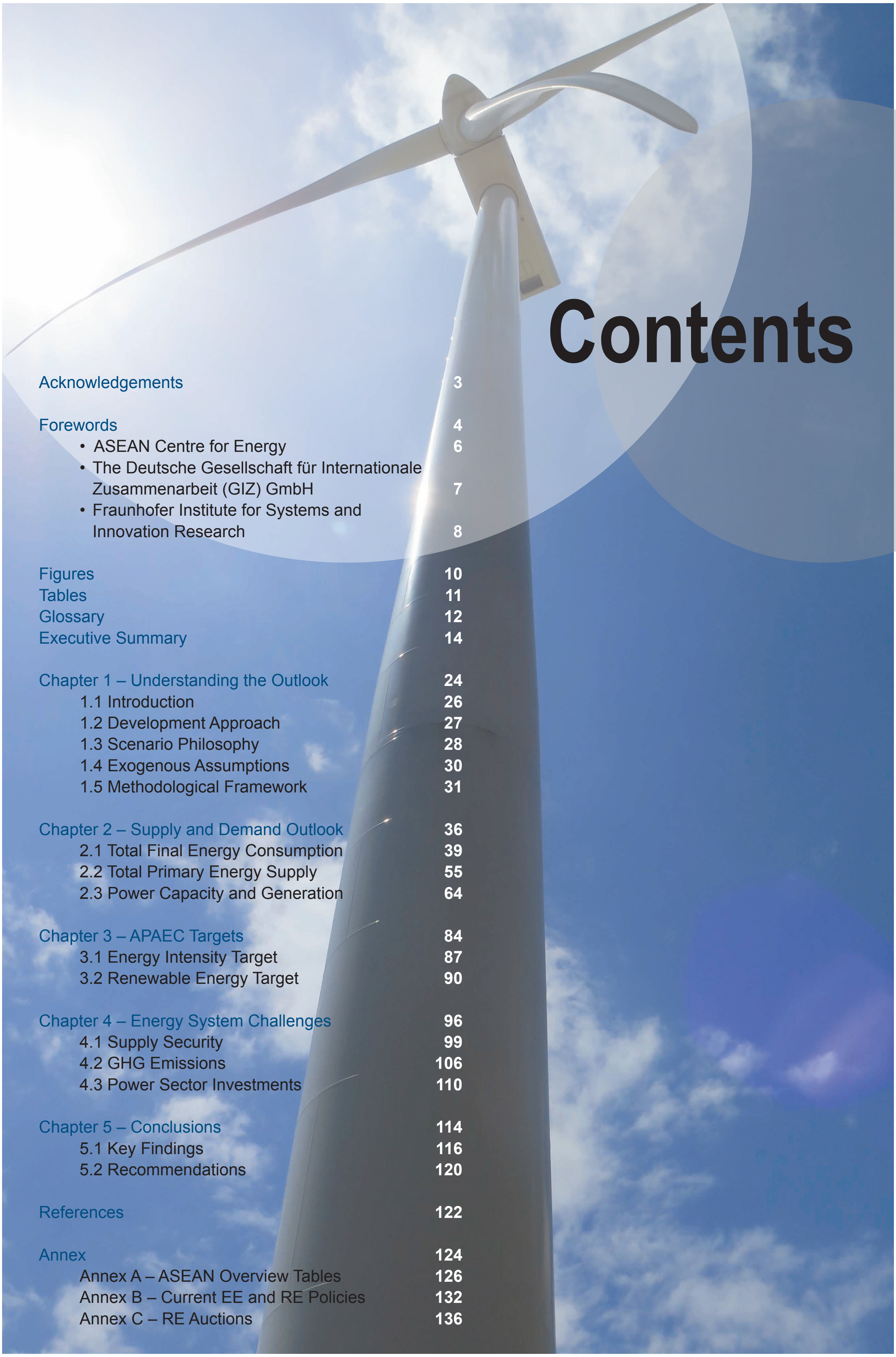
While the ASEAN region relied in the past strongly on the use of fossil fuels, the cost reduction for RE technologies at the global level has become a game-changer in the energy markets. The latest auctions in Mexico, Dubai and even cloudy Germany have shown never-before observed low-costs for solar PV power plants. With further cost decreases expected in the next years, renewable technologies will play a major role in meeting ASEAN´s future energy needs.

Renewable energy (RE), energy efficiency (EE) and the new markets arising from those technologies are not only about providing reliable and sustainable energy, but go along with numerous benefits other than clean energy as well as energy and greenhouse gas emission savings. The economic, environmental, fiscal, health-related multiple benefits of EE and RE are now widely recognized. They comprise the creation of local value added and corresponding local jobs, poverty alleviation, improved health, higher exports of fossil fuels, lower import dependency, relaxing state budgets, among many others. Still in an early stage of development, ASEAN economies can fully exploit the benefits from these new markets.

We are pleased to support the ASEAN Centre for Energy (ACE) in the development of *AEO5*. Such an extensive exercise requires major efforts for all involved participants and organisations. We would like to thank the AMS for their cooperation in the development of *AEO5*. I would also like to acknowledge the role of the persons who have carried a heavy load during the development of this outlook, notably, Jose Antonio Ordonez, Project Coordinator at Fraunhofer ISI; Beni Suryadi, Project Coordinator at ACE; as well as Rizky Fauzianto, Project Coordinator at GIZ. We are looking forward to continuing our strong partnership with ACE and are confident that the result of this joint effort will provide policymakers and stakeholder with valuable insights towards coping with future challenges in ASEAN.

Prof. Dr. Wolfgang Eichhammer
Head of Competence Centre Energy Policy and Energy Markets, Fraunhofer ISI

Contents



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Figures

Tables

Glossary

ABBREVIATIONS

ACE	ASEAN Centre for Energy
AEC	ASEAN Economic Community
AEDP	Alternative Energy Development Plan
AEO4	The 4th ASEAN Energy Outlook
AEO5	The 5th ASEAN Energy Outlook
AGEP	ASEAN-Germany Energy Programme
AMEM	ASEAN Ministers on Energy Meeting
AMS	ASEAN Member States
APAEC	ASEAN Plan of Action for Energy Cooperation
APS	ASEAN Progressive Scenario
ASEAN	Association of Southeast Asian Nations
ATS	AMS Target Scenario
BAU	Business as Usual Scenario
CAGR	Compound Annual Growth Rate
CO_2	Carbon dioxide
COP21	Twenty-first session of the Conference of Parties
EE	Energy Efficiency
EI	Energy Intensity
FiTs	Feed in Tariffs
GDP	Gross Domestic Product
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
IEA	International Energy Agency
INDC	Intended Nationally Determend Contributions
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
LEAP	Long-range energy alternatives planning system
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
PPP	Purchasing Power Parity
PV	Photovoltaic
PwC	PriceWaterhouse Coopers

RAPID	Refinery and Petrochemicals Integrated Development
REPP-SSN	Regional Energy Policy and Planning Sub-sector Network
RE	Renewable energy
RUEN	Rencana Umum Energi Nasional (National Energy Plan)
TFEC	Total Final Energy Consumption
TPES	Total Primary Energy Supply
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

UNITS

bbl	Barrels
bcm	Billion cubic metres
CO_2eq	Carbon dioxide equivalent
Gt	Giga tonnes
GW	Gigawatt
ktCO_2eq	Kilo tonnes of carbon dioxide equivalent
mbbl/d	Million barrels per day
Mt	Mega tonnes
Mtce	Metric tonnes carbon equivalent
MtCO_2eq	Million tonnes of carbon dioxide equivalent
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
MWh	Megawatt hour
tCO_2eq	Tonnes of carbon dioxide equivalent
TWh	Terawatt hour

CURRENCIES

EUR	Euro
USD	United States Dollar
THB	Thai Baht

Credit: Bioenergy Resources, GIZ

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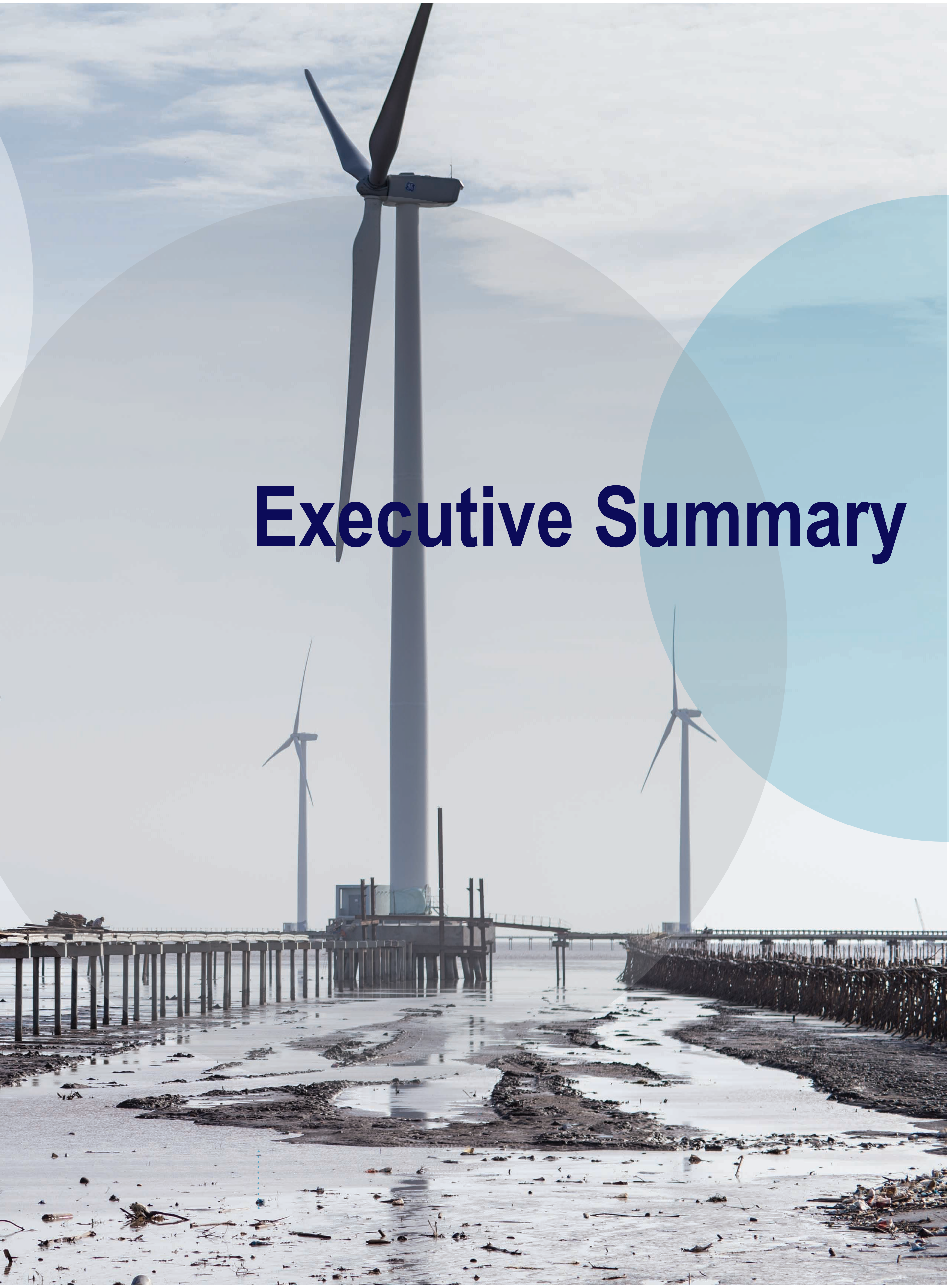
Executive Summary



Executive Summary

The 5th ASEAN Energy Outlook (AEO5) aims to provide policymakers and stakeholders in the Association of Southeast Asian Nations (ASEAN) with an understanding of mid- and long-term energy and environmental related challenges up to 2040. *AEO5* builds on previous *Outlooks*, the most recent of which was launched at the 33rd ASEAN Ministers on Energy Meeting (AMEM) in Kuala Lumpur, Malaysia in 2015. *AEO5* underpins the *ASEAN Plan of Action for Energy Cooperation* (APAEC) 2016-2025, which among other defines objectives, region-wide targets for energy efficiency (EE) and renewable energy (RE).

To estimate future demand in *AEO5*, energy system models were developed for each ASEAN Member State (AMS). The results from each AMS were aggregated to obtain the regional outlook, and validated by an independent regional model. Thus, the final results of *AEO5* are in-line with AMS expectations of their future energy landscape. In particular, the most influential inputs to *AEO5* projections are based on AMS national expectations of future economic and population growth.

DEVELOPMENT APPROACH

***AEO5* was developed based on four pillars:**

- **Cooperative approach:** *AEO5* was developed based on remarkably strong cooperation between AMS representatives, the ASEAN Centre for Energy (ACE) and the Fraunhofer Institute for Systems and Innovation Research (ISI) as consultant, with the support of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

- **Harmonised approach:** A set of comparable models was developed in order to increase comparability and learn from the results among AMS as well as from the previous relevant studies. The energy models were defined using the same projection methodology and with comparable structures in final consumption sectors, transformation modules (i.e. power sector, refining sector) and primary supply. Of note, the harmonisation of the models was not intended to account for the heterogeneity in the energy system of each AMS.

- **Controlled approach:** AMS projections were reviewed by computing a set of sensitivities. An independent regional model was created to validate and control the results.

- **Guided approach:** Data, process and results were reported and consulted with ASEAN's Regional Energy Policy and Planning Sub-sector Network (REPP-SSN) Focal Points for validation and confirmation, and also for their guidelines for alignment with the region's priorities and goals under APAEC 2016-2025.

Cooperative Approach	Harmonised Approach	Controlled Approach	Guided Approach
Strong cooperation between AMS and ACE with support from Fraunhofer ISI (consultant) and GIZ	Increase the comparability by having comparable energy simulations and same methodology	Validation of result using regional model	Validation and verification by REPP-SSN

SCENARIO PHILOSOPHY

What are the consequences to energy demand and supply, as well as CO_2 emissions, if AMS continue to follow past practices, to strongly meet the growing energy needs based on fossil fuels?

It represents BUSINESS-AS-USUAL SCENARIO (BAU); without significant changes to past practices and assuming that AMS develop no specific policies in reaching their most recently issued EE and RE targets.

What are the implications for energy demand and supply, as well as CO_2 emissions, if AMS attain their officially issued EE and RE national targets?

It represents AMS TARGETS SCENARIO (ATS); target-based scenario assuming that the most-recently-issued EE and RE national targets are reached.

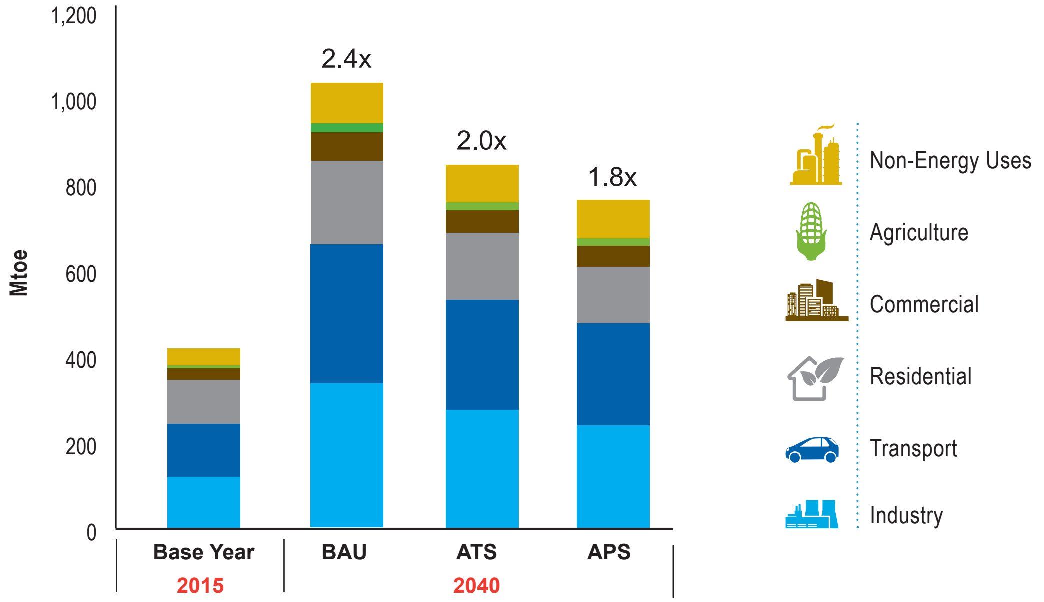
What efforts are required from each AMS on EE and RE to meet the regional APAEC 2016-2025 targets?

It represents ASEAN PROGRESSIVE SCENARIO (APS); target-based scenario assuming that regional targets defined in APAEC 2016-2025 are reached. It has a higher ambition level in EE and RE for each AMS as opposed to ATS.

TOTAL FINAL ENERGY CONSUMPTION (TFEC)
TOTAL PRIMARY ENERGY SUPPLY (TPES)

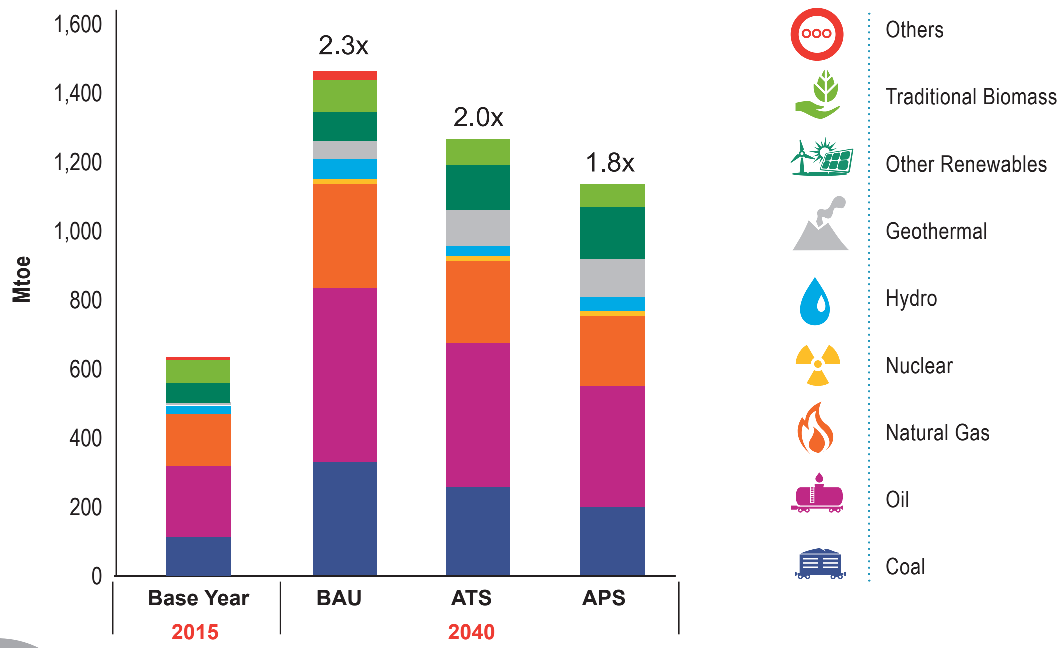
- TFEC escalates from 427 Mtoe in 2015 to 1,046 Mtoe (BAU), 856 Mtoe (ATS), and 771 Mtoe (APS) in 2040. The increase is driven by industry, transport and residential sectors. These sectors provide opportunities for potential energy savings and efficiency gains.
- Under AMS Targets Scenario (ATS) and ASEAN Progressive Scenario (APS), EE targets lead to savings in TFEC of 18.2% and 26.3% respectively in 2040, as compared to BAU.
- Industry and transport sectors expand in ATS with a CAGR of approximately 3.3% and 3.1%, respectively. The residential sector shows a moderate growth as a result of a shift away from traditional biomass, and increasing access to grid-quality electricity.
- Oil is dominant in TFEC, both historically and in the projection period in all scenarios. Notably, biofuels play a significant role with a CAGR of 3.6% in ATS.
- In the absence of enhanced EE and RE, between 2015 and 2040, TPES will increase more than double.

Projections of Total Final Energy Consumption (TFEC)



- Under Business-as-Usual Scenario (BAU), TPES is expected to increase by a factor of 2.3 reaching 1,450 Mtoe by 2040. Under AMS Targets Scenario (ATS) and ASEAN Progressive Scenario (APS), EE and RE targets lead to savings in TPES of 13.9% and 22.6% respectively in 2040, as compared to BAU.
- In 2040 in all scenarios, oil is still the largest fuel in the primary energy mix followed by coal in BAU and ATS. In APS, RE is the second largest fuel, a result of more ambitious initiatives for RE. A number of population in rural and remote areas are still relying on traditional biomass, but it loses its relevance in the ASEAN energy mix by decreasing its share from 10.6% in 2015 to only 5.8% in 2040 under ATS.
- Contribution of RE changed significantly in 2040, from only 14.0% in BAU, to 21.2% in ATS and 31.4% in APS.
- Collaboration of EE and RE contributes to making the overall TPES increase only 1.8 times in APS, compared to 2.3 and 2.0 times in the other two scenarios.

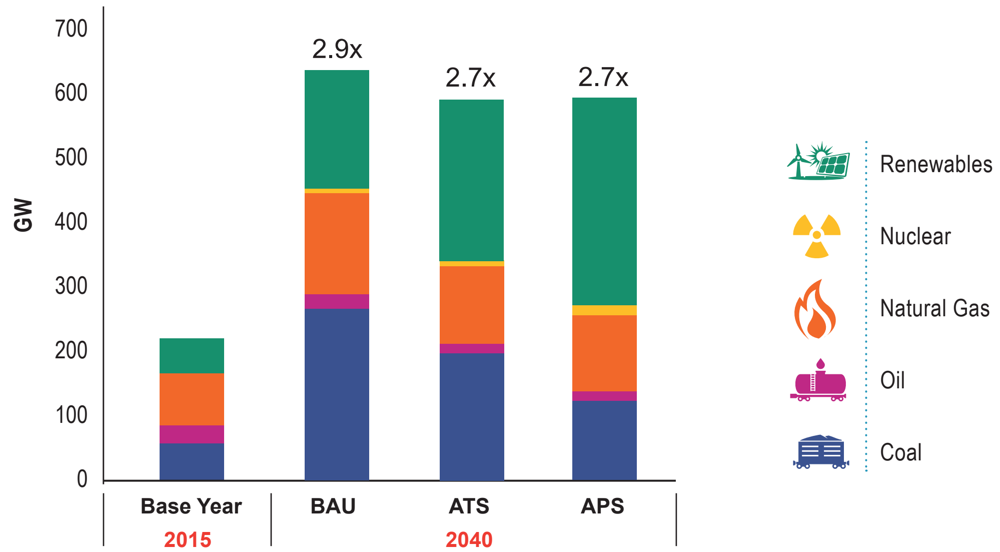
Projections of Total Primary Energy Supply (TPES)



POWER GENERATION CAPACITY

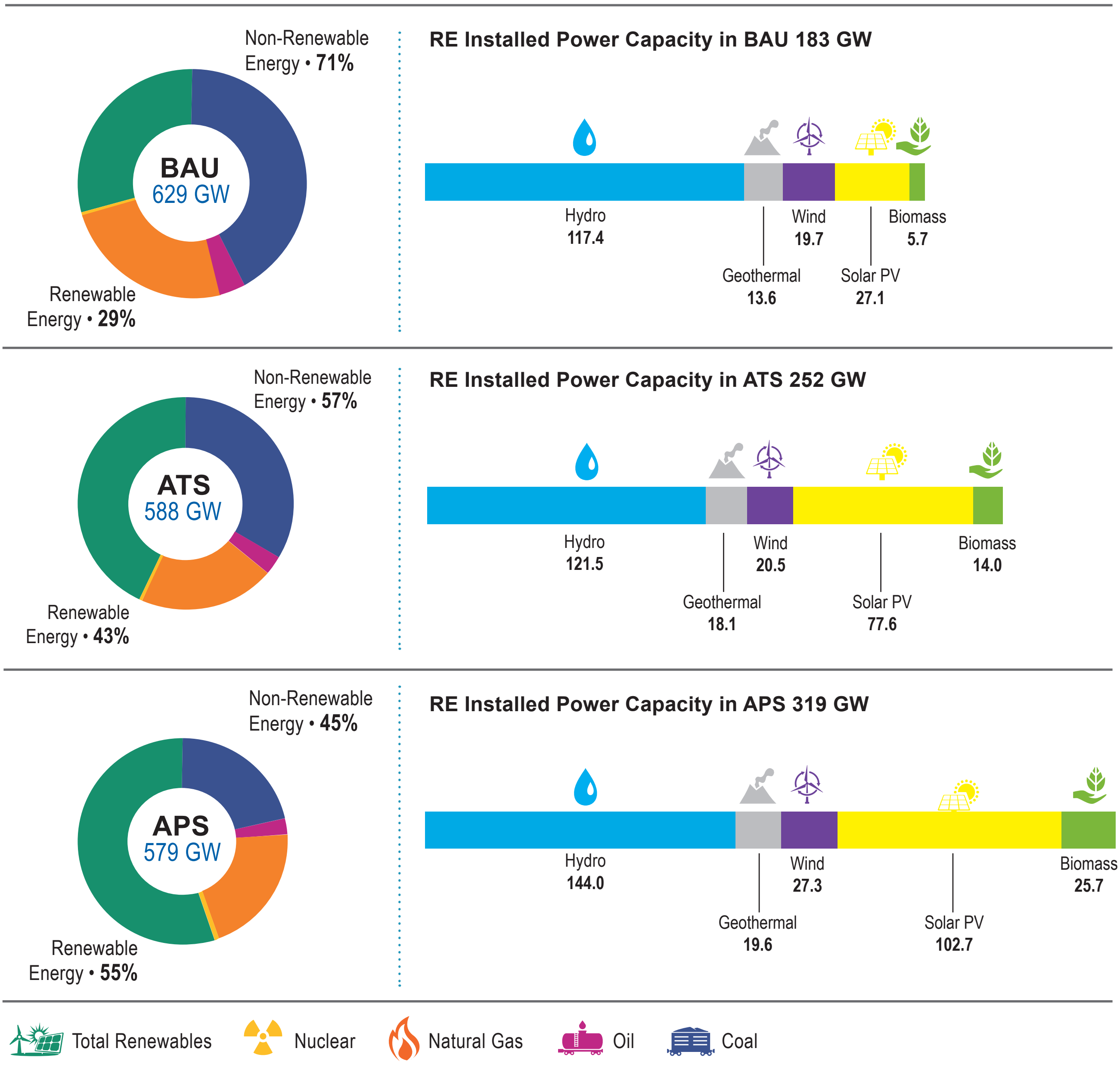
- Increasing electrification ratio and wealth in ASEAN will lead to a strong increase in the power capacity. It is necessary to cope with rising electricity demand, and the enhanced efficiency is expected to lower the capacity requirements.
- RE (hydro, geothermal, solar PV, wind, biomass) plays an important role in dealing with rising power demand, while coal makes a strong contribution in BAU.
- Under BAU, power capacity in 2040 is required to increase three-fold to 629 GW to cope with strongly rising electricity demand. A total of 424 GW will be added, of which 42.4% is produced from coal, followed by RE at 29.2%. However, enhanced efficiency can lower the installed capacity requirements substantially avoiding additional capacity requirements of 42 GW under ATS and 50 GW under APS.
- Under all scenarios, the share of oil and gas continue to decline while coal and RE continue to grow as the result of the abundant availability of coal and the cost reduction of RE technologies.
- Hydro, solar PV and wind are expected to be major drivers of RE, with variable RE (e.g. solar PV and wind) making contributions of 16.7% (ATS) and 22.4% (APS) to the total installed power capacity in 2040.

Projections of Power Generation Capacity



Credit: ACE

Capacity Composition in 2040



APAEC 2016-2025 TARGETS

- *AEO5* shows that ASEAN is well-placed to reach the target of reducing the energy intensity (EI). The medium-term (2020) component is reached in all scenarios, exceeding the target by 5% in BAU, 8% in ATS and 9% in APS. In the long-term (2025) component , EI is reduced by 29% in 2025 in BAU, thereby missing the target with a gap of 1%. However, it exceeds by 5% and 8% in ATS and APS, respectively.
- Increasing the component of RE to 23% by 2025 in the energy mix will require stronger efforts by AMS than currently foreseen. BAU stays under 13%, ATS reaches 17.5%, while only through APS can RE reach 23% by 2025.
- The highest contribution to RE targets under APS comes from the power generation sector (14.9%), while the remainder comes from RE in final energy demand (modern biomass and biofuels).
- Both the EI and the RE target components of APAEC 2016-2025 are complementary. Improving EI by enhancing RE leads to lower energy demand and supply. Thus, reaching the RE target component is facilitated if TPES is reduced by fostering EE. In view of ASEAN being well on track to reach the EI target, ASEAN could tighten the EI target to facilitate achievement of the RE target.

TARGET ACHIEVEMENT AND TARGET FRAME

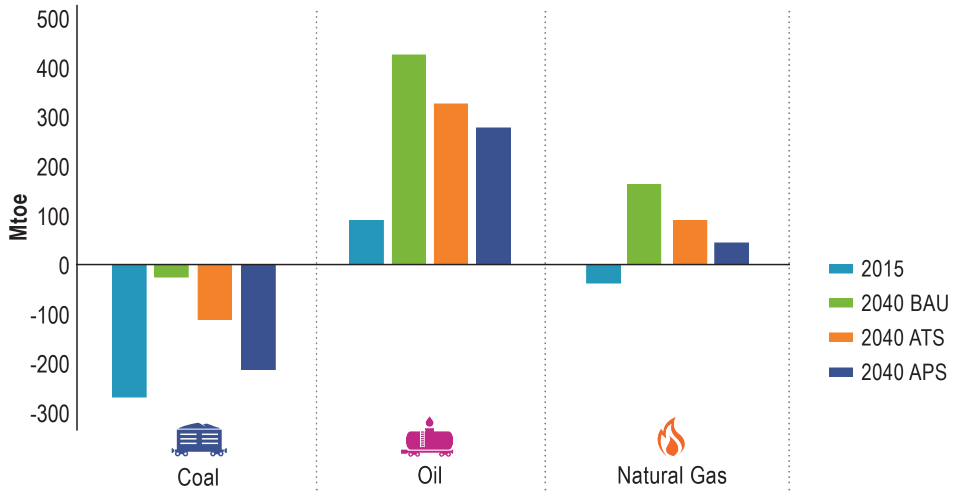
- *AEO5* highlights how ASEAN is already coping with challenges up to 2040 (BAU and ATS), and which efforts are necessary to enhance the ambition of the ASEAN approach as required by APAEC. Notably EE and RE options appear as cornerstones for future energy policy.
- *AEO5* projects that ASEAN is on track to reach the APAEC EI target. This creates opportunities for further EE efforts in support of the RE targets, as both are interacting and complementing each other.
- *AEO5* shows that enhancing EI targets in the perspective of a 2030 frame for EE and RE and beyond up to 2050 is relevant for the ongoing process of target setting.
- The 2030 frame will create opportunities for more coordinated EE and RE policies among AMS. Similar coordinated efforts on RE, notably on the integration of electricity grids and markets in ASEAN when facing larger shares of RE, could bring significant benefits to the whole region. In the next decades, the 2030 policy frame could also significantly support the ongoing Paris process to combat climate change.
- While *AEO5* highlights numerous benefits for AMS if they reach their nationally issued EE and RE targets, or even higher benefits if AMS increase the ambition level to reach the APAEC 2016-2025 targets, implementing policies to meet these targets will be necessary.
- Political targets solely represent a goal to be reached in the future, which can only be attained by incorporating adequate (EE and RE) policy measures. This approach necessitates well-honed transition plans in light of present dependence on fossil-fuels in the generation mix.

SUPPLY SECURITY CHALLENGES ON FOSSIL FUELS

- ASEAN is a major coal producing region, while oil and natural gas are produced by several AMS. Strongly rising energy demand affects ASEAN supply security and capability to export energy carriers, and thus the ability to generate economic value.
- During the *Outlook* period, ASEAN as a region remains a net exporter of coal, mostly attributed to Indonesia and Vietnam. Reaching EE and RE targets in ATS and APS leads to substantially reduced domestic demand which could also enhance the energy security.
- Import dependency for natural gas increases. With limited pipeline import options, ASEAN will need to rely on LNG. This would increase the exposure of risks to geopolitical uncertainties, although the supply seems to be adequate at the moment.
- ASEAN is already a net importer of crude oil and significant additional imports of crude oil will be required in all scenarios.
- In the long-term, post 2025, the demand for oil products surpasses refining capacity. If the national (ATS) and regional (APS) EE and RE targets are reached, refining capacity expansions will surpass domestic demand for oil products, making refined oil products available for export.
- In the more ambitious scenarios, assuming the attainment of EE and RE targets and implementation of corresponding policies (ATS and APS), import dependency is reduced considerably.

Credit: ACE

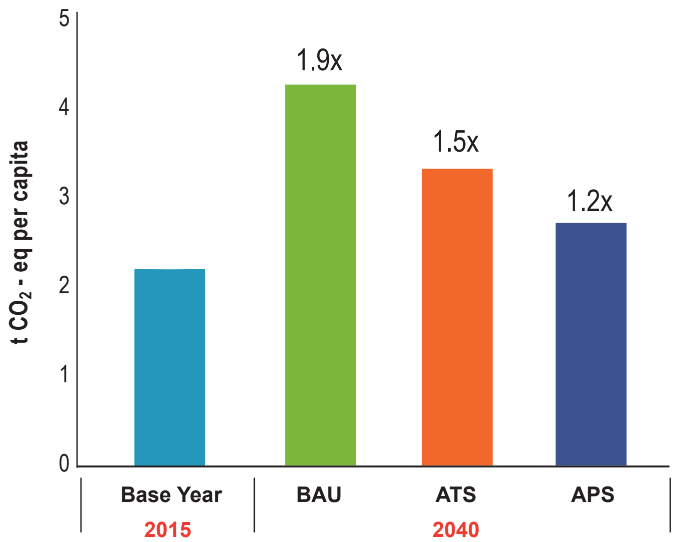
Projections on Fossil Fuels Import



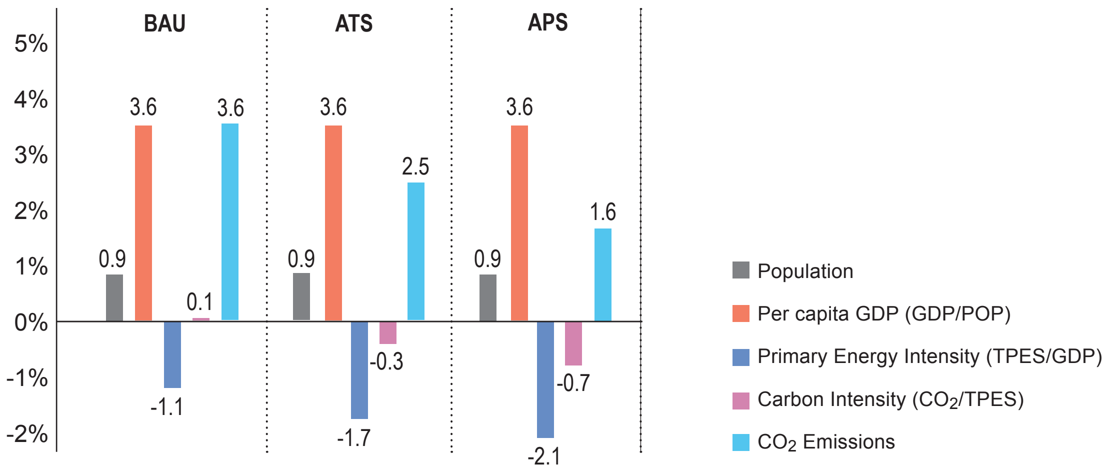
EMISSION PROJECTIONS

- Total CO_2 emissions will increase in the years ahead, from 1,446 Mt CO_2eq in 2015 to reach 3,460 Mt CO_2eq in BAU by 2040. APS is expected to limit the growth to only 2,168 Mt CO_2eq in 2040.
- Per capita emissions will increase by a factor of 1.9 in BAU, while they could be limited to a factor of 1.2 in APS.
- Kaya decomposition analysis shows that emissions will be driven by the increasing wealth (per capita GDP) and population growth.
- It also shows that ASEAN can substantially reduce CO_2 emissions by enhancing EE and RE (reduction of 23.4% in ATS, and 37.3% in APS as compared to BAU).

Projections on Emissions



Kaya Decomposition Analysis



POWER SECTOR INVESTMENTS

- Power sector is one of the most significant contributors for the region to achieve its aspirational goal of 23% share of RE in TPES by 2025.
- The APAEC target of 23% by 2025 can only be reached in APS. The region will need to increase the total installed capacity by another 1.7% as compared to ATS. The projected incremental cost for this as compared to ATS is USD 1.3 billion annually.
- Beyond the APAEC horizon, the required amount of the investments for ATS and APS are significantly lower than BAU. This finding proves that ASEAN's goal for integration and sustainability of RE can be achieved with lesser investment in the long term.

RECOMMENDATIONS

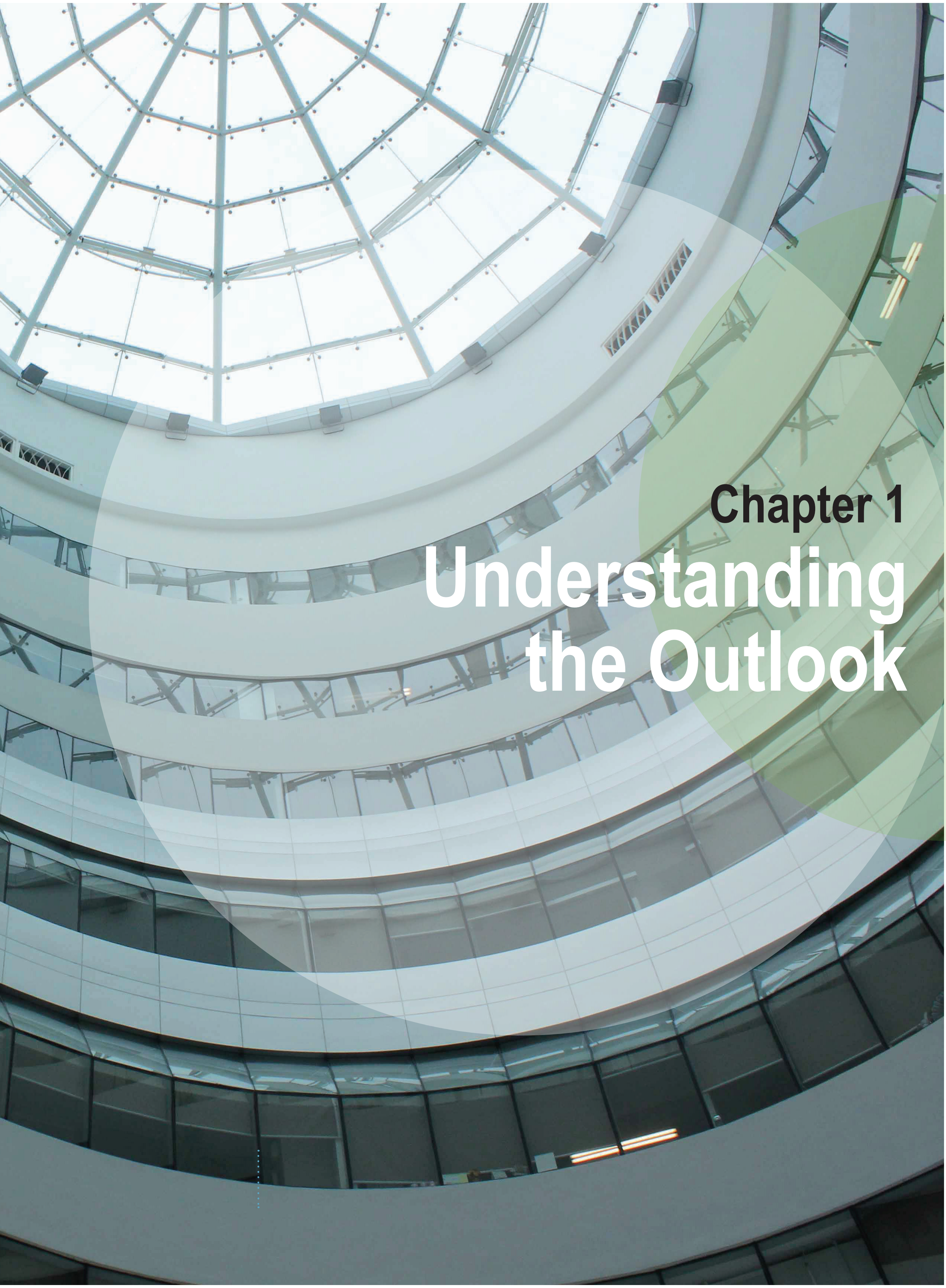
1. **Enhance synergies between EE and RE targets.** Improving EE and reducing EI leads to lower requirements of power capacity and generation. ASEAN is well on track to reach the APAEC 2016-2025 EI target, but stronger efforts will be required to reach the RE target. Hence, ASEAN could consider tightening the EI target component and thereby help to reach the RE target component.

2. **Implement stronger policies in both EE and RE.** This will be required to reach both the EI and RE component of the APAEC 2016-2025 targets:
   a. Regarding EE, stronger cooperation in the introduction and harmonisation of labelling and minimum energy performance standards could be targeted by AMS.
   b. Regarding RE, auctions as an incentive to foster competition and more substantially deploy RE capacity in the power sector could be more strongly considered and targeted by AMS.

3. **Develop RE policies beyond the power sector.** While RE in the power sector contributes most to the target achievements, reaching the APAEC targets will require not only focusing on the power sector, but also deploying RE in end-use sectors. Fostering the use of RE in end-use sectors such as modern biomass, biogas and biofuels as well as solar thermal applications should as well be targeted by AMS. Enforcing strong sustainability criteria in the production of biofuels must also be considered in order to guarantee environmental benefits from their increased use.

4. **Improve data availability.** While this Outlook has considerably improved the database for the projection, a continued work on data availability is required. Developing harmonised energy indicators could support AMS efforts to improve their statistical databases, as the key for policy and planning development.


Credit: ACE



Chapter 1
Understanding the Outlook

Understanding the Outlook

1.1 INTRODUCTION

The Association of Southeast Asian Nations (ASEAN) is a regional bloc consisting of 10 ASEAN Member States (AMS) with a population of about 630 million and a combined GDP of USD 2.4 trillion in 2015. With an average annual real GDP growth rate of 5.3% during the period 2007-2015, ASEAN has consistently outperformed global growth. However, considerable differences of economic development still exist among the Member States.

The establishment of the ASEAN Economic Community (AEC) in late 2015 is a major milestone in the regional economic integration agenda of ASEAN, offering opportunities as well as challenges to meet the primary energy requirement that has grown at an average of 3.6% annually between the period 2007-2015.

This has resulted in a significant change in the energy landscape. In 2015, the ASEAN economy was the sixth largest in the world and the third largest in Asia. It was also the third largest in the world by population, with more than half of the region's inhabitants are under the age of 30, and about 53.3% are living in rural areas. In 2015, it was estimated that about 107 million people were living without grid-connected electricity. The region's average electricity consumption per capita is only about 1,287 kWh annually, which is less than half of the world's average.

AMS cooperation in the energy sector is guided by the policy document *ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025 Phase 1: 2016-2020*. This emphasises that energy is key to the realisation of the ASEAN Economic Community (AEC) which calls for a well-connected ASEAN to drive an integrated, competitive and resilient region.

The ASEAN Centre for Energy (ACE) which serves as think-tank, catalyst, and knowledge hub of ASEAN's energy affairs develops the *ASEAN Energy Outlook (AEO)* on a regular basis to supply policy advice to AMS. ACE's *Outlook* provides an analysis of the energy development and emerging energy landscape in the region and serves as important reference to policymakers in building a coherent, coordinated, focused and robust energy policy agenda and strategy for ASEAN.
The publication of *the 5th ASEAN Energy Outlook (AEO5)* builds on *the 4th ASEAN Energy Outlook (AEO4)* presented at the 33rd ASEAN Ministers on Energy Meeting (AMEM) on 7 October 2015 in Kuala Lumpur, Malaysia. The 33rd AMEM welcomed the key findings of *AEO4* that emphasised the need for the implementation of cleaner coal technologies while continuing to tap the potential of renewable energy (RE) and enhancing energy efficiency (EE). *AEO4* received positive feedback from ASEAN Dialogue Partners (DPs), International Organisations (IOs), and the private sector. As a result, the 34th AMEM held on 21 September 2016 in Nay Pyi Taw, Myanmar welcomed ACE efforts on the development of *AEO5* to be published in 2017. *AEO5* is expected to strengthen and raise the region's expertise in energy policy analysis and planning that will eventually lead to enhanced support for the implementation of ASEAN's energy cooperation measures.

ACE has developed *AEO5* in collaboration with AMS national experts under the guidance of the ASEAN Regional Energy Policy and Planning Sub-sector Network (REPP-SSN). Support was also provided by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH under the framework of ASEAN-Germany Energy Programme (AGEP), and Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI) which served as consultant.

AEO5 builds on the latest official energy and macroeconomic data as well as the official energy policy of AMS, to project future trends on energy in responding to the vision of *APAEC 2016-2025 Phase 1: 2016-2020* to achieve Energy Security, Accessibility, Affordability and Sustainability for All, as well as the reference for the development of *APAEC 2016-2025* Phase 2: 2021-2025.

***AEO5* is structured as follows:**

- Chapter 1 outlines the methodological framework and key assumptions used in defining the scenario philosophy.
- Chapter 2 details the analysis of energy supply and demand outlook, by fuels and by sectors, in three different scenarios up to 2040.
- Chapter 3 reviews the progress and process in achieving the targets on EI and RE.
- Chapter 4 analyses the challenges faced by ASEAN on energy supply security, CO_2 emission and power sector investments.
- Chapter 5 offers conclusions, key findings and policy recommendations for the region.

ACE hopes that policymakers, researchers, private sector actors, academia and the energy community in general, as well as interested readers, find this publication an

1.2 DEVELOPMENT APPROACH

With *AEO5* representing an extensive modelling exercise, extending over more than a year and involving strong coordination in the work of different teams, an outlook philosophy was defined prior to its development. This approach was determined to be based on four main pillars: a cooperative approach, a harmonised approach, a controlled approach, and a guided approach.

Cooperative approach: The fundamental characteristic of *AEO5*, as opposed to other energy outlooks, is that it was developed based on remarkably strong cooperation, coordination, interaction and integration between ACE and an *AEO5* Working Group consisting of statisticians and outlook experts from the 10 AMS. Through a series of modelling workshops, national experts developed their own country energy simulation models. Furthermore, visits were performed by ACE to each AMS to validate the framework assumptions and modelling projection results. AMS representatives defined the respective parameters in their energy models based on in-depth understanding of energy demand and supply trends, as well as knowledge of nationally endorsed energy plans. Thus, all parameters and assumptions reflect official AMS expectations on future energy development.

Harmonised approach: A set of comparable models was developed in order to increase comparability and learning among AMS as well as the previous relevant studies. The energy models were defined using the same projection methodology and with comparable structures in final consumption sectors, transformation modules (i.e. power sector, refining sector) and primary supply. However, it should be noted that the harmonisation of the models was not intended to account for the heterogeneity in the energy system of each AMS.

Controlled approach: AMS projections were reviewed by computing a set of sensitivities. An independent regional model was created to validate and control the results.

Guided approach: Data, process and results were reported in consultation with ASEAN's Regional Energy Policy and Planning Sub-sector Network (REPP-SSN) Focal Points for their validation and confirmation, and their guidelines were used for alignment with the region's priorities and goals under APAEC 2016-2025.

Credit: ACE

1.3 SCENARIO PHILOSOPHY

AEO5 aims to provide policymakers and energy communities in the ASEAN region with a better understanding of future regional energy trends during the period up to 2040.

Specifically, the scenario philosophy developed in *AEO5* was derived from the following guiding questions:

- What are the consequences to energy demand and supply, as well as CO_2 emissions, if AMS continue to follow past practice, primarily to use fossil fuels to meet growing energy needs?
- What are the implications for energy demand and supply, as well as CO_2 emissions, if AMS attain their officially issued EE and RE national targets?
- What efforts are required from each AMS on EE and RE to meet the regional APAEC 2016-2025 targets?

To respond to the guiding questions above, AEO5 was developed with the following three scenarios:

- **Business-as-Usual Scenario (BAU)**
  Responding to the first question, BAU projects the future development of the ASEAN energy system(s) given no significant changes to past practices, with the assumption that AMS put little effort into reaching their most recently issued EE and RE targets. It does, however, take into consideration the latest national power development plans, and primary production of fossil fuels and refineries.

- **AMS Targets Scenario (ATS)**
  Responding to the second question, ATS projects the future development of the ASEAN energy system(s) in a target-based scenario assuming that officially issued energy policies and targets, in particular EE and RE targets, at national level, are fully attained. It therefore implies the successful implementation of existing EE and RE policies to reach the targets.

- **ASEAN Progressive Scenario (APS)**
  Responding to the third question, APS projects the future development of the ASEAN energy system(s) if AMS collectively strive to reach the regional targets on energy intensity (EI) and RE as defined in APAEC 2016-2025 Phase 1: 2016-2020. The scenario assumes a higher ambition level in EE beyond the designed official timeframe, and stronger penetration of RE technologies as a result of untapping domestic potentials.

Notwithstanding energy security requirements which are paramount, AMS are aspiring to optimise use of RE and promulgate EE for resource diversification, efficiency and economic prosperity. While BAU continues past developments, ATS and APS are target-based scenarios, which differ in the way they consider the national and regional targets on EE and RE. All scenarios are computed based on the same future economic and demographic growth.

The adopted target frameworks in ATS were assumed to be attained by all AMS within the timeframe. Information was collected using policy and questionnaires that were officially submitted to ACE by national experts under the guidance of the REPP-SSN Focal Points. The official targets set by AMS varied in terms of sector or timeframe, as illustrated in **Table 1**. In the context of timeframe, some AMS such as Lao PDR and Malaysia set the target on EE by reducing the value in percentage units in a particular target year, while others such as the Philippines set it as the progressing reduction on an annual basis. In terms of target sector, most AMS set the target at end-sector, but some, such as Cambodia and Thailand, defined it in general terms regarding final consumption as a whole. Indonesia and Vietnam defined the specific target in specific sectors. Similar principles applied on RE targets, which also vary among AMS, be it in percentage or absolute terms, and in energy mix or electricity mix. The Power Development Plan (PDP) of most AMS do not contain the latest officially issued RE targets. Hence, ATS differs from BAU in that it considers most recently issued RE targets respective to the power sector.

Table 1. AMS Energy Policies and Targets

AMS	Sectors	Reference Documents	Official Targets
Brunei Darussalam	EE	Energy White Paper 2014	• Reducing Energy Intensity (TFEC/GDP) to 2035 by 45% based in 2005 level.
	RE	Energy White Paper 2014	• In power generation: 124 GWh RE by 2017 and 954 GWh by 2035 (10% RE share in power generation).
Cambodia	EE	Cambodia Energy Efficiency Plan	• Reducing Energy Consumption (TFEC) by 20% in 2035 as compared to BAU. • Industry: up to 20% in garment factories and 70% in ice factories • Residential: up to 50% • Commercial: 20 to 30% • Rural Electrification Energy Savings: up to 80% • Replacement of biomass use 30-50%
	RE	PDP 2008-2021 (for hydro target)	• No specific RE target, excluding large hydro: 2,241 MW (approximately 80% of the total installed capacity) by 2020.
Indonesia	EE	Government Regulation No. 79/2014: National Energy Policy	•To achieve 1% energy intensity reduction per annum, up to 2025 and energy elasticity less than 1 in 2025. • Reducing Energy Consumption (TFEC) in 2025 by 17% in industry, 20% in Transportation, 15% in household, 15% in commercial building as compared to BAU.
	RE	Government Regulation No. 79/2014: National Energy Policy	• 23% RE share of TPES (around 92.2 Mtoe in 2025) which consist of 69,2 Mtoe (45.2 GW) for electricity and 23 Mtoe for non-electricity and 31% RE share in 2030.
Lao PDR	EE	National Energy Efficiency Policy 2016	• Reducing TFEC 10% in 2030 as compared to BAU.
	RE	RE Development Strategy Policy 2016	• 30% RE share of total energy consumption by 2025 (approximately 1,479 ktoe), excluding large hydro (>15 MW capacity)
Malaysia	EE	National Energy Efficiency Action Plan	• Reducing Electricity Consumption by 8% in 2025 as compared to BAU.
	RE	National RE Policy and Action Plan and 11th Malaysia Plan	• RE installed capacity of 2080 MW (excluding large hydro) by 2020 contributing to 7.8% of total installed capacity in Peninsular Malaysia and Sabah.
Myanmar	EE	National Energy Efficiency & Conservation Policy, Strategy and Roadmap	• Reducing Electricity Consumption by 20% in 2030 as compared to BAU.
	RE	National RE Policy and Planning (Draft)	• By 2030-2031, the energy mix of 38% (8896 MW) hydro, 20% (4758 MW) of natural gas, 33% (7940 MW) of coal and 9% (2000 MW) of renewable sources.
Philippines	EE	Energy Efficiency Roadmap for the Philippines, 2017-2020	• Reducing TFEC by 1% per year as compared to BAU until 2040, equivalent with the reduction of one third of energy demand. • Reducing Energy Intensity (TFEC/GDP) by 40% in 2040 as compared to 2005 level.
	RE	National RE Program Roadmap 2010-2030	• 15,2 GW RE installed capacity in 2030: RE additional target: Additional biomass capacity of 277 MW in 2015, additional wind capacity of 2345 MW in 2022, additional hydro of 5398 MW in 2023, additional ocean energy capacity of 75 MW in 2025, additional solar capacity of 284 MW in 2030, and additional geothermal capacity of 1495 MW.
Singapore	EE	Singapore Sustainable Blueprint 2009	• Reducing EI (TFEC/GDP) by 35% from 2005 levels by 2030.
	RE	Sustainable Blueprint 2015	• Solar power installation of 350 MWp by 2020 and 10,140 tonnes per day by 2018 for Waste to Energy Plant.
Thailand	EE	Thailand EE Policy 2015	• Reducing Energy Intensity (TFEC/GDP) by 30% in 2036 compared 2010 level.
	RE	Alternative Energy Development Plan 2015-2036	• 30% renewable in total energy consumption by 2036, in form of electricity (20.11% in generation, approximately 19,684 MW), heat (36.67% of heat production, approximately 25,088 ktoe), and biofuels (25.04% in transportation sector, approximately 8,712.43 ktoe).
Vietnam	EE	National Target Program for EE and Conservation	• Reducing TFEC by 8% in 2020 as compared to BAU. • Reduce Energy Intensity of Energy Intensive Industries by 10% by 2020.
	RE	Decision 428/QĐ-TTg dated 18th March 2016	• 21% RE of 60 GW installed capacity in 2020, 13% RE of 96 GW in 2025 and 21% RE of 130 GW in 2030 consist of 2.1% wind, 15.5% hydro, 2.1% biomass, and 3.3% solar.

APS was developed to identify the additional efforts required by every AMS to cumulatively achieve the aspirational targets under APAEC 2016-2025. On RE, the reference point for APS is the RE technology options identified in the 2016 study, "*Renewable Energy Outlook for ASEAN: A REmap Analysis*"[1], a joint collaboration between ACE and the International Renewable Energy Agency (IRENA). It contains a detailed country by country assessment of the RE technologies required to meet the aspirational target of achieving 23% RE in the total primary energy supply by 2025. Since the release of the Report in October 2016, the results have been updated through further consolidation with national experts and adjusted to reflect the latest development and efforts at national level. For EE, the energy saving rates were derived from the targets defined in ATS, but it is assumed that the energy saving rates will be in place during the whole projection period, until 2040. It is important to note that the feasibility and challenges of implementing each option varies by sectors and AMS, depending on their particular circumstances and on the level of commercialisation the technologies have reached.

1.4 EXOGENOUS ASSUMPTIONS

Gross Domestic Product (GDP). Economic growth remains the main driver of the energy projections. In AEO5, GDP value was derived from the AMS official statistics and the World Bank. Existing value in national currencies are converted into USD, and chained as purchasing power parity (PPP). Accounting for inflation, GDP PPP was pegged to the constant 2005 value. The future development of economic growth is based on national projections. Each AMS was requested to submit national projections on GDP based on official GDP forecasts. Noting that the official AMS projections are mostly available only until 2025, *AEO5* adopts the year 2025 – which is also the year for the APAEC target – as the cut-off for the official economic projection, while for the remaining period projections were developed based on the indicative findings of the PricewaterhouseCoopers (PwC) report, "The World in 2050"[2]. The report comprises long-term projections for the largest economies in the world, based on econometric estimates. In the long-term, GDP growth rate is expected to decline over time as the economic output becomes higher. *AEO5* accordingly considers this trend and has thus consistently adjusted the economic growth rate for 2026-2040. This has prevented over-estimating future energy demand in an exponential manner. As depicted in Table 2, GDP is expected to grow at annual rate of 5.4% until 2025, or at 4.7% on average every year during the projection period. ASEAN's combined GDP is therefore projected to increase by a factor of 3.1 from 2015 to 2040.

Population. As opposed to economic growth, demographic trends are not subject to high uncertainty, yet future population growth and urbanisation rates remain the fundamental assumptions for energy demand projections. Population growth rates and urbanisation rates were also provided by AMS and reflect their expectations. Whenever national forecasts were unavailable, the UN World Population Prospects for the medium fertility population forecasts as per 2015 were used as reference. By 2040, ASEAN's total population is expected to reach 782.8 million inhabitants, of which 369.1 million will live in urban areas, reflecting an annual average growth rate of 0.9%.

Crude Oil Price. Whereas the prices of fossil fuels have a crucial effect on future energy requirements, the price of oil is of pivotal importance. Depending on the demand and supply patterns of major consumers and producers, as well as geopolitical shocks or strategic considerations of oil producing nations, the future price of oil is subject to large uncertainty. In *AEO5*, the price development chosen reflects the current expectations set in the International Energy Outlook 2016, prepared by the U.S. Energy Information Administration (U.S. EIA). It is noted that real oil prices (in 2013 dollars) have fallen precipitously since 2011, from about USD 115 per barrel to about USD 50 per barrel in 2015 (according to EIA's March 2016 Short-Term Energy Outlook). Prices are expected to gradually recover over the course of the projection period, reaching USD 141 per barrel in 2040.

[1] IRENA & ACE (2016). Renewable Energy Outlook for ASEAN: a REmap Analysis. International Renewable Energy Agency (IRENA), Abu Dhabi and ASEAN Centre for Energy (ACE), Jakarta. Available at: *http://www.aseanenergy.org/resources/publications/renewable-energy-outlook-for-asean-a-remap-analysis/*
[2] PwC. The World in 2050. The long view: how will the global economic order change by 2050? *https://www.pwc.com/gx/en/issues/economy/the-world-in-2050.html*

Table 2. Socio-Economic Profiles and Projections

AMS[3]	GDP (USD Billion) Current Value	GDP PPP Projection CAGR (%)		Population (thousand people)	Population CAGR 2016-2040 (%)
		2016- 2025	2016-2040		
Brunei Darussalam	12.9	4.0%	1.0%	417	0.9%
Cambodia	18.5	7.2%	6.2%	15,581	1.1%
Indonesia	857.6	5.6%	4.5%	257,754	0.8%
Lao PDR	12.6	7.8%	6.3%	6,809	1.2%
Malaysia	294.4	3.8%	3.1%	30,440	1.1%
Myanmar	65.4	7.4%	6.8%	53,972	1.0%
Philippines	289.5	7.4%	6.2%	100,735	1.5%
Singapore	291.9	2.0%	2.0%	5,555	1.4%
Thailand	395.7	3.9%	3.5%	68,003	0.03%
Vietnam	193.4	6.8%	5.5%	91,706	0.6%
ASEAN	2,432.0	5.4%	4.5%	630,971	0.9%

1.5 METHODOLOGICAL FRAMEWORK

Modelling Approach. *AEO5* was developed by combining a top-down, statistical approach for the final energy demand, with a bottom-up technology specific modeling in the transformation sectors. To project the final energy demand, regression analysis was applied by using econometric software, in order to compute the relationship between the sectoral final energy demand and explanatory socio-economic variables. The analysis yielded in a set of sectoral energy consumption equations for every country, each one relating the energy consumption of a particular sector with the corresponding socio-economic variables. Furthermore, the technology specific parameters of the transformation sector (power sector, refineries) were defined, resulting in the corresponding future primary energy requirements.

With the aim of increasing the transparency and understanding of the modelling logic of *AEO5*, and thus allowing the interpretation of the results of this *Outlook* in comprehensive manner, the main methodological steps followed to compute the energy projections in *AEO5* are illustrated as follow:

- **Step 1:** The first step to develop the energy system models involved defining the socio-economic assumptions such as the future growth rate of the national Gross Domestic Product (GDP) and other future demographic developments (i.e. population growth rate and urbanisation), as well as prices for future energy carriers.

- **Step 2:** Next, regression analysis was applied to determine the historical relationship between final energy demand by sectors and the explanatory socio-economic variables. The regression analysis yielded a set of sectoral energy consumption equations, relating the energy consumption by sectors with corresponding socio-economic variables.

- **Step 3:** Further, the future energy demand by sector was determined using the socio-economic variables defined in Step 1 and the relationship between energy demand and the historic socio-economic parameters computed in Step 2. This yielded sectoral energy demand projections based on the chosen socio-economic assumptions. Of note, in the ASEAN energy nomenclature, the energy demand is referred to as Total Final Energy Consumption (TFEC).

[3] Source: ASEAN Statistical Year Book 2015 of ASEAN Secretariat, World Development Indicators of Word Bank, and ASEAN Energy Database System of ACE.

- > Projecting final energy demand is based on a top-down, statistical approach. Given data limitations associated with creating detailed bottom-up projections of the final energy consumption sectors, projecting final energy demand in *AEO5* for all AMS and sectors is based on regression analysis.
- > Regression analysis was applied using econometric software in order to compute the relationships between the sectoral final energy demand and explanatory socio-economic variables. The analysis yielded a set of sectoral energy consumption equations per country, each one relating the energy consumption of a particular sector with corresponding socio-economic variables.
- > While reliable regression results were obtained when computing sectoral equations, it remains difficult to explain Sub-sectoral developments (i.e. fuel use development in a given sector) by the use of regression analysis. The fuel shares at a Sub-sectoral level were thus defined by the use of trend analysis, paired with case-by-case considerations and evaluation.

• **Step 4:** To determine the future primary energy requirements, the transformation parameters for the projection period were exogenously defined. The power sector is of particular prominence among the transformation modules. The future development of the power sector was specified by declaring the composition of the power portfolio by technology as well as by the specific parameters related to each technology (e.g. efficiency, degree of conversion, capacity factor, dispatch, etc.). An analogous procedure was applied to other transformation modules such as, among others, the oil refining sector.

• **Step 5:** Further, the primary production of fossil fuels (i.e. coal, oil and natural gas) was defined exogenously.

• **Step 6:** Finally, the primary energy requirement is computed using the exogenously defined final energy demand and the specification of the transformation module parameters. Of note, in the ASEAN energy nomenclature, the primary energy requirement is referred to as Total Primary Energy Supply (TPES).

- > Projections were developed using a simulation tool, the Long-Range Energy Alternatives Planning System (LEAP) software[4]. This allows the future development of the whole energy system to be projected, including the final energy demand by sectors and fuels, energy consumption in the transformation sector (e.g. power sector and refining sector), the primary energy requirements, primary production of fossil fuels and reserves, as well as the CO_2 emissions. The software allows energy system models to be created which can be structured according to the general scope of the modelling exercise and the chosen methodology, as well as data availability.
- > Primary energy requirement projections are computed using the final energy demand projections and the specification of the transformation module's conversion parameters. Thus, the transformation parameters for the projection period must be exogenously defined. As outlined, the power sector plays a pivotal role among the transformation modules. Projection of the power sector was specified by declaring the composition of the power portfolio by technology, as well as the corresponding parameters related to each technology, such as the conversion efficiency, capacity factor, dispatch, etc. A similar procedure was applied to other transformation modules such as, among others, the refining sector.

• **Step 7:** By defining the base year (2015) reserves, the theoretical reserves deployment ratio in absence of reserves additions is computed (reserves to production ratio approach).

• **Step 8:** The energy related CO_2 emissions are generated from the model adopted by the Intergovernmental Panel on Climate Change (IPCC) Tier 1 calculation methodology[5]. This is the official methodology endorsed by the IPCC in calculating National Greenhouse Gas (GHG) Inventories. The methodology applies fuel-specific greenhouse-gas emission factors for the conversion of fossil fuels in the energy system.

All steps were strictly taken into consideration in all scenarios with the injection of various assumptions and modelling inputs for each scenario.

[4] Heaps, C.G., 2016. Long-range Energy Alternatives Planning (LEAP) system. [Software version: 2017.0.11] Stockholm Environment Institute. Somerville, MA, USA. *https://www.energycommunity.org*
[5] Intergovernmental Panel on Climate Change (IPCC) Tier 1 calculation methodology. *https://www.ipcc.ch/meetings/session25/doc4a4b/vol1.pdf*

Modelling Parameters and Inputs. The guiding principles to define the modelling parameters for each scenario are illustrated in **Table 3**.

Table 3. Modelling Parameters on Scenarios

Parameters	Business-as-Usual Scenario (BAU)	AMS Target Scenario (ATS)	ASEAN Progressive Scenario (APS)
Socio-Economic	• GDP growth: used AMS official projections into 2025, adjusted with moderate rate after 2025 based on PwC's The World in 2050. • Population growth: used AMS official projections, or the UN World Population Prospect for the medium fertility population forecasts as per 2015.		
Final Energy Demand	• Determined using regression analysis for each AMS at sectoral level.	• Based on BAU, but adopting full achievement on AMS national targets on EE, RE (i.e. biofuels and modern biomass).	• Extended ATS targets, applied until 2040. • *ASEAN RE Outlook*: higher share of biofuels.
Power Sector	• Official Power Development Plan (PDP).	• Adopted the official national target on RE.	• *Renewable Energy Outlook for ASEAN*: *RE map Analysis*: used for higher share of RE to achieve APAEC's 23% Target of RE on TPES by 2025.
Refining	• National plans on new units or future expansion.		
Production of Fossil Fuels	• National plans on future productions.		
Reserves	• Follows reserves to production approach: reserves are assumed to be constant at the 2015 value. Reserve development thus shows the theoretical depletion assuming no additions to reserves are present during the projection period.		

Final energy demand in BAU is the computed regressions with no modification. In ATS, the energy saving rates derived from every AMS officially issued EE targets are applied to BAU. Thus, if a country has the target to save 20% of energy among the total final energy consumption sectors in the next 20 years, the respective saving rate per year of 1.1% to achieve the targeted saving in the next 20 years is applied to BAU. If the target is defined on a sectoral level (e.g. only referring to the industrial sector), the yearly energy savings rate is only applied to the respective sector (industry). If the target is referring to a specific fuel-type, the yearly energy savings are applied only to that specific fuel. In APS, the energy saving rates derived from the targets are also applied to BAU, but it is assumed that the energy saving rates will be in place during the whole projection period, up to 2040.

Recognising the multiple paths through which AMS can increase RE in their energy system beyond the official national targets, in order to collectively reach the aspirational target of having 23% RE in TPES by 2025, *Renewable Energy Outlook for ASEAN: A REmap Analysis* (hereinafter referred to as *REmap*) was used as the starting point. *REmap* approach covers all sectors and energy services – it looks at power, heating, transport and cooking. However, *AEO5* focuses on power sector, transportation sector (biofuel) and industrial sector (modern biomass).

For power sector, as power development plans for most AMS do not contain the most recently issued official RE targets, hence ATS differs from BAU in that it considers most recently issued RE targets. These targets, in particular on EE, lead to a lower electricity demand in the final energy consumption and hence the required installed power capacity to meet this demand in ATS compared to BAU is reduced. This highlights how EE and RE targets are complementary. APS has a higher level of installed renewable capacity in the power sector and it assumes that AMS determinedly develop their power systems through harvesting their domestic RE potentials by implementing RE technologies into their power generation portfolio.

Credit: ACE

RE capacities for each AMS are based by starting with the *REmap* results contained in the joint ACE and IRENA report from 2016 and updated to account for recent developments. These results contained a detailed country by country assessment of RE technologies required to meet the APAEC 2016-2025 regional target. However, the development path of each technology in every AMS follows the electricity demand as projected in *AEO5*. Due to inherent differences (resulting differing framework parameters and methodology, as well as the update from AMS) between the electricity demand projections between *AEO5* and the earlier *REmap* projections, the development of installed capacities in *AEO5* does not exactly match *REmap* publication. Therefore, further optimisation of RE potential based on existing and future policies, RE in the transport sector (biofuel) and industrial sector (modern biomass) were analysed to close the gap to reach the region's aspirational target.

Data. The historical energy data used in the modelling projections were sourced from official AMS statistics, which were submitted through the REPP-SSN Focal Points using standard formats, supplemented with official national energy statistics publications released by AMS. Additional data extracted from public sources were used to complement the modelling. Base years for projections are 2014 and 2015, as per the latest year of the official data submitted by AMS[6]. Any recent updates by AMS were also considered, when available. The projection was conducted for the period 2015-2040.

Socio-economic data are extracted from the official publication of the ASEAN Secretariat's *ASEAN Statistical Year Book 2015*. However, the available data on GDP are for current market prices only where the calculation – with regard to the basis in calculating the ASEAN EI target – should be made in GDP PPP Constant 2005 USD. When data were retrieved from a secondary source, World Bank's World Development Indicators, which gives GDP PPP Constant 2010 USD, values were converted into GDP PPP Constant 2005 USD. Then the GDP in current value of every AMS (in national currencies) is pegged with the 2005 PPP conversion factor of GDP (national currency per USD) from the World Bank.

Limitations. It is crucial to understand that uncertainty is an inherent factor in the nature of every energy outlook. The reader should keep in mind that the insights presented are not to be interpreted as an unambiguous forecast of upcoming developments, but as projections of possible future paths based on a consistent set of framework assumptions, even though many of these are subject to considerable uncertainty in the years to come. By comparing scenario results based on different assumptions, *AEO5* aims to provide sounder understanding on how changing parameters such as the share of RE in the power sector, or stronger EE in the final energy consumption sectors, affect the whole energy system.

Further, it should be highlighted that saturation effects and structural breaks can only be approximated using detailed bottom-up models. While data collection and availability in ASEAN is a main priority of ACE's agenda, and has shown considerable progress over the recent years, creating detailed bottom-up models for the final energy consumption remains unattainable at present in view of current data limitations, at least in view of a common approach to all 10 AMS.

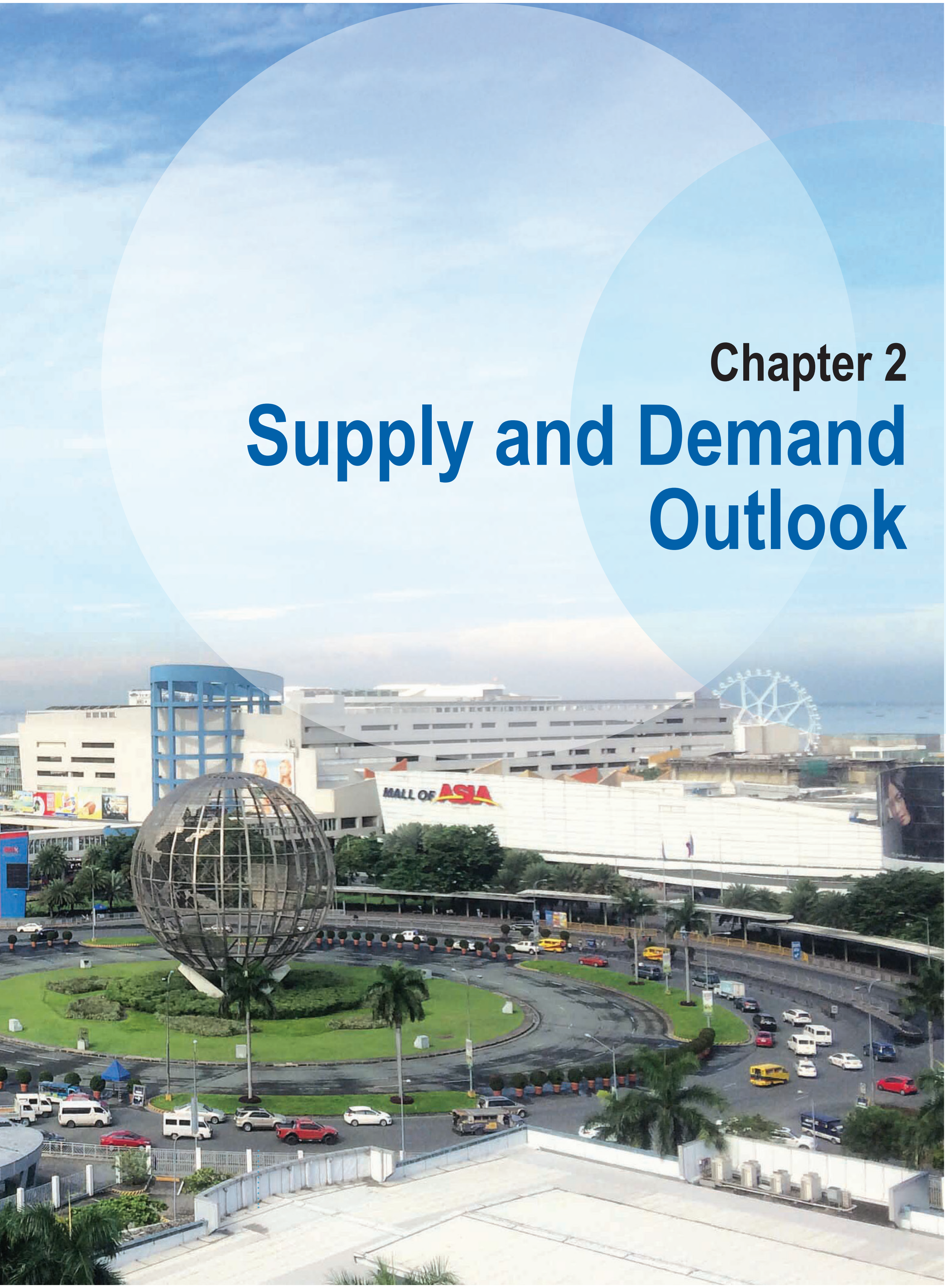
AEO5 represents an extensive modelling exercise with various inputs from different teams and data sources. Many of these inputs required processing and harmonising in order to be used in a comparable manner. As such, discrepancies in data are present in this *Outlook*, and other statistical publications by AMS or ACE, reflecting the nature of such wide-ranging modelling exercises. Data discrepancies may also exist due to the rounding manner. Nevertheless, it should be highlighted that the findings of the projections considered in *AEO5* are not affected by data discrepancies.

[6]ASEAN's energy data 2005-2015 is available at the ASEAN Energy Database System (AEDS). *http://aeds.aseanenergy.org*

Credit: ACE

Chapter 2

Supply and Demand Outlook



Supply and Demand Outlook

This section provides the results of the projections on ASEAN's energy supply and demand system with the findings offering comparisons from all scenarios.

HIGHLIGHTS

- *TFEC escalates from 427 Mtoe in 2015 to 1,046 Mtoe (BAU), 856 Mtoe (ATS), and 771 (APS) in 2040. The growth is driven by industry, transport and residential sector – which reflect urbanisation trends consistent to all scenarios. Industry and transport sectors expand the most, while the residential sector shows moderate growth as a result of a shift away from traditional biomass and successful increasing electrification access. Oil will keep its dominance in all fuels at a share of 40-50% in all scenarios between 2015 and 2040.*

- *TPES will considerably increase during the projection period due to economic and population growth. In BAU, TPES is expected to increase by a factor of 2.3 times in the period 2015 to 2040. In ATS and APS, through a combination of EE and RE contributions, energy savings of 13.9% and 22.6% could be achieved respectively. In all scenarios, oil is still the largest fuel in primary energy mix followed by coal in BAU and ATS; while RE is the second largest in APS resulting from more ambitious RE injection.*

- *Among other fossil fuels, coal shows the strongest growth rate with CAGR of 4.3% in BAU. Natural gas registers a moderate growth and loses its relevance in all scenarios. Traditional biomass loses its relevance in the ASEAN energy mix by decreasing its share from 10.6% in 2015 to only 6.4% in 2040 in BAU.*

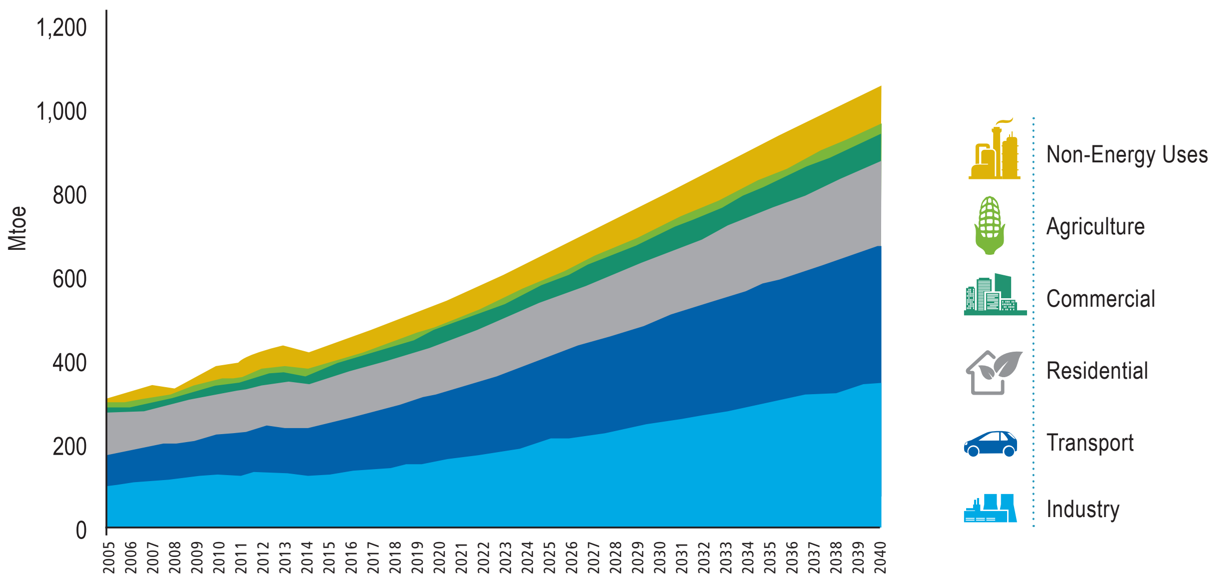
- *Power capacity almost triples over the period, to around 629 GW in 2040, to cope with the strongly rising electricity demand in ASEAN. Coal-based power plants will rise from 63 GW in 2015 to 267 GW in 2040 with a CAGR of 5.9% in BAU. In all scenarios, the share of oil and gas continues to decline as coal and RE continue to grow as the result of the abundant availability of coal and decreasing of RE prices. Hydro, solar PV and wind are expected to be major drivers of RE.*

2.1 TOTAL FINAL ENERGY CONSUMPTION

BAU. TFEC in ASEAN is expected to increase in the next decades with a steeper growth in BAU, in comparison to the historical period. It will grow with a CAGR of 3.6%, increasing by a factor of 2.4 from 427 Mtoe in 2015 to 1,046 Mtoe in 2040.

Figure 1 shows the projection of TFEC by sectors. In 2015, the industry, transport and residential sectors together accounted for the largest share of 82.4% (352 Mtoe) of total TFEC. In 2040, these three sectors together represent a nearly unchanged share of 83% (866 Mtoe) of TFEC. With the exception of non-energy uses and the residential sector, all other sectors experience strong growth with a CAGR of approximately 4%, rising by a factor of 2.7 in 2040 as compared to 2015 levels. The transport, commercial and industry sectors expand the most with a CAGR of approximately 4.1%. The residential, agriculture and non-energy use sectors are projected to grow by a CAGR of 2.5%, 3.7% and 3.2% respectively, increasing their absolute values by factors of 1.9, 2.5 and 2.2 in 2040 compared to 2015 levels.

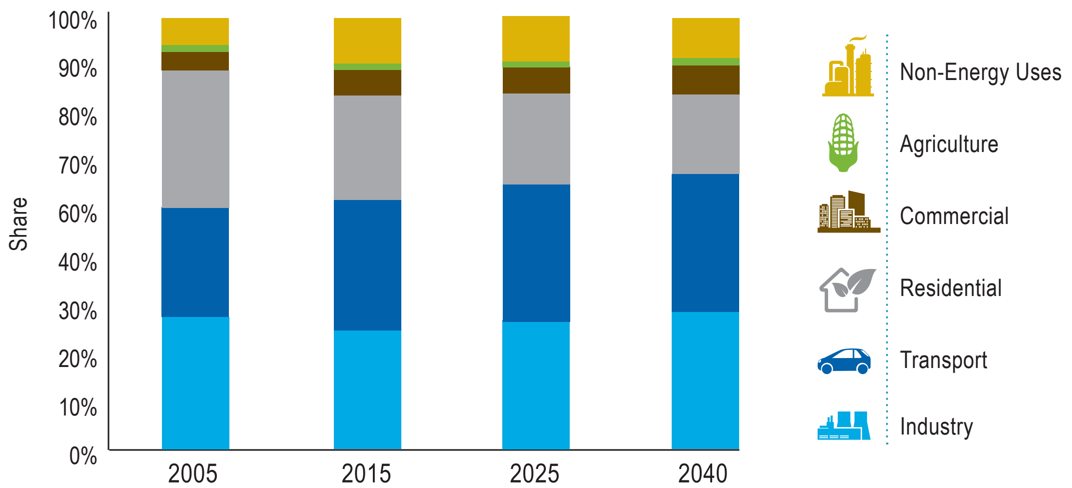
Figure 1. **TFEC Projections in BAU by Sector**



Credit: ACE

Figure 2 presents TFEC by sector-share in BAU for the years 2005, 2015, 2025 and 2040. Whereas industry, transport and residential altogether are still dominant among TFEC through the projection period 2015-2040, the composition of the share of TFEC by sector is subject to a moderate shift over time. In 2005, the industry sector was dominant among TFEC, comprising a share of 31.4%, closely followed by residential at 31.0% and transport at 25.7%. In the year 2015, the residential sector represented a lower share of TFEC with only 24.4% of TFEC. The most relevant sectors in 2015 were transport at 29.1% and industry at 28.9%. In 2040, the residential sector accounts for only 18.7%, further losing significance compared to the other strongly growing sectors: industry at 32.5% and transport at 31.6%.

Figure 2. **TFEC Projections in BAU by Sector-share**

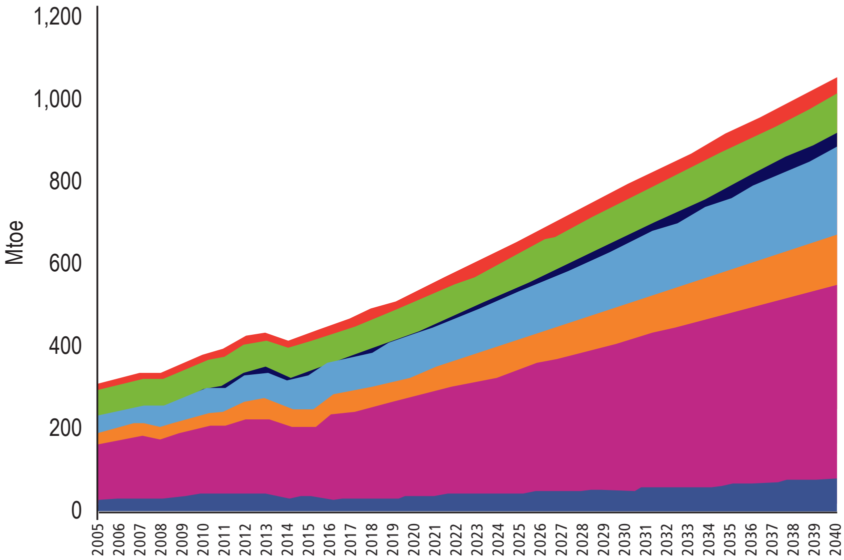


The increasing energy demand in the transport and industry sectors reflects on the one hand, urbanisation trends, which lead to an increased need for transport services, and on the other hand, the shift from agriculture towards a more industrialised ASEAN. With the transport and industry sectors already representing more than one half of TFEC in 2015, and increasing their relevance to make up one third each of TFEC in 2040, these sectors reflect opportunities for energy savings and efficiency gains.

Figure 3 shows TFEC by fuels in the timeframe 2005-2040, while **Figure 4** illustrates the relative shares of TFEC by fuels in the same timeframe. All fuels expand during the projection period. Oil is dominant in TFEC, both in the historical period as well as in the projection period. Of note, oil refers mainly to oil products, predominantly used in the transport and agriculture sectors. Growing by a CAGR of 4.2%, oil products demand increases considerably from 168 Mtoe in 2015 to 472 Mtoe in 2040, representing a growth by a factor of 2.8. This growth is mainly attributable to the strong increase in the overall demand of the transport sector. Oil will keep its dominance in all fuels, at a share of 40-50% between 2015 and 2040.

Electricity had the second highest share in 2015, and is projected to experience a considerable CAGR of 3.8% from 2015 to 2040, increasing from 82 Mtoe in 2015 to 207 Mtoe in 2040, and growing by a factor of 2.5. This reflects both an increasing trend towards greater use of electricity in the industry and commercial sectors, as well as increased electrification efforts in ASEAN, which also result in an increasing relevance of electricity in the residential sector.

Figure 3. **TFEC Projections in BAU by Fuel**



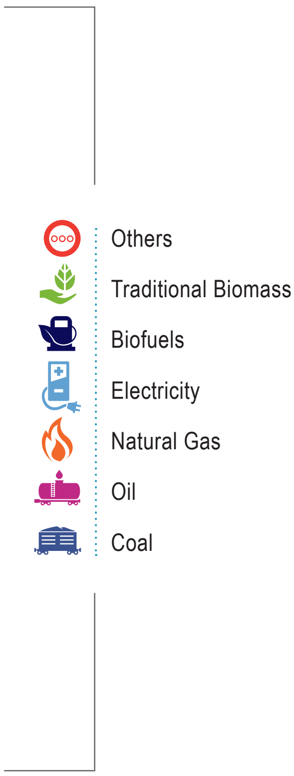
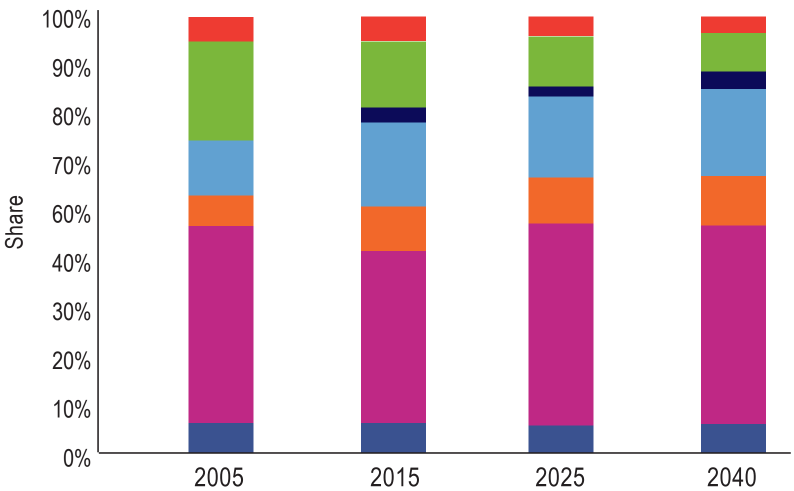


Figure 4. **TFEC Projections in BAU by Fuel-share**



Traditional biomass had the third highest share among TFEC in the base year 2015. However, even in BAU, traditional biomass is projected to lose its relevance during the projection period, as can be seen in Figure 4**.** In 2015, traditional biomass represented 15.4% of TFEC, reducing its share to only 8.9% by 2040 as it grows only at a CAGR of 1.4%. The reduced relevance of traditional biomass reflects the increasing prosperity in ASEAN, in which electrification efforts continue to provide access to grid-connected electricity and thereby reduce the relevance of traditional biomass. A later section provides further insights on the projected use of traditional biomass.

Natural gas also increases strongly during the projection period, growing with a CAGR of 4.1%. Mainly driven by industry-led growth, natural gas increases its relevance in TFEC, expanding from 44 Mtoe in 2015 to 121 Mtoe in 2040. This represents an expansion by a factor of 2.8. This growth rate will lead to an increase in the relative contribution of natural gas to TFEC, from 10.3% in 2015 to 11.6% in 2040.

Coal, in contrast, will grow more moderately with a yearly growth rate of 3.6%, maintaining its share at around 7% from 2015 to 2040. In absolute terms, coal will grow from 30 Mtoe in 2015 to 73 Mtoe in 2040.

Notably, biofuels exhibit the highest growth at a CAGR of 8.4%, increasing absolute value from 14 Mtoe in 2015 to 39 Mtoe in 2040. This represents growth by a factor of 2.9. The development landscape of TFEC by country is presented in **Figure 5** and **Figure 6**. All AMS are expected to experience an expansion of TFEC. Vietnam, Lao PDR and Cambodia will grow the most with a CAGR of 4.8%, 4.1% and 3.8% respectively, multiplying their TFEC by factors of 3.2, 2.7 and 2.5, but altogether still accounting only for 18.3% of the total in 2040. The five major contributors remain Indonesia, Thailand, Vietnam, Malaysia and the Philippines. Their dominance in TFEC increases from a combined share of 388 Mtoe (90.8%) in 2015 to 972 Mtoe (92.9%) in 2040. In ASEAN, Indonesia remains the largest energy consuming country, with 417 Mtoe or 39.9% of TFEC in 2040.

Figure 5. **TFEC Projections in BAU by Country**

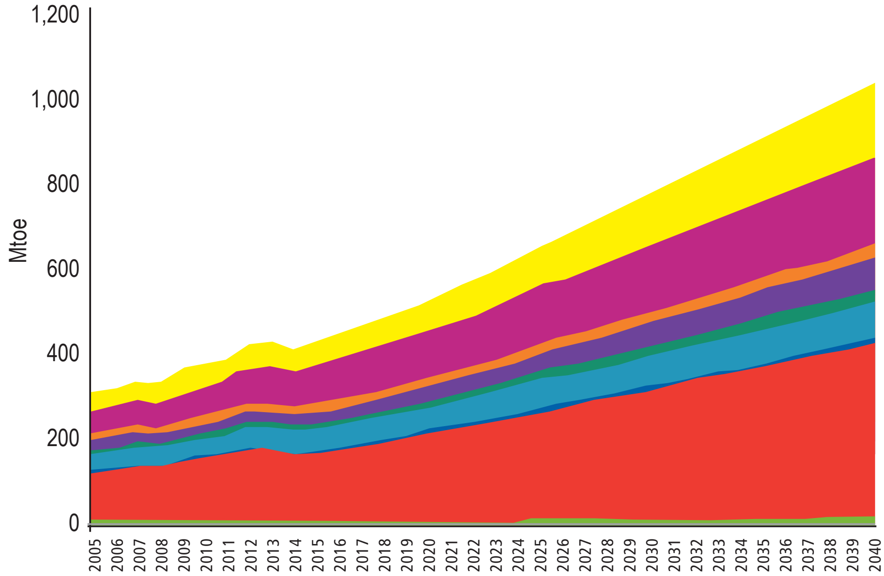
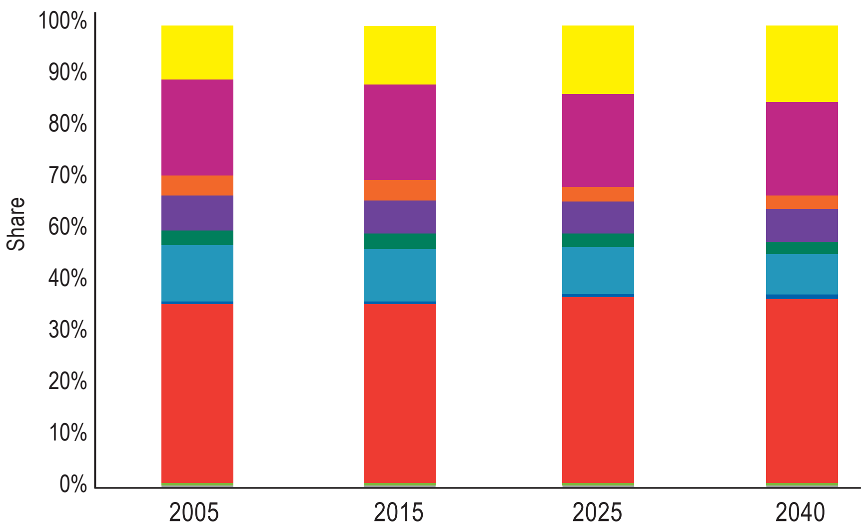


Figure 6. **TFEC Projections in BAU by Country-share**



ATS. The official EE targets in ASEAN are considered in the final energy demand projection. **Table 4** shows the targets and correspondingly applied saving rates for every country, which describe the energy savings relative to BAU presented in the previous section. Of note, the targets are issued by AMS at different end points in the future. After the targets end, the energy savings are assumed to be lower than those derived from the target, but still higher than zero. The rationale accounts for the fact that during the target implementation period more energy efficient devices, appliances, processes, building envelopes, vehicles, etc. are in place as compared to BAU. Even after the targets end, these higher efficient technologies lead to further energy savings as compared to BAU.

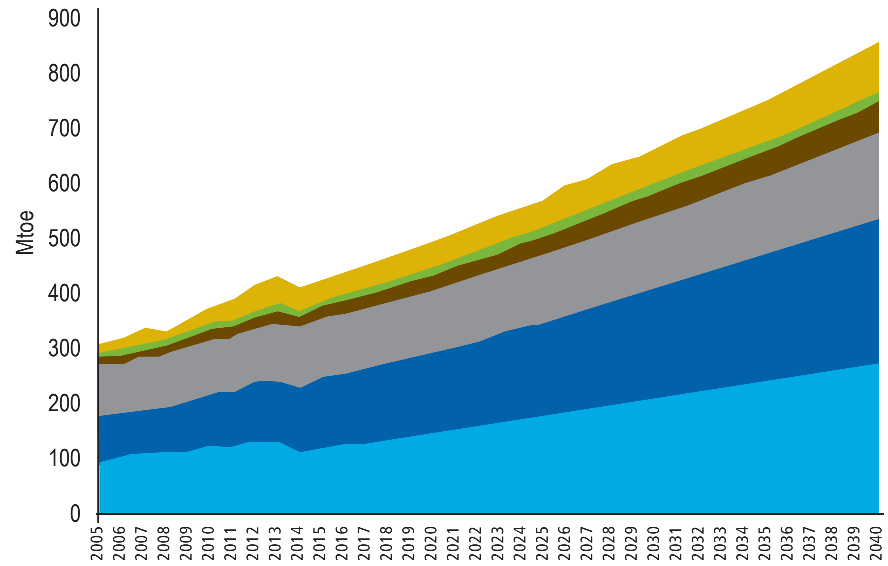
ATS is projected to grow with a CAGR of 2.8% to reach only 856 Mtoe in 2040, a reduction of 18.1% compared to BAU. Growing by a factor of 2.0 when compared to 2015, it shows substantial savings achieved by reaching the nationally issued EE targets by AMS as considered in this scenario.

Table 4. Modelling Saving Rate on EE Targets for ATS

AMS	Target Description	Saving Rate per year	Horizon
Brunei Darussalam	• Reduce EI (TFEC/GDP) to 2035 by 45% based on 2005 levels.	All sectors: 2.7%	2035
Cambodia	• Reduce TFEC by 20% in 2035 compared to BAU.	All sectors: 1.2%	2035
Indonesia	• Reduce TFEC in 2025 by 17% in industry, 20% in transport, 15% in household, 15% in commercial building as compared to BAU.	Industry 1.9% Transport 2.4% Residential 1.6% Commercial 1.7%	2025
Lao PDR	• Reduce TFEC 10% in 2030 compared to BAU.	All sectors: 0.7%	2030
Malaysia	• Reduce Electricity Consumption in TFEC by 8% in 2025 as compared to BAU.	Electricity: 0.9%	2025
Myanmar	• Reduce Electricity Consumption in TFEC by 20% in 2030 as compared to BAU.	Electricity: 1.5%	2030
Philippines	• Reduce TFEC by 1% per year compared to BAU until 2040.	All sectors: 1.0%	2040
Singapore	• Reduce EI (TFEC/GDP) by 35% from 2005 levels by 2030.	All sectors: 0.3%	2030
Thailand	• Reduce EI (TFEC/GDP) by 30% in 2030 compared to 2010 level.	All sectors: 2.6%	2030
Vietnam	• Reduce TFEC by 8% in 2020 compared to BAU.	All Sectors: 1.7%	2020

Figure 7 and **Figure 8** illustrate TFEC by sector, in absolute value and share. In 2015, the industry, transport and residential sectors dominated TFEC with 82.4% or 352 Mtoe of 427 Mtoe. This combined share only slightly decreases to 81.2% or 695 Mtoe of 856 Mtoe in 2040. All sectors experience an expansion during the projection period. Industry grows at the fastest rate with 3.3% CAGR, increasing the absolute value by a factor of 2.2 compared to 2015. The residential, commercial and non-energy use sectors grow by a CAGR of 1.6%, 3.1% and 3.1% respectively, increasing their absolute values by a factor of 1.5, 2.2 and 2.1 in 2040 compared to their levels in 2015.

Figure 7. **TFEC Projections in ATS by Sector**



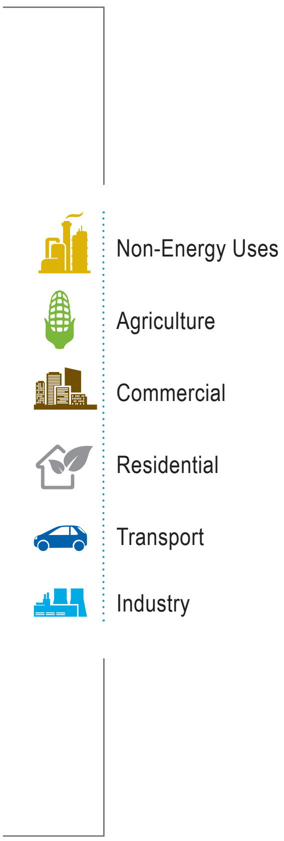
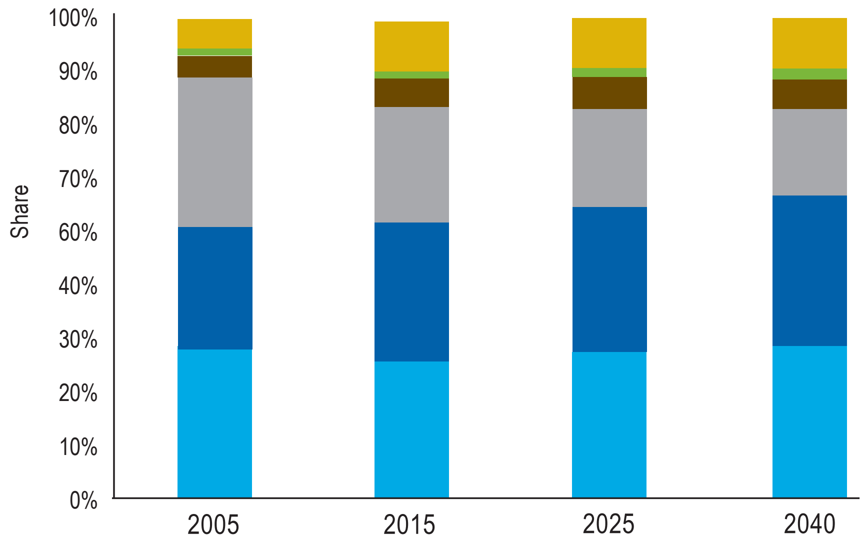
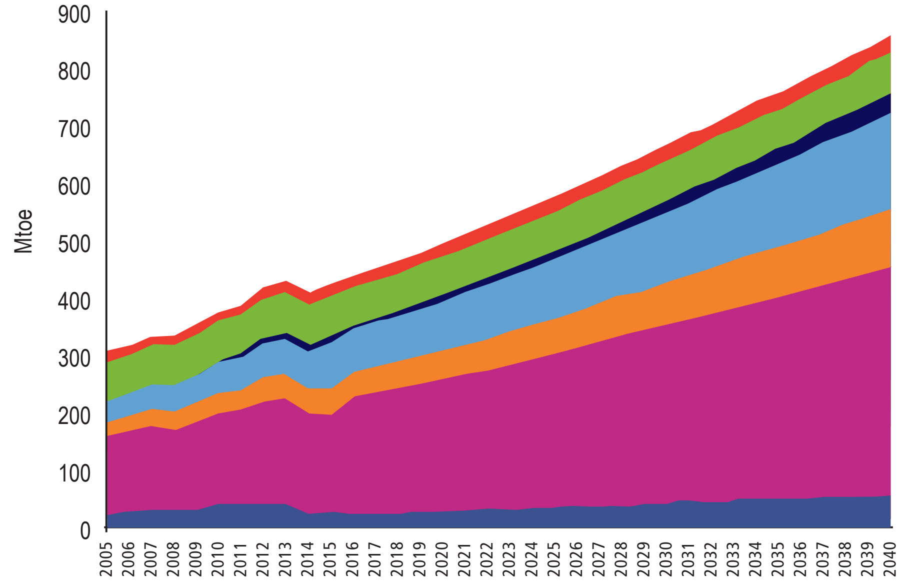


Figure 8. **TFEC Projections in ATS by Sector-share**



During the projection period, as illustrated in **Figure 9** and **Figure 10**, all fuels expand in TFEC. Due to the injection of policies and targets on having more biofuels in the market in Indonesia, Thailand and Malaysia, biofuels also experience strong growth showing a CAGR of 3.6%. Increasing by a CAGR of 3.5%, oil products increase their absolute value from 168 Mtoe in 2015 to 394 Mtoe in 2040, growing by a factor of 2.4. Natural gas also grows in the projection period, with a CAGR of 3.5%, expanding by a factor of 2.4 as compared to the 2015 level. This growth in fossil fuels takes place due to the strong increase in the transport and industry sectors. Furthermore, as electricity shows strong growth with a CAGR of 2.9% increasing by a factor of 2.0, traditional biomass is losing its importance among TFEC, growing with a CAGR of 0.3%, and reducing its share of TFEC from 15.4% in 2015 to 8.3% in 2040.

Figure 9. **TFEC Projections in ATS by Fuel**



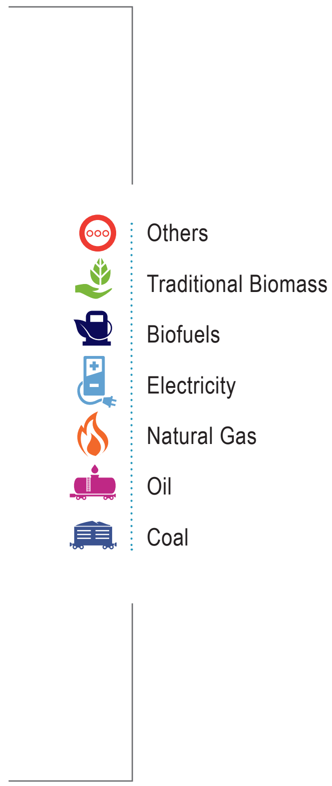
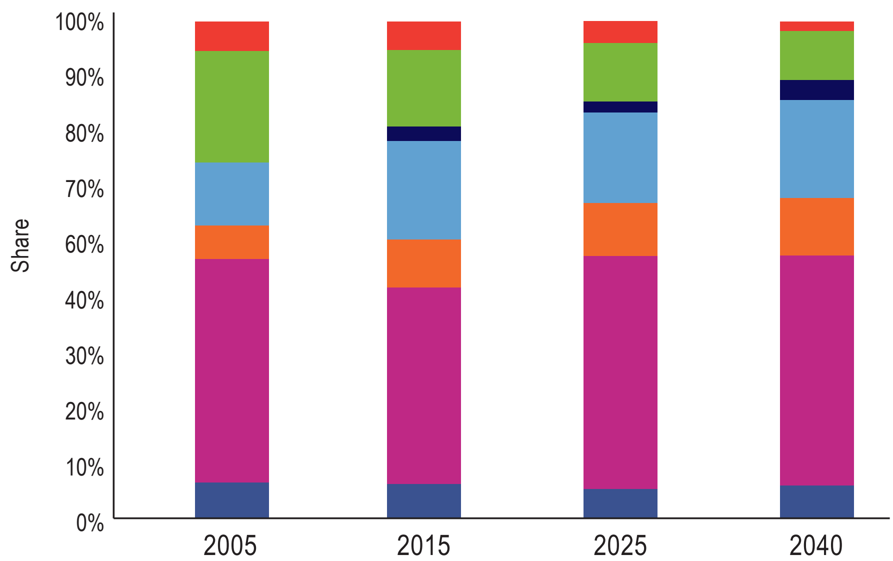


Figure 10. **TFEC Projections in ATS by Fuel-share**



The development of TFEC by country is illustrated in **Figure 11** and **Figure 12**. All AMS are expected to show a growing trend. The same five AMS as in BAU are still the main contributors to TFEC. During the projection period, Indonesia, Thailand, Vietnam, Malaysia and the Philippines actually increase their dominance in TFEC from a combined share of 388 Mtoe or 90.8% in 2015 to 790 Mtoe or 92.2% in 2040. In 2040, the highest energy demand of ASEAN is in Indonesia with 347 Mtoe or 40.4% of TFEC.

Figure 11. **TFEC Projections in ATS by Country**

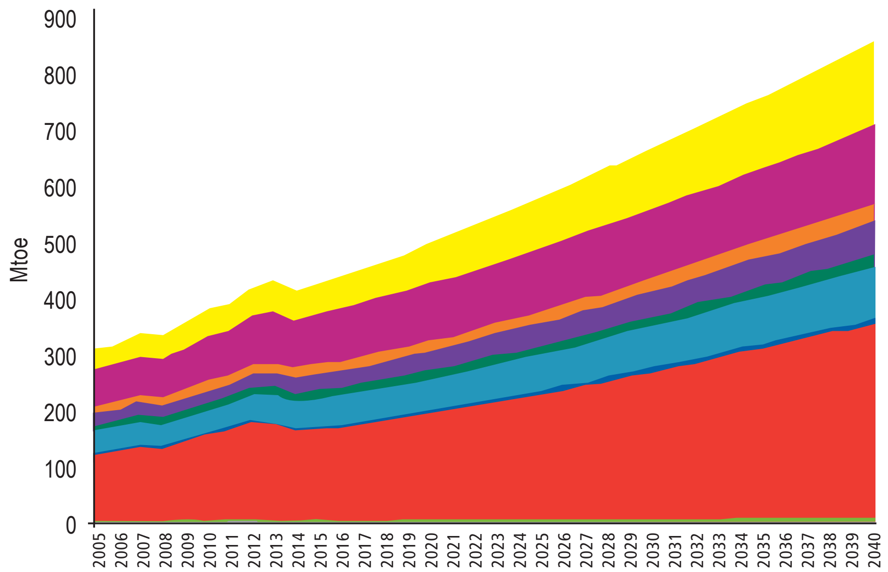
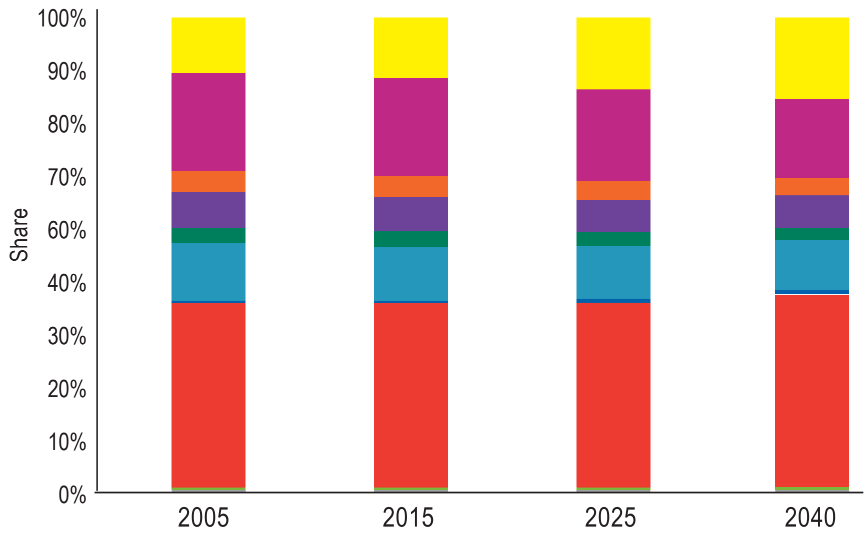


Figure 12. **TFEC Projections in ATS by Country-share**



APS. TFEC is projected to grow at the lowest rate, with only 2.4% CAGR resulting in 771 Mtoe in 2040, an increase of only 1.8 times as compared to the 2015 level. Accordingly, among all scenarios, TFEC in APS exhibits the highest energy savings during the projection period due to the effect of the EE targets included in this scenario, almost one quarter of the demand in BAU.

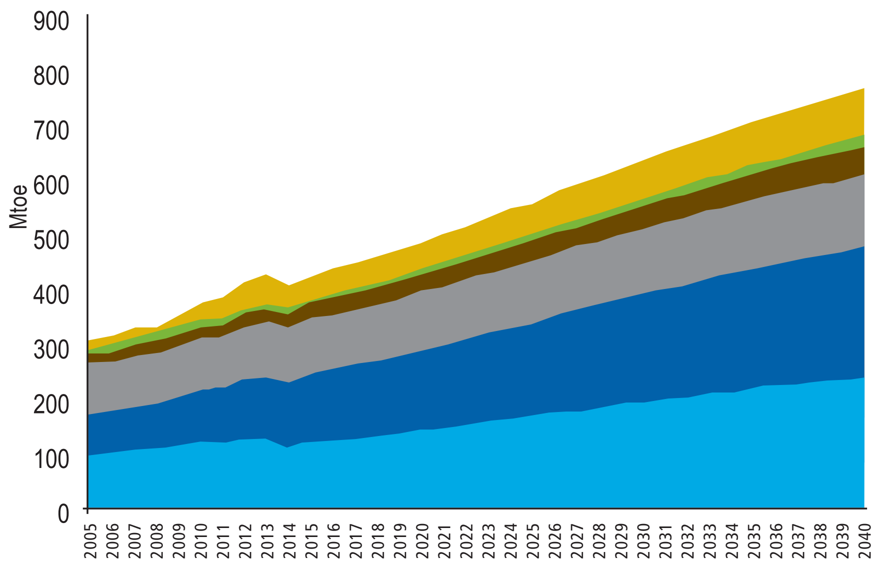
Table 5 shows the energy savings and correspondingly applied saving rates in APS. Of note, the saving rates are derived from official AMS targets and are therefore the same as in ATS. However, while the targets of AMS end in between 2020 and 2040, in APS, the saving rates are applied for the whole projection period.

Table 5. Modelling Saving Rate on EE Targets for APS

AMS	Reference Targets	Saving Rate per year	Horizon
Brunei Darussalam	• Reduce EI (TFEC/GDP) to 2035 by 45% based on 2005 level.	All sectors: 2.7%	2040
Cambodia	• Reduce TFEC by 20% in 2035 compared to BAU.	All sectors: 1.2%	2040
Indonesia	• Reduce TFEC in 2025 by 17% in industry, 20% in transport, 15% in household, 15% in commercial building compared to BAU.	Industry 1.9% Transport 2.4% Residential 1.6% Commercial 1.7%	2040
Lao PDR	• Reduce TFEC by 10% in 2030 compared to BAU.	All sectors: 0.7%	2040
Malaysia	• Reduce Electricity Consumption in TFEC by 16% in 2025 compared to BAU.	Electricity: 1.7%	2040
Myanmar	• Reduce Electricity Consumption in TFEC by 20% in 2030 compared to BAU.	Electricity: 1.5%	2040
Philippines	• Reduce TFEC by 1.3% per year compared to BAU until 2040.	All sectors: 1.3%	2040
Singapore	• Reduce EI (TFEC/GDP) by 35% from 2005 levels by 2030.	All sectors: 0.3%	2040
Thailand	• Reduce EI (TFEC/GDP) by 30% in 2030 compared to 2010 level.	All sectors: 2.6%	2040
Vietnam	• Reduce TFEC by 8% in 2020 compared to BAU.	All Sectors: 1.7%	2040

Figure 13 and **Figure 14** show the different sectors and their contribution to TFEC, in absolute value and share. All sectors still grow during the projection period. The strongest growth is projected in non-energy use (CAGR of 3.1%), followed by agriculture (CAGR of 2.9%), which both increase their values by a factor of 2.2 in 2040 compared to 2015. The relatively strong growth in non-energy use and agriculture in APS results from the fact that EE targets lead to a substantial reduction in TFEC in the industry, transport and residential sectors. Thus, the transport and industrial sectors show a smaller CAGR of 2.6% and 2.7% respectively, expanding by factors of 1.9 and 2.0 in 2040. Residential and commercial sectors experience 1.5% and 2.8% CAGR respectively, increasing their values by a factor of 1.2 and 2.0 in 2040 compared to 2015.

Figure 13. **TFEC Projections in APS by Sector**



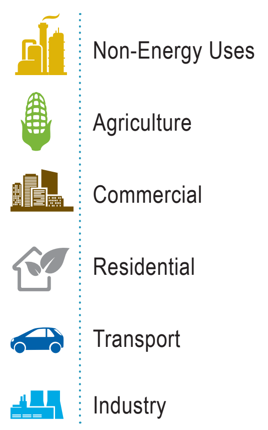


Figure 14. **TFEC Projections in APS by Sector-share**

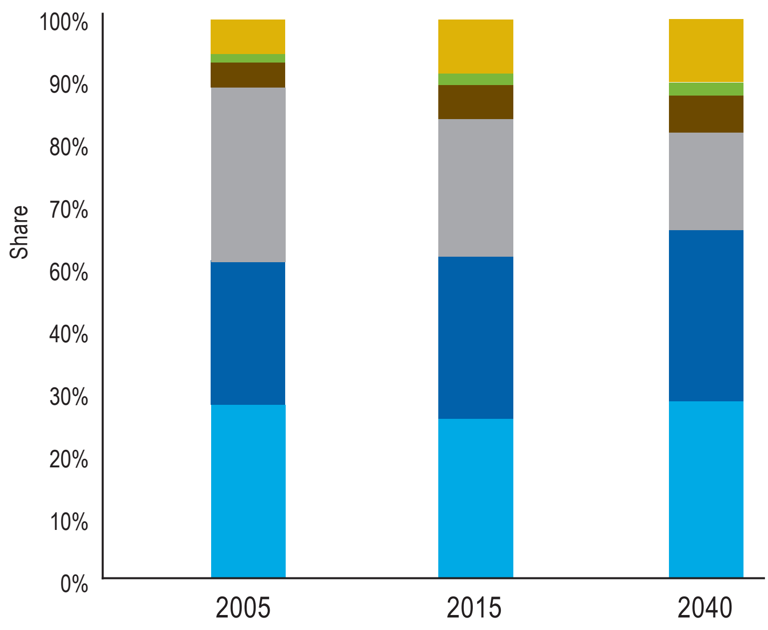
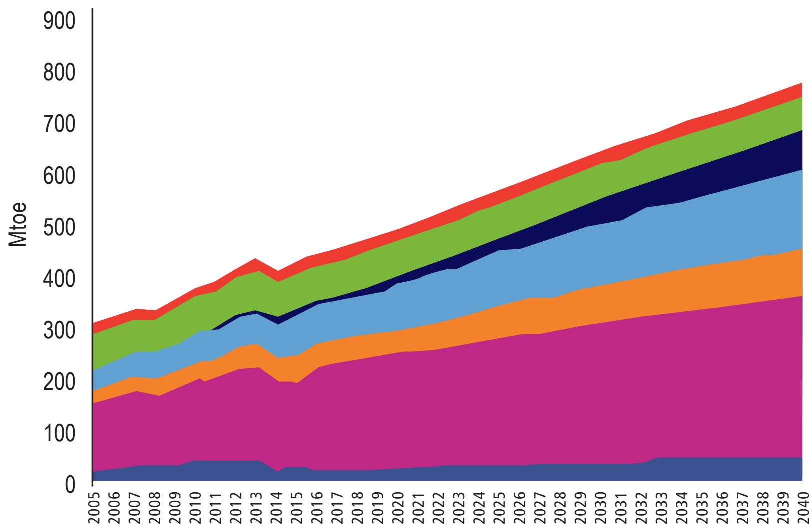


Figure 15 and **Figure 16** depict TFEC by fuels from 2005 to 2040. All fuels in TFEC show a steady expansion during the projection period. Biofuels experience the strongest growth by a CAGR of 7.4%. They increase their absolute value from 14 Mtoe in 2015 by a factor of 6.0 to 81 Mtoe in 2040. Biofuels comprise a considerable share of TFEC in 2040, with a value of 10.4% as compared to only 3.2% in 2015. In contrast, the demand for oil products is reduced by enhanced EE in the transport sector, and this is offset by the strong development of biofuels, which will primarily be used as blend component of oil products in the transport sector. As a consequence, oil products grow with a CAGR of 2.5% during the projection period 2015-2040, expanding by factor of 1.8 and reaching a share of 40.0% in 2040 (compared to 39.2% in 2015). Natural gas shows a growth in the projection period at a rate of 3.1%, rising by a factor of 2.2 as compared to its 2015 level.

Also in APS, the growth in the demand for fossil fuels can be attributed to the expanding growth in the transport and industry sectors. In addition, electricity grows moderately, expanding by a CAGR of 2.4% and increasing by a factor of 1.8. The growth in electricity reflects both increasing wealth in ASEAN, and stronger efforts to reduce consumption of traditional biomass. It is worthy to note that in APS, traditional biomass will decrease in the projection period, showing a negative CAGR of 0.5%, lowering its share of TFEC from 15.4% in 2015 to 7.7% in 2040. Lastly, coal use in the final energy demand will grow moderately, increasing with a CAGR of 2.1% during the projection period and slightly losing share among TFEC, from 7.1% in 2015 to 6.6% in 2040.

Figure 15. **TFEC Projections in APS by Fuel**



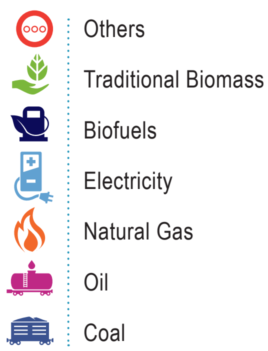
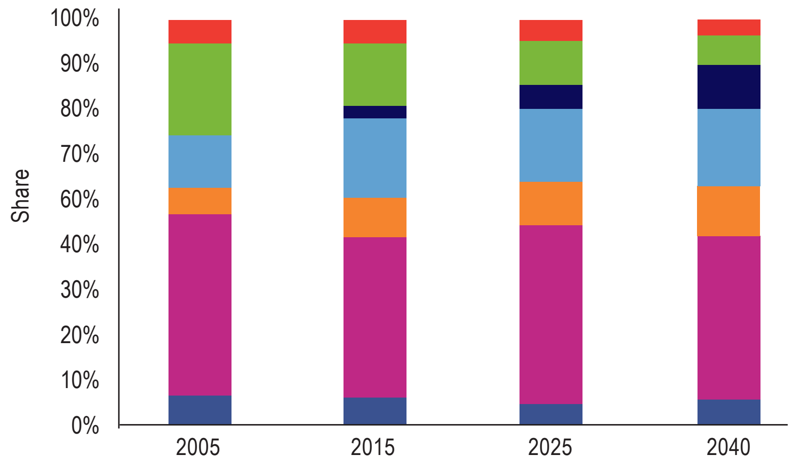


Figure 16. **TFEC Projections in APS by Fuel-share**



The development of TFEC by country is illustrated in **Figure 17** and **Figure 18**. All AMS are still expected to show a growing trend in TFEC, but at a lower rate than ATS. Five AMS, as in BAU, remain main contributors to TFEC. During the projection period, Indonesia, Thailand, Vietnam, Malaysia and the Philippines even increase their dominance in TFEC with a combined share of 90.8% or 388 Mtoe in 2015, increasing to 91.8% or 708 Mtoe in 2040. Implementing various EE policies, the highest energy demand of ASEAN in 2040 still comes from Indonesia with 305 Mtoe or 39.6% of TFEC.

Figure 17. **TFEC Projections in APS by Country**

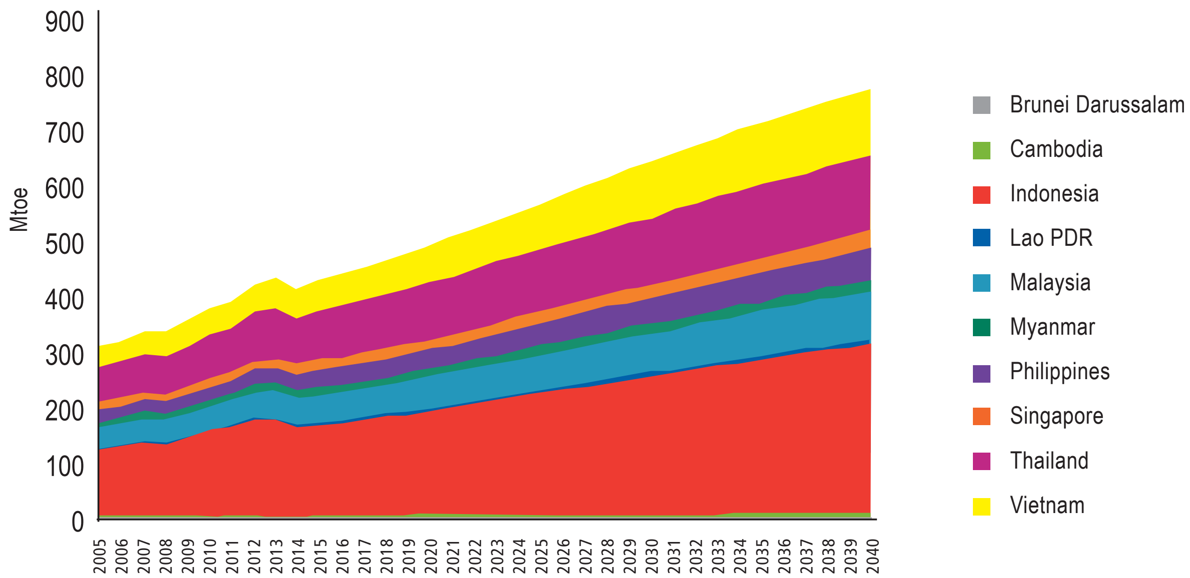
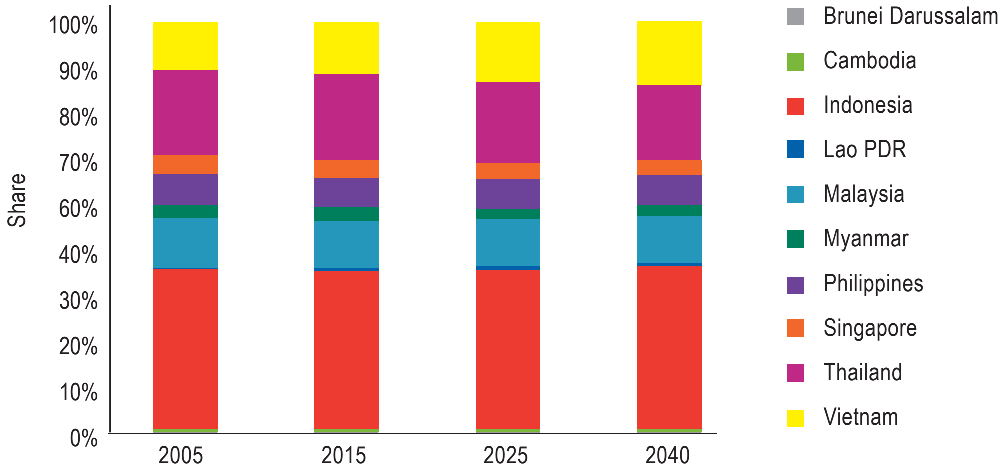


Figure 18. **TFEC Projections in APS by Country-share**

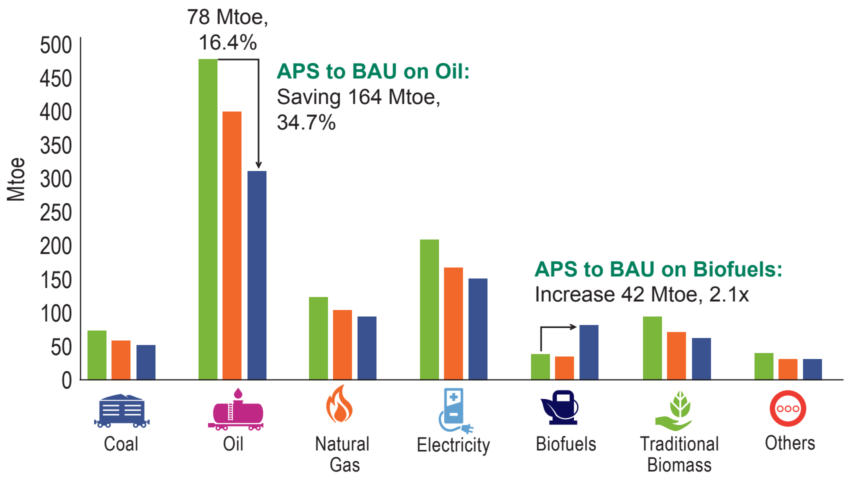


Comparison of Scenarios. The implementation of various targets in different sectors as projected in ATS is expected to reduce TFEC by 18.1% in 2040 compared to BAU. This reduction is equal to a saving of 190 Mtoe, which is similar to Vietnam's TFEC in BAU by 2040.

Furthermore, APS is expected to cut the demand by one quarter compared to BAU, amounting to 275 Mtoe saving. This value is equivalent to TFEC of the Philippines, Singapore and Vietnam combined in BAU by 2040.

Figure 19, **Figure 20** and **Figure 21** show the reduction by sector, fuel type and country. The biggest reduction in fuel is expected to come from the savings in oil, attributed to, among other factors, from enhancement in EI in the transport sector, as well as the shift to increased biofuels use in Indonesia, Malaysia and Thailand.

Figure 19. **Scenarios Saving in TFEC by Fuel**



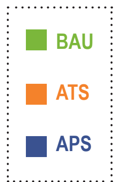


Figure 20. **Scenarios Saving in TFEC by Sector**

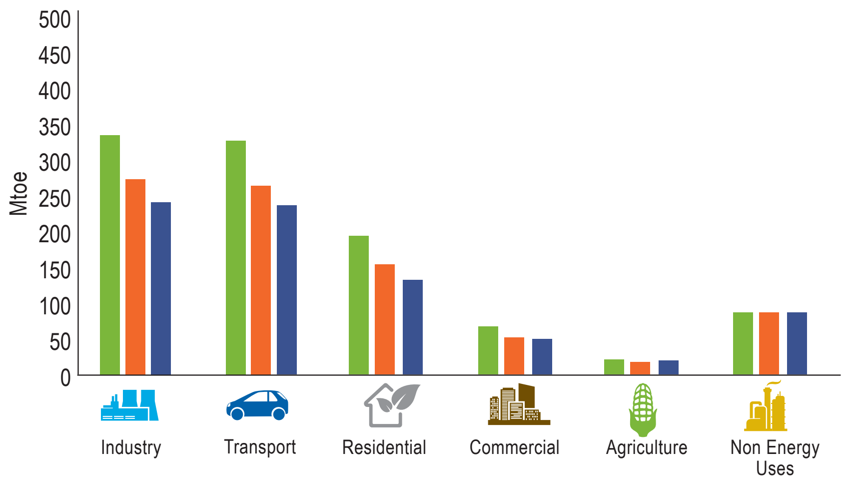
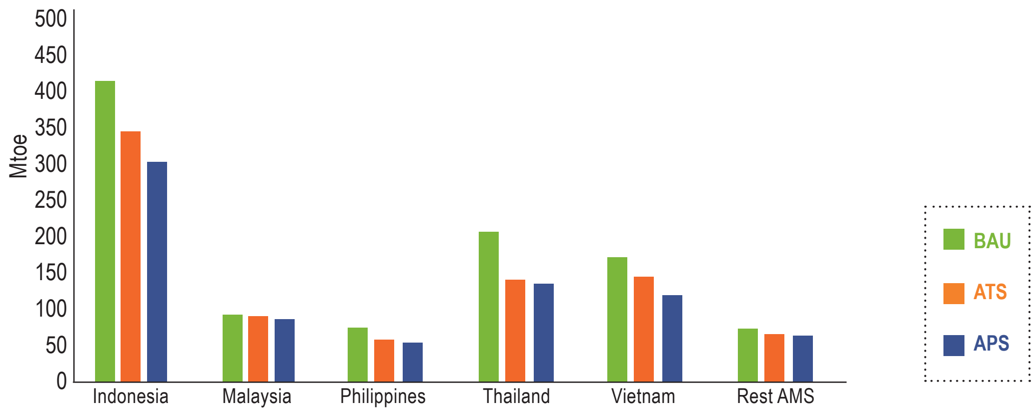


Figure 21. **Scenarios Saving in TFEC by Country**



Hence, the combined AMS nationally issued EE targets represent a yearly savings rate during the timeframe 2015-2040 of 0.9% per year. This leads to a TFEC in 2040 at a level of 81.9% of BAU. Similarly, keeping the ambition level of the nationally issued EE targets over the whole period 2015-2040 as modelled in the APS, results in yearly energy savings of 1.2%. This leads to a TFEC in 2040 at a level of 73.7% of BAU. Every sector exhibits a decrease across the scenarios. While the residential sector declines the most, the agricultural sector is the least affected by the EE targets. The residential sector declines the most, consuming 78.4% in ATS and only 68.6% in APS of the amount it requires in BAU. Additionally, the smallest savings are realised in non-energy use which show a reduction of only 2.8% in ATS and 2.9% in APS as of BAU. The ASEAN region will experience strong and dynamic economic development during the projection period, where the industry and transport sectors greatly increase their energy demands. Of note, this strong growth in energy demand can be counteracted in ATS and APS: reaching the EE as incorporated in the target scenario would lead to substantial savings, yielding a similar level of TFEC at only around 81% of BAU in ATS, and about 72% of BAU in APS.

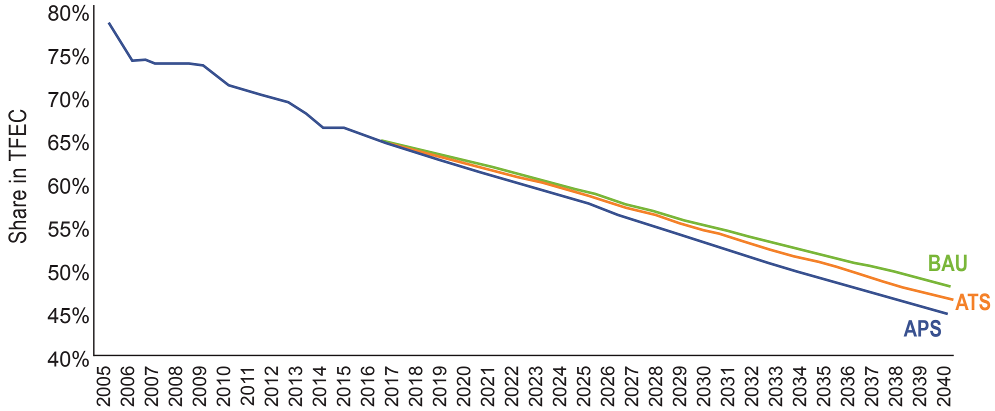
Credit: ACE

Traditional Biomass and Electrification Ratio

Traditional biomass mostly consists of wood fuels, agricultural by-products and manure which are used for cooking and heating purposes. Traded informally and non-commercially, it is widely harvested and used in an unsustainable way.

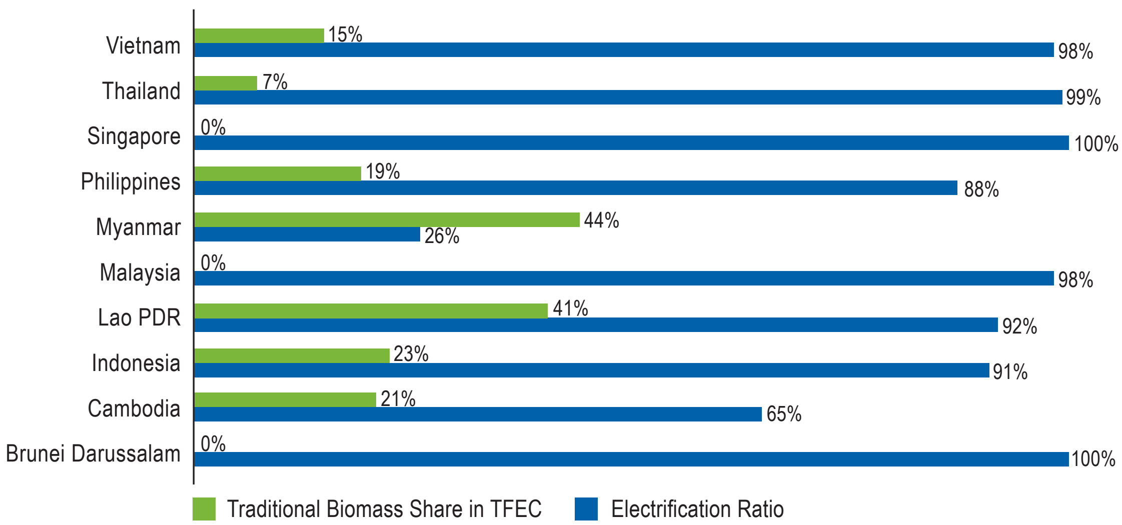
The figure below depicts the share of traditional biomass in the residential sector in BAU, ATS and APS, noting that over 90% of traditional biomass is consumed in this sector. Looking at its development, it is evident that the importance of traditional biomass, as a share of residential TFEC in 2040, is projected to decrease in ASEAN across all scenarios, from 65% in 2015 to 48% in BAU, to 46% in ATS, and 44% in APS. This decline is due to increasing wealth and prosperity in ASEAN, leading to increased access to electrification.

Traditional Biomass in Residential Sector



The figure below visualises the electrification rate of households in AMS contrasted with the use of traditional biomass in 2015. The increasing use of traditional biomass is notable in countries with low access to modern electrification services. While some AMS with a 100% electrification of households, i.e. Brunei Darussalam and Singapore do not rely on the use of traditional biomass in their TFEC, other AMS with lower electrification rates such as Myanmar or Cambodia tend to use significantly more traditional biomass to satisfy their energy demand. Providing access to electricity in countries with low electrification rates, in particular to inhabitants in rural areas with no grid connection, is key to reducing the use of traditional biomass.

Electrification Ratio and Share of Traditional Biomass in 2015
(Electrification figures refer to grid-connected electricity only)

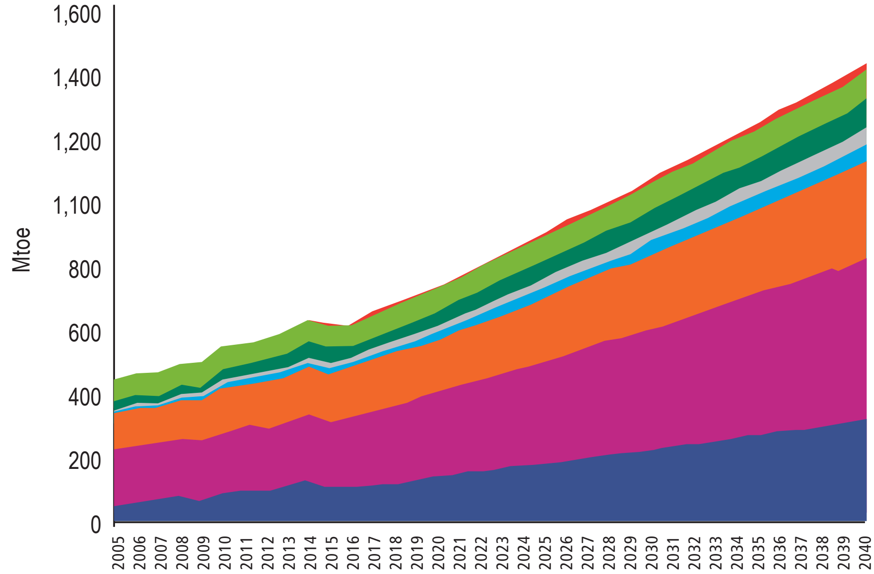


2.2 TOTAL PRIMARY ENERGY SUPPLY

BAU. In 2015, TPES of the region was 627 Mtoe. Continuing the historical trend, it experiences a steady growth in the projection period 2015-2040. Growing with a CAGR of 3.4%, TPES is projected to increase by a factor of 2.3 as compared to its level in 2015. In absolute terms, TPES is projected to increase from 627 Mtoe in 2015 to 1,450 Mtoe in 2040.

Presenting TPES by fuel types, **Figure 22** and **Figure 23** illustrate the dominance of fossil fuels in the ASEAN energy supply. In 2015, oil was the dominant fuel in TPES with a value of 207 Mtoe, representing 33.0% of TPES. It was followed by natural gas with nearly 150 Mtoe or 23.7% of TPES. Coal, while still comprising the substantial number of 116 Mtoe in 2015, had the lowest share among fossil fuels with 18.5%. During the projection period, all fossil fuels show a considerable increase in TPES.

Figure 22. **TPES Projections in BAU by Fuel**



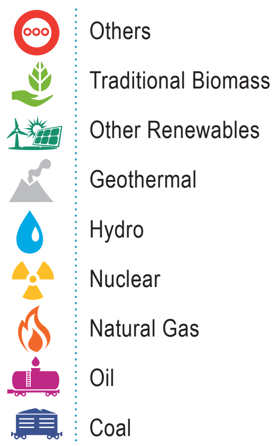
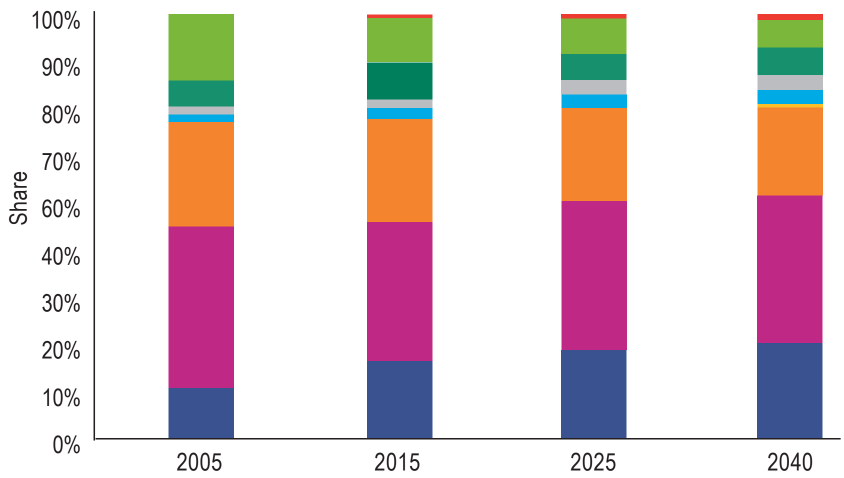


Figure 23. **TPES Projections in BAU by Fuel-share**



Oil, starting from the highest value in TPES with a share of 33.0%, grows with a CAGR of 3.6% during the projection period and increases by a factor of 2.4 compared to its 2015 level. It maintains its position as primary energy source in ASEAN accounting for 34.8% (505 Mtoe) of TPES in 2040.

Coal, while starting with a lower initial share of 18.5% of TPES in 2015, shows the strongest growth rate among fossil fuels with a CAGR of 4.3%. It increases by a factor of 2.8 as compared to the 2015 level and thereby has the highest increase among fossil fuels during the projection period. In 2040, coal is the second main source of primary energy accounting for 22.7% (329 Mtoe) of TPES.

Natural gas registers a moderate growth of 2.9% per year, increasing by a factor of 2.0 as compared to its 2015 level. In 2040, it accounts for 21.0% of TPES, corresponding to approximately 305 Mtoe.

The development of oil, coal and gas exhibits the persisting importance of fossil fuels in ASEAN during the projection period, accounting for 78.6% or about 1,139 Mtoe of the total 1,450 Mtoe of TPES in 2040. Fossil fuels represent the main source of primary energy in BAU.

RE represents 13.6% of TPES in 2015. Most importantly, it is comprised of 18 Mtoe (2.9%) of hydro, 12 Mtoe of geothermal (1.9%) and 55 Mtoe of other RE[7] (8.8%). Starting from low values as compared to fossil fuels in 2015, RE shows a very rapid increase in TPES with a CAGR of 4.0% during the projection period.

Geothermal and hydro are projected to have the highest growth in TPES, increasing by a factor of 4.6 and 2.8 respectively, compared to their levels in 2015, with CAGR of 6.3% and 4.2%. Worthy of note is that the growth rates of geothermal is the highest among all fuels and surpass those of fossil fuels. Other RE, a category in TPES comprising wind, solar, biomass and biofuels, will grow with a CAGR of 2.0% increasing their value among total TPES by a factor of 1.7 to 92 Mtoe in 2040. Geothermal and hydro account for 54 Mtoe and 51 Mtoe at the end of the projection period respectively, and will jointly contribute a share of 7.2% to the TPES of ASEAN in 2040.

Traditional biomass will lose its relevance in ASEAN's energy supply by decreasing its share from 10.6% in 2015 to only 6.4% of TPES in 2040. Of note, in absolute numbers, traditional biomass will still increase from 67 Mtoe in 2015 to 94 Mtoe in 2040. The small growth rate of 1.4% per year as compared to the TPES growth rate of 3.4% leads to a reduction in the relevance of traditional biomass.

In 2035, nuclear energy for civilian power generation will be added to the ASEAN energy mix, leading to a contribution of nuclear energy to TPES of 1.5 Mtoe. Up to 2040, this value will double to 3 Mtoe, as the region is expected to see the operationalisation of nuclear power plants in Thailand and perhaps others. In early 2017, the Philippines has reembarked their plan on nuclear power plants to secure energy requirements. Despite the planned introduction of nuclear power plants, its share of TPES with less than 0.5% still represents an insignificant contribution to the TPES in 2040 in BAU.

[7] Other RE refer to solar PV and wind.

Figure 24 and **Figure 25** show TPES by country in BAU. As illustrated, TPES in all AMS is expected to grow constantly during the projection period. Lao PDR, Vietnam and the Philippines will experience the strongest growth during the projection period with CAGR of 6.1%, 4.7% and 3.7% respectively, and thereby multiply their TPES by factors of 4.4, 3.2 and 2.5, while altogether they only account for a share 26.7% of TPES in 2040.

The five main contributors to TPES during the projection period remain Indonesia, Thailand, Vietnam, Malaysia and the Philippines. Their dominance in TPES increases from a combined share of 91.2% or 571 Mtoe in 2015 to 92.3% or 1,339 Mtoe in 2040. The two largest contributors to the primary energy requirements are projected to be Indonesia and Thailand with 537 Mtoe (37.0% of TPES) and 286 Mtoe (19.7% of TPES) in 2040. Notably, due to strong economic development, Vietnam will surpass Malaysia in 2023 to become the third largest contributor to TPES in 2040.

ATS. This portrays the implications for the ASEAN energy system in meeting the nationally issued EE and RE targets. Both EE, by reducing the final demand, and RE, by offsetting fossil fuels and changing the overall conversion degree of the power sector, affect TPES. The impact is notable in reducing the value from BAU. TPES is projected to increase by a factor of 2.0 from 627 Mtoe in 2015 to 1,249 Mtoe in 2040, reflecting a CAGR of 2.8%.

Figure 24. **TPES Projections in BAU by Country**

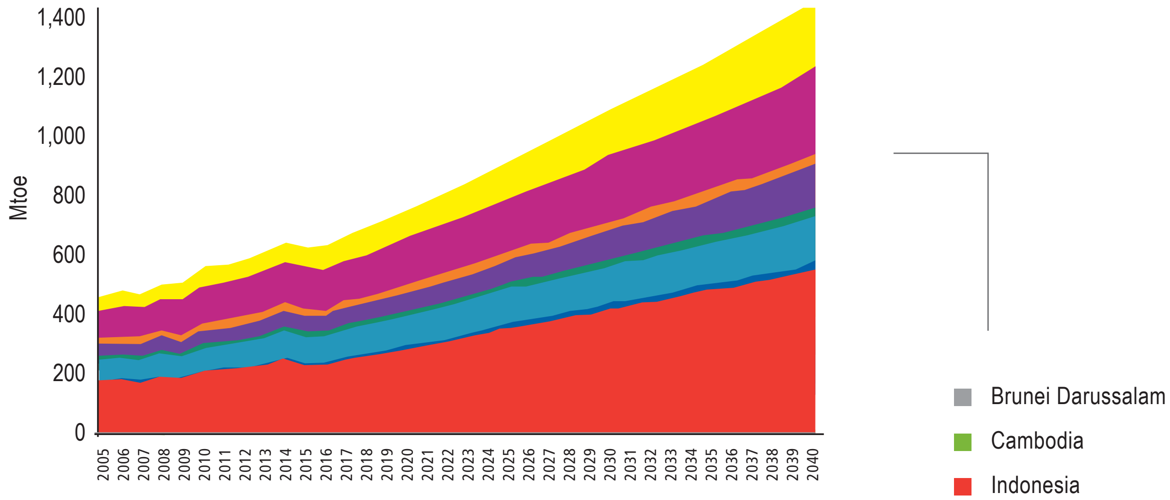


Figure 25. **TPES Projections in BAU by Country-share**

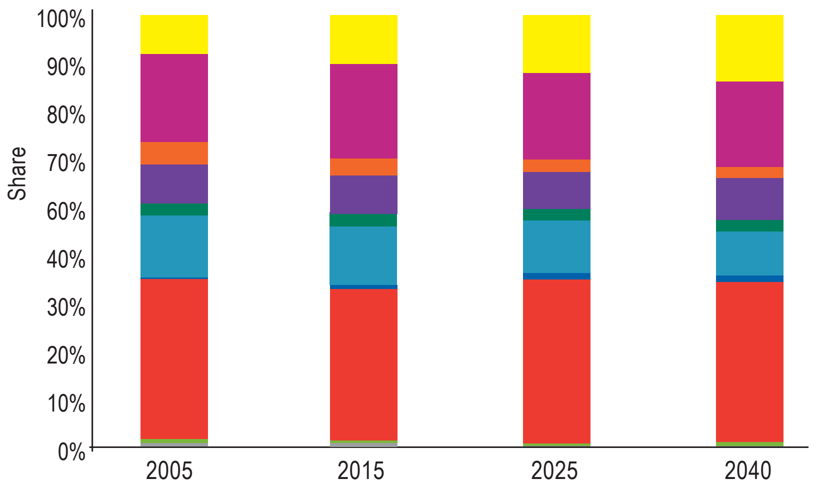
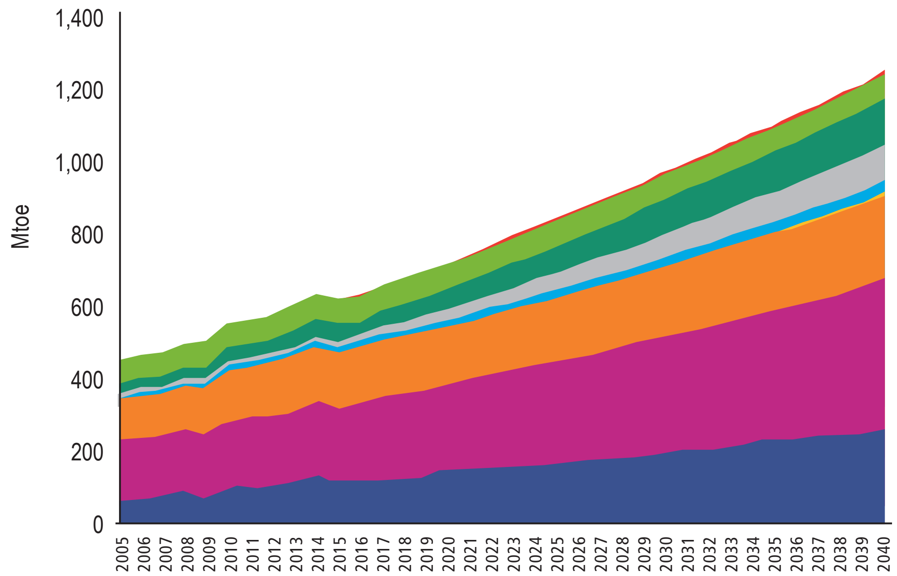


Figure 26 and **Figure 27** show the growth of every type of energy in regional needs. In 2015, fossil fuels (coal, oil and natural gas) constitute the main fuels with 75.2% share of the energy mix, whereas all RE have a 13.6% share. With the exception of traditional biomass, all fuels are projected to grow at various paces. Oil will remain the major fuel with a one-third share during the period, but the region is expected to see the significant growth of coal at a CAGR of 3.4% to supply energy demand. In 2040, fossil fuels will see a small decline to just under three quarters of demand (73.2%), but traditional biomass will reduce its share by about one half during the period (5.8%), replaced by growing RE (21.4%).

Figure 26. **TPES Projections in ATS by Fuel**



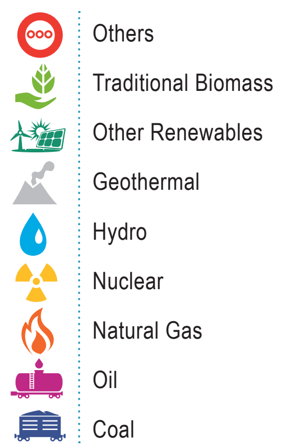
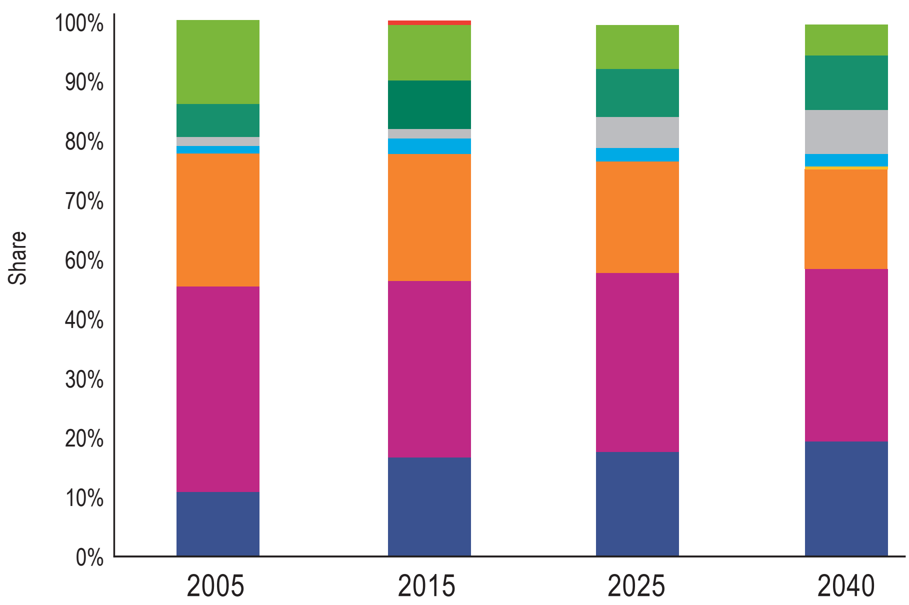


Figure 27. **TPES Projections in ATS by Fuel-share**



Coal has the highest growth rate among fossil fuels, with a CAGR of about 3.4%. Starting from a share of 18.5%, coal increases by a factor of 2.3 in 2040 as compared to its 2015 level. With 269 Mtoe, it represents a share of 21.5% of TPES in 2040.

Oil is projected to grow by a CAGR of 2.8%, increasing by a factor of 2.0 in 2040 compared to 2015. With 32.7% or 409 Mtoe, oil maintains a similar share in 2040 as it does in 2015.

Natural gas exhibits a moderate growth of 1.9%. However, increasing by a factor of 1.6 to 237 Mtoe compared to its 2015 level, it loses its share from 23.7% in 2015 to 19.0% of TPES by 2040.

As already seen in BAU, fossil fuels constitute the main energy source in ASEAN during the projection period. Despite ASEAN's ambitious energy targets in ATS, fossil fuels account for 73.2% or about 914 Mtoe of 1,250 Mtoe TPES in 2040.

Geothermal and hydro are major drivers in the development of RE. They exhibit CAGR of 9.0% and 2.4%, which represent an increase in their absolute values by factors of 8.7 and 1.8 compared to 2015 levels, respectively. In energy terms, geothermal and hydro have shares of 8.2% (103 Mtoe) and 2.6% (33 Mtoe) of TPES in 2040, respectively. Together, they provide 10.9% of TPES, jointly constituting almost one half of the RE sector.

Other RE (wind, solar, biomass and biofuels) will grow by a CAGR of 3.5%, increasing their share by a factor of 2.4 compared to their level in 2015, from only 55 Mtoe in 2015 to 131 Mtoe by 2040.

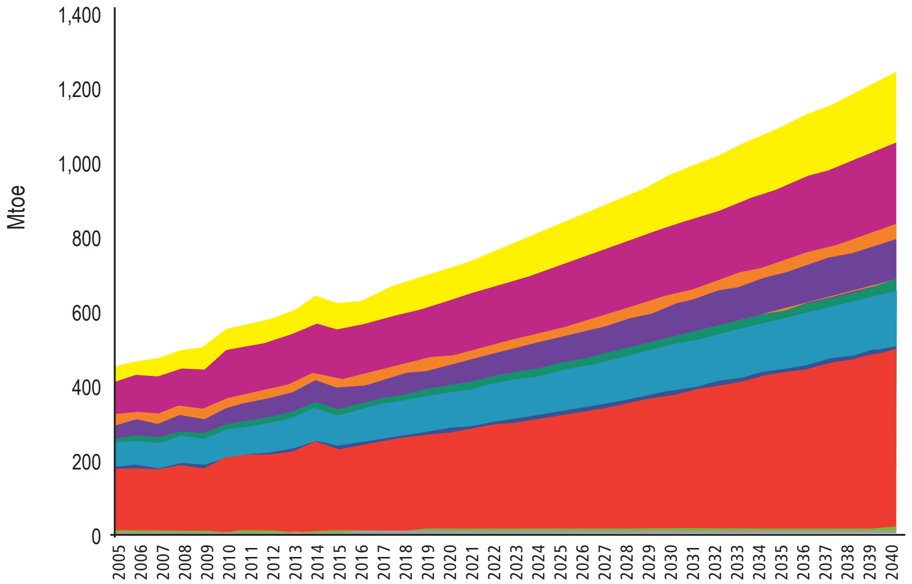
Traditional biomass will slightly grow from 67 Mtoe in 2015 to 72 Mtoe in 2040 in absolute terms, but the share decreases by almost one half, from 10.6% in 2015 to only 5.8% in 2040.

Nuclear is expected to begin contributing to TPES in 2035 and concludes its position with 3 Mtoe in 2040, 0.2% of the energy mix.

Credit: ACE

Figure 28 and **Figure 29** show the main contributors to TPES during the projection period remain Indonesia, Malaysia, the Philippines, Thailand and Vietnam. Their dominance in TPES remains around 90% during the whole projection period. The largest primary energy requirement in ASEAN is projected to come from Indonesia, which also experiences the highest growth (CAGR 3.2%), with 483 Mtoe or 38.6% of TPES in 2040.

Figure 28. **TPES Projections in ATS by Country**



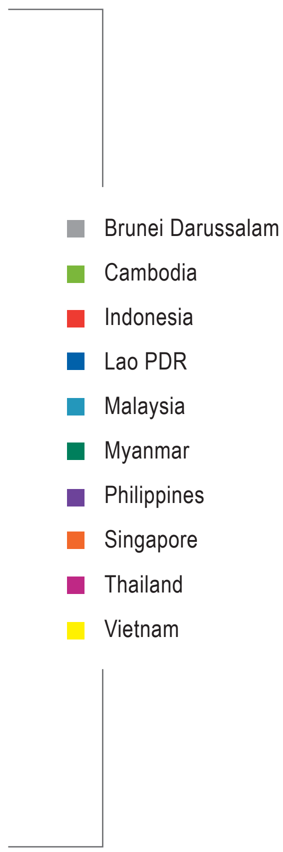
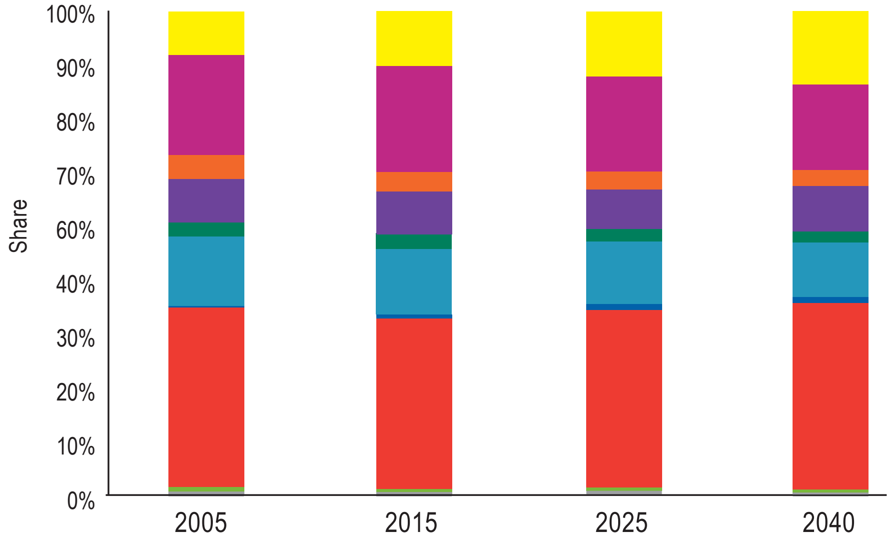


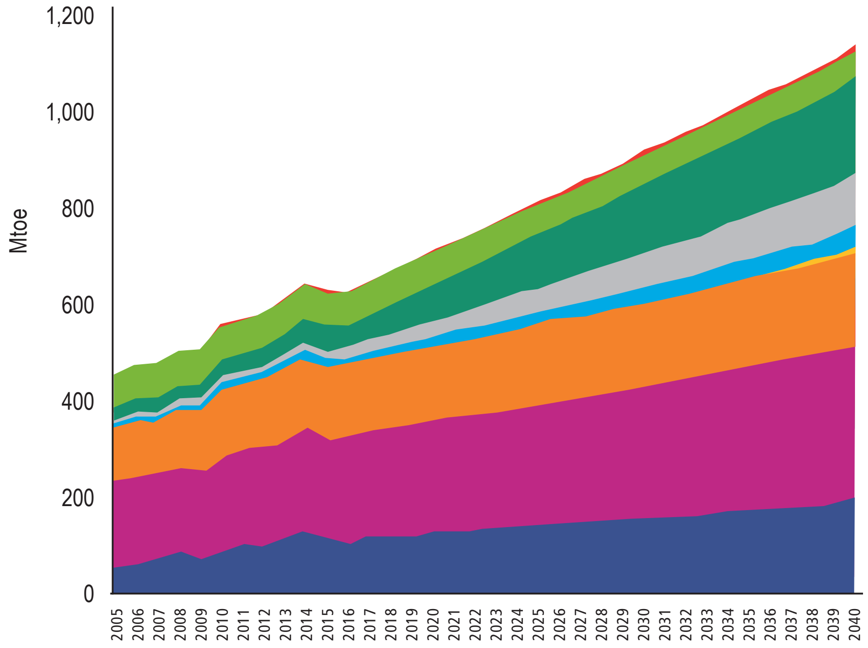
Figure 29. **TPES Projections in ATS by Country-share**



APS. The projection of TPES is expected to have the lowest expansion factor of only 1.8 by 2040 compared to the 2015 level. Mostly due to assumptions on EE, APS grows by a moderate CAGR of 2.4% to reach 1,123 Mtoe in 2040. With a more efficient use of primary energy, savings in TPES in ATS become feasible.

Figure 30 presents TPES in APS during the projection period by fuel, while **Figure 31** presents the distribution of TPES by fuel share.

Figure 30. **TPES Projections in APS by Fuel**



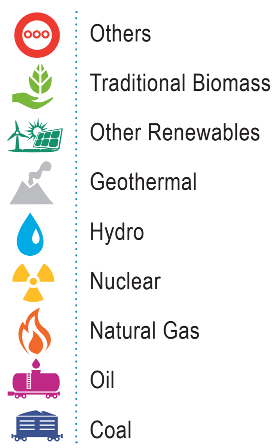
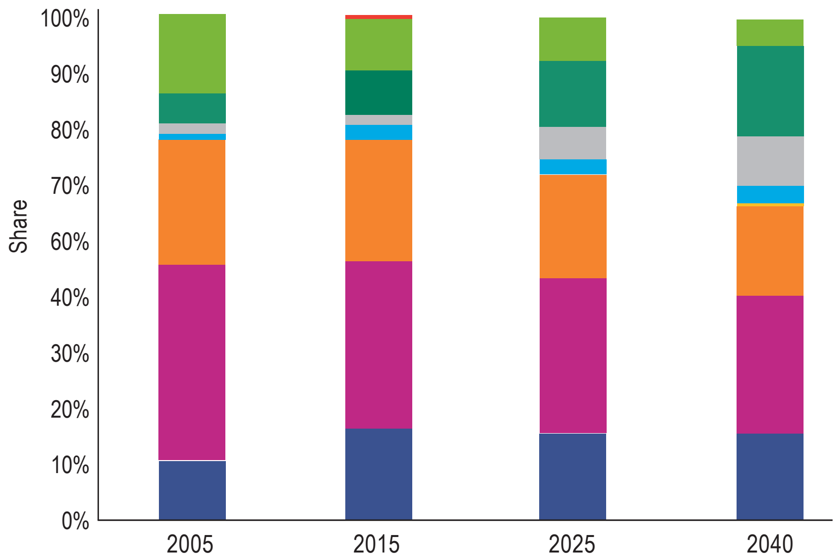


Figure 31. **TPES Projections in APS by Fuel-share**



Oil exhibits a CAGR of 1.7%, rising by a factor of 1.5 from 207 Mtoe in 2015 to 315 Mtoe in 2040. Decreasing its share from 33.0% to 28.1%, oil still represents the dominant fuel in TPES at the end of the projection period.

The primary requirement for coal, similar to BAU and ATS, is projected to expand at a CAGR of 2.1%. Increasing by a factor of 1.7 from 116 Mtoe in 2015 to 196 Mtoe in 2040, coal contributes a share of 17.5% to TPES in 2040, decreasing its share by about 1% compared to the 2015 level.

Natural gas, as in the other scenarios, experiences a moderate growth of 1.2%. While it will expand by a factor of 1.3 from 149 Mtoe in 2015 to 198 Mtoe in 2040, it will account for 17.7% of TPES in 2040, considerably lowering its relevance in TPES by about 6%.

Fossil fuels are thus still dominant in APS among ASEAN TPES in 2040. However, in comparison to other scenarios, fossil fuels show an 12.0% decline in their share to 63.2%, or 710 Mtoe of a total 1,123 Mtoe in the 2040 TPES.

Meanwhile, the RE sector exhibits the strongest growth in all scenarios, with a CAGR of about 5.9%. It strongly expands its value from 85 Mtoe (13.6%) in 2015 to 357 (31.8%) Mtoe in 2040, compensating for the decline of fossil fuels.

Geothermal, as in the other scenarios, also experiences the highest growth during the projection period, increasing with a CAGR of 9.5% in APS. Expanding by a factor of 9.45 in 2040 compared to 2015, geothermal will grow from 12 Mtoe to 111 Mtoe. In addition, its relevance in the distribution of total TPES in 2040 will increase, representing a share of 9.9% in 2040 as compared to 1.9% in 2015. Hydro will expand by a CAGR of 3.4% in APS and remains of modest importance to TPES, yielding a share of 3.8% or 43 Mtoe or 4.3% of TPES in 2040.

As traditional biomass shows a small decline from 67 Mtoe in 2015 to about 61 Mtoe in 2040, its share in 2040 will decrease from 10.6% in 2015 to 5.4% in 2040.

Other RE, mainly solar PV and modern biomass, will grow significantly by a CAGR of 5.3%, increasing by a factor of 3.7 compared to 2015 levels. At 203 Mtoe, this represents a share of 18.0% in TPES in 2040.

Compared to the other scenarios, nuclear shows a higher contribution, rising to 5 Mtoe in 2040. Overall, nuclear remains low, with 0.5% contribution to TPES in 2040 in APS.

Comparison of Scenarios. Figure 32 illustrates the different landscapes of TPES in 2015, compared to 2040 for all scenarios.

It highlights the successively reduced TPES in ATS and APS as compared to BAU. In BAU, the primary energy supply is the highest among all scenarios, with a value of 1,450 Mtoe in 2040. In ATS and APS, considerable energy savings are reflected in a significant lower TPES of 1,249 Mtoe (86.1% of BAU) and 1,123 Mtoe (77.4% of BAU), respectively. Both target-based scenarios, ATS and APS, thus experience a smaller growth in TPES. Expanding with a CAGR of 3.4%, TPES in BAU increases considerably slower in ATS and APS with CAGR of 2.8% and 2.4%, respectively. This difference in TPES across the scenarios is strongly attributed to the higher energy efficiency rates that are achieved in ATS and APS.

Figure 32. **TPES in 2040 All Scenarios**

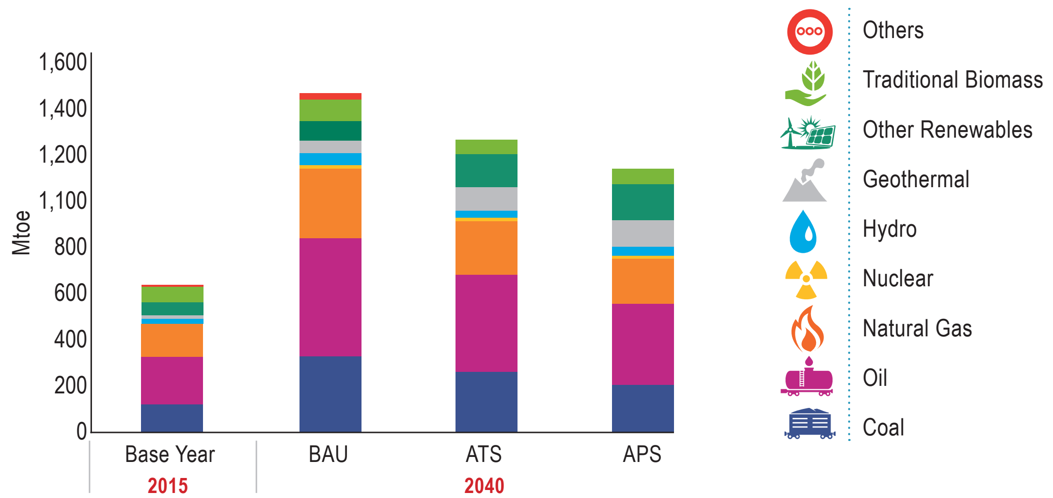
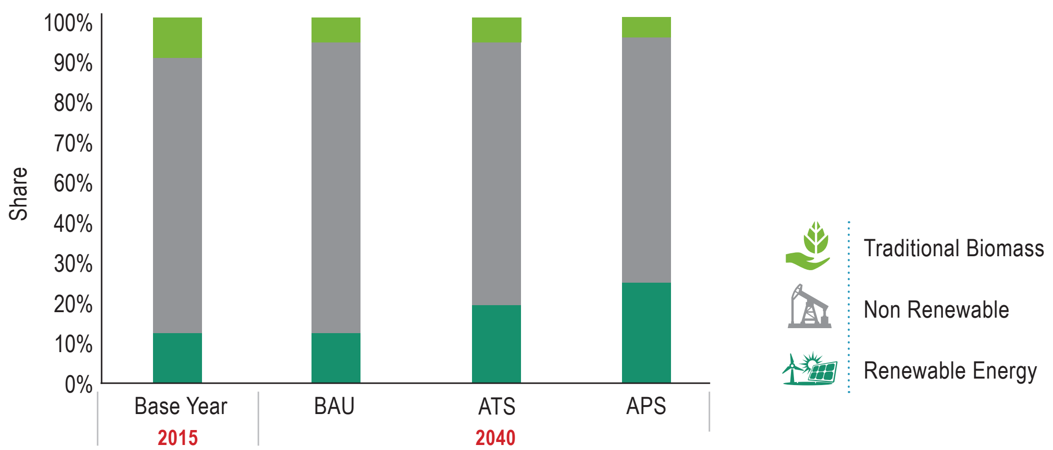


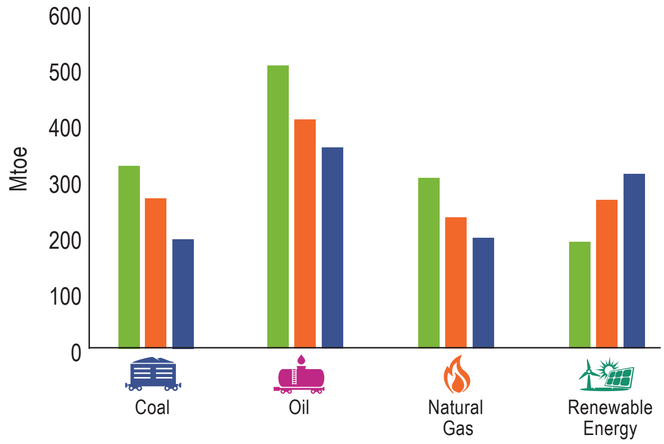
Figure 33 shows how RE grows in all scenarios in 2040. Remaining around 13% in BAU in 2040, ATS is expected to see 21.2% of RE, and an even higher figure of 27.5% in APS. This is caused not only by the move from fossil fuels to RE, but also by the move from traditional biomass into RE.

Figure 33. **TPES Fuel Share in 2040 All Scenarios**



Further detail on the reduction of fossil fuels, which are replaced by growing RE, is illustrated in **Figure 34**. It is also correlated with the saving in energy demand, in particular in oil. The impact on lower energy demand in various Member States as projected in the results of their targets is also illustrated in **Figure 35**. Indonesia and Thailand are considered leading Member States.

Figure 34. **Scenarios Saving in TPES by Fuel**



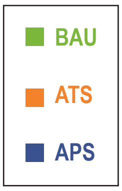
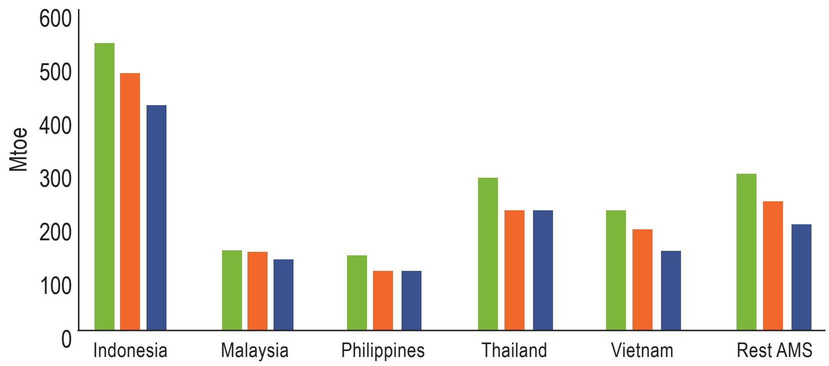


Figure 35. **Scenarios Saving in TPES by Country**



2.3 POWER CAPACITY AND GENERATION

BAU. The installed power capacity increases consistently during the projection period, demonstrating the constantly growing need for power in ASEAN. In BAU, the overall capacity increases from 205 GW in 2015 to 323 GW in 2025 and is projected to reach 629 GW in 2040. Growing with a CAGR of 4.6% per year, the installed power capacity rises by a factor of 3.0 compared to its 2015 level. **Figure 36** and **Figure 37** show the installed power capacity in BAU and its share in the timeframe 2005-2040 by technologies.

Figure 36. **Installed Capacity Projections in BAU by Technology**

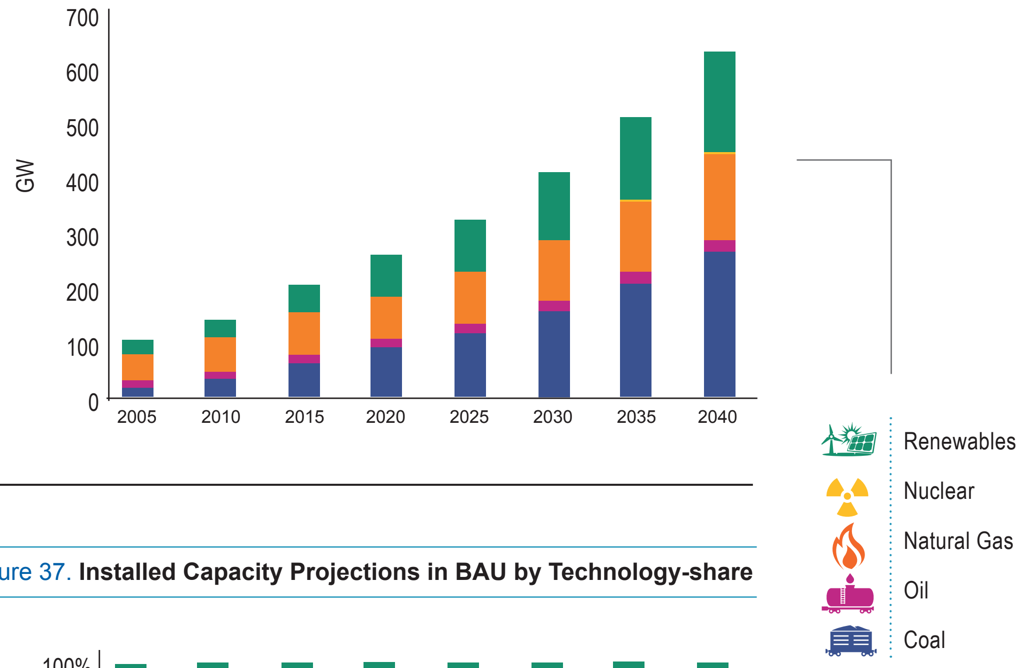
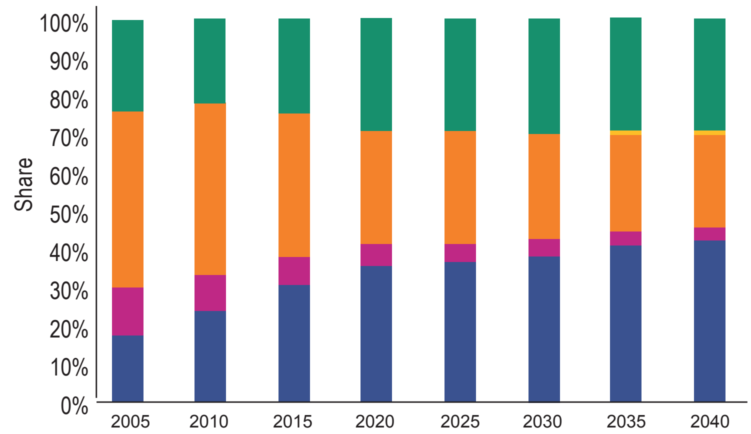


Figure 37. **Installed Capacity Projections in BAU by Technology-share**



Coal-based power plants will rise from 63 GW in 2015 to almost double that amount in 2025 with 119 GW. Reaching 267 GW in 2040, coal-based plants increase by a factor of 4.2 compared to the 2015 level, with a considerable CAGR of 5.9%.

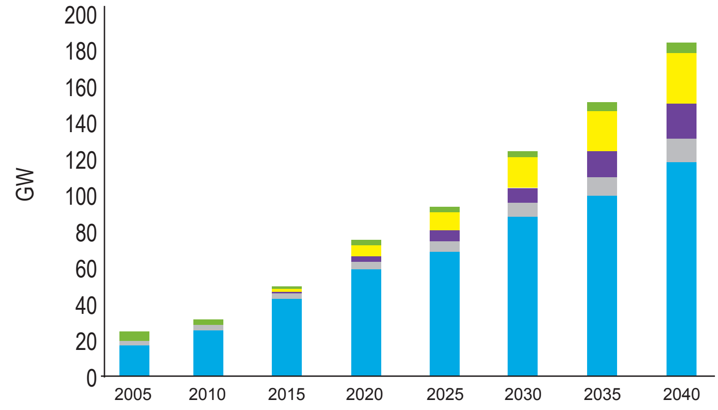
Natural gas-based power plants had an installed capacity of 77 GW in 2015 and are projected to increase in capacity with a CAGR of 2.9%, reaching 94 GW in 2025 and 156 GW by 2040. Over the projection period, natural gas-based power plants will approximately double in installed capacity.

Oil-fired power plants will grow from 16 GW in 2015 to 21 GW capacity in 2040 resulting in a change by a factor of 1.3. Despite a capacity increase in the Philippines, most AMS, including Indonesia, Malaysia and Thailand will lower their installed capacity, or even dismiss oil-based power plants from their power plant portfolio by 2040, yielding the lowest CAGR (1.2%) among all technologies.

RE technologies in the power sector are projected to increase in BAU from 50 GW in 2015 (24.3% of total installed capacity) to 93 GW in 2025 (28.9%) and up to 183 GW (29.2%) in 2040. Even in BAU, after coal, RE technologies are projected to have the highest yearly growth rate of 5.4%, expanding their capacity by a factor of 3.7 between 2015 and 2040.

A closer look at RE in the power sector is illustrated in **Figure 38** and **Figure 39**. The share of hydro in the total renewable installed capacity declines from 85.7% in 2015 to 64.0% in 2040. However, it remains the largest deployed RE technologies by far, expanding by a factor of 2.7 with 43 GW in 2015, 69 GW in 2025 and 117 GW in 2040. Hydro grows by a CAGR of 4.1% during the projection period.

Figure 38. **Installed RE Capacity Projections in BAU by Technology**



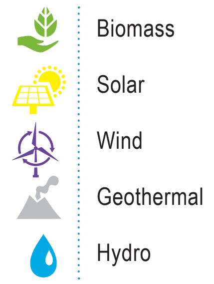
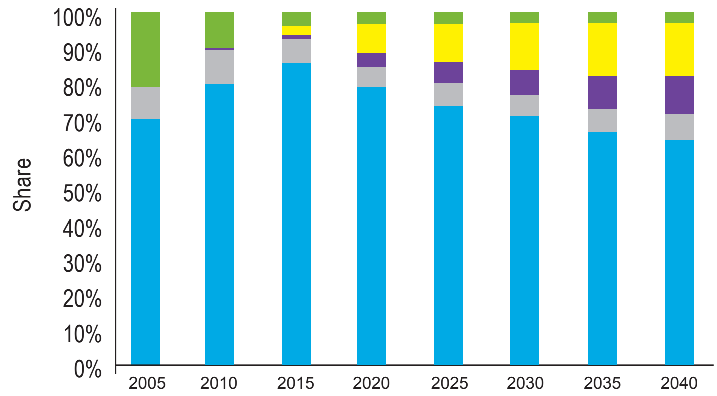


Figure 39. **Installed RE Capacity Projections in BAU by Technology-share**



Wind and solar PV play a minor role in the power supply in 2015. Starting from low initial values, these technologies are projected to experience the highest CAGR by technology by far, with 14.9% for wind and 12.9% for solar PV, respectively. Wind capacity will increase by a factor of 32.2 from 0.6 GW in 2015 to 6 GW in 2025, and up to 20 GW in 2040. Similarly, solar PV is expected to increase its capacity by a factor of 20.8 from 1.3 GW in 2015 to 10 GW in 2025 and to reach 27 GW in total in 2040.

Geothermal is expected to have the fourth highest CAGR of 5.8% between 2015 and 2040 and is thus projected to expand by a factor of 4.0, reaching 6 GW in 2025 and 14 GW in 2040, representing 2.2% of total installed capacity.

Biomass capacities will grow with a CAGR of 4.6% from 1.9 GW in 2015 to 3 GW in 2025 and 5.7 GW in 2040, thus rising in capacity by a factor of 3.4 by 2040 as compared to 2015. However, given the higher installation rates of solar PV and wind, the share of biomass among the installed renewable capacity remains constant at a level of 3% between 2015 and 2040.

Figure 40 illustrates ASEAN power generation by technology in BAU in the timeframe 2005-2040, while **Figure 41** presents the share of each technology.

Coal-based power plants are projected to become the main pillar of the electricity supply in BAU. Their contribution will increase by a factor of 3.4 from 308 TWh in 2015 to 570 TWh in 2025 and further to 1,062 TWh in 2040, growing with a CAGR of 5.1%. The share of coal in electricity generation will rise from 33.3% in 2015 to 40.3% in 2040.

Natural gas-based power plants are projected to produce 497 TWh in 2025 and 772 TWh in 2040, thus increasing by a factor of 2.0 with a CAGR of 2.9%.

Figure 40. **Generation Projections in BAU by Technology**

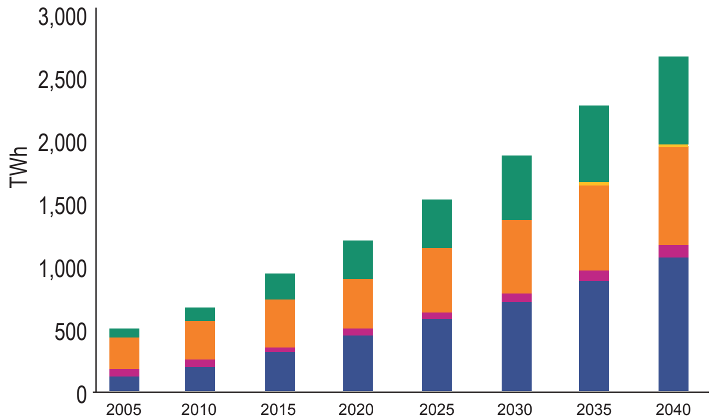


Figure 41. **Generation Projections in BAU by Technology-share**

Renewables
Nuclear
Natural Gas
Oil
Coal

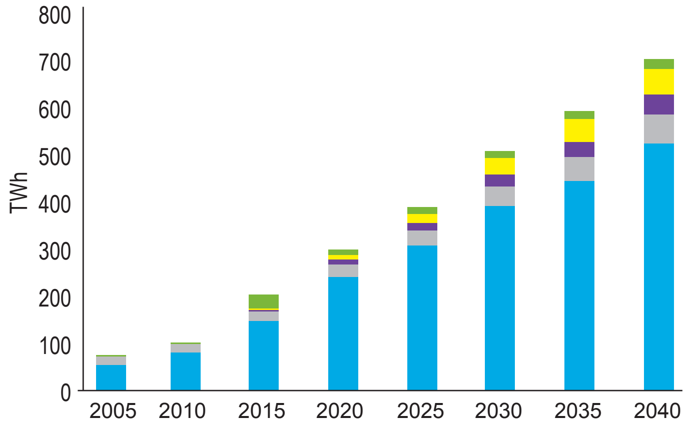
The share of power generated by oil-fired power plants will decrease from 4.0% in 2015 to 3.5% in 2040. However, the electricity production from oil will still increase by a factor of 2.5 from 37 TWh in 2015 to 60 TWh in 2025 and to 92 TWh by 2040, growing with a CAGR of 3.8% during the projection period.

Similar to the installed power capacity, and as previously outlined, the importance of oil and gas for the power supply will constantly reduce, while renewable energies and especially coal are projected to become more important for the electricity mix in BAU. Thus, the share of natural gas in electricity generation is projected to decrease from 41.1% in 2015 to 29.2% in 2040.

Electricity generation based on RE sources is projected to increase by a factor of 3.5 from 201 TWh in 2015 to 386 TWh in 2025, and up to 696 TWh in 2040 (CAGR of 5.1%). In 2040, RE technologies are projected to account for 26.4% of the total ASEAN power generation. In summary, in BAU, the power generation in ASEAN is projected to increase from 927 TWh in 2015 to 1,514 TWh in 2025, and to further increase to 2,638 TWh in 2040.

Figure 42 and **Figure 43** provide further details on the projected power generation by RE technologies.

Figure 42. **Generation Projections in BAU by RE Technology**



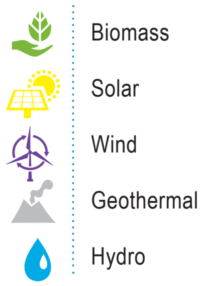
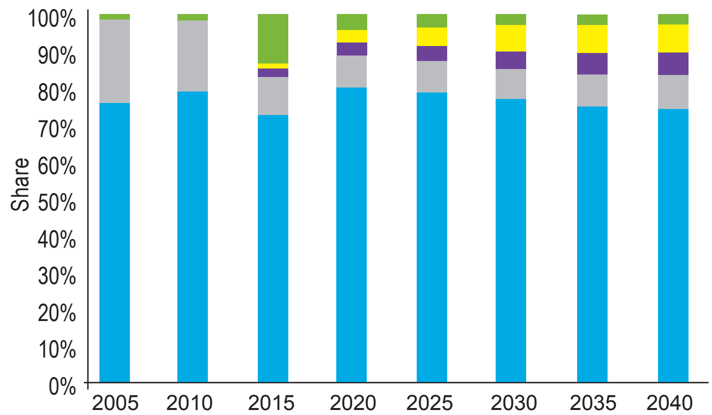


Figure 43. **Generation Projections in BAU by RE Technology-share**



Among RE technologies in the power sector, hydro will clearly remain the major technology. Hydro power-based electricity generation in ASEAN is projected to expand by a factor of 3.6 from 146 TWh in 2015 to 304 TWh in 2025, and to 519 TWh in 2040. Despite the expected increase in the installed capacities of solar PV and wind until 2040, the high and constant running time (capacity factor) of hydro power stations lead to an anticipated CAGR of 5.2% for hydropower-based electricity. As a result, hydroelectric power is expected to maintain a share of 74.5% in overall renewable electricity generation from 2015 until 2040.

Solar PV-based generation is projected to increase by a factor of 16.1 from 3 TWh in 2015 to 19 TWh in 2025, and further to 54 TWh in 2040. Growing by a CAGR of 11.8% over the projection period, it accounts for 7.7% of the RE based electricity generation in 2040.

Wind has the second highest growth among all RE technologies at 10.0% CAGR, and will multiply its electricity generation by a factor of 10.8 from 4 TWh in 2015 to 16 TWh in 2025, and further to 42 TWh in 2040. This implies that, in 2040, wind energy will represent 6.1% of the total renewable electricity generation in ASEAN.

Geothermal electricity generation is projected to grow by a factor of 3.0 from 21 TWh in 2015 to 33 TWh in 2025, and to 62 TWh in 2040. As geothermal electricity production is growing only by a CAGR of 4.4%, its share in RE-based electricity generation is expected to slightly decline in BAU from 10.5% in 2015 to 9.0% in 2040.

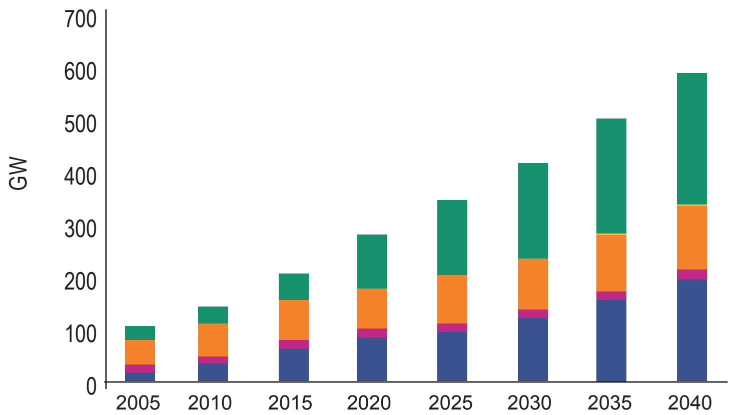
Electricity generated from biomass will reduce marginally by a factor of 0.7 from 27 TWh in 2015 to 19 TWh in 2040 and will only grow slowly by a CAGR of 0.6%.

Credit: HIVOS

ATS. In the power sector, ATS differs from BAU in that it is altered by considering the official nationally issued EE and RE targets in addition to those set in national Power Development Plans (PDP). In ATS, the overall installed capacity is projected to reach 588 GW in 2040, lower than in BAU.

Figure 44 and **Figure 45** present the installed capacity in ATS in the timeframe 2005-2040, in absolute value and share.

Figure 44. **Installed Capacity Projections in ATS by Technology**



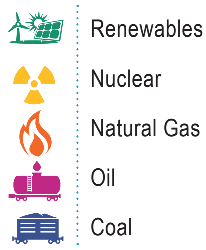
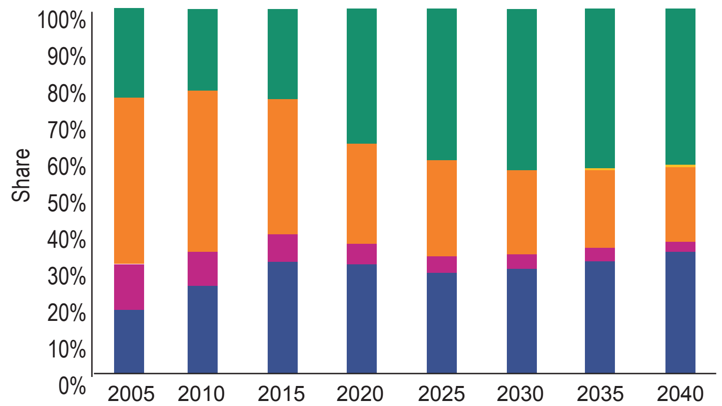


Figure 45. **Installed Capacity Projections in ATS by Technology-share**



Coal-fired power plants are projected to experience a considerable yearly growth rate of 4.6% between 2015 and 2040 and are thus projected to grow by a factor of 3.1 from 63 GW in 2015 to 95 GW in 2025, and to 196 GW in 2040.

While natural gas comprises the largest installed capacity in 2015 with a share of 37.3%, coal power plants are projected to surpass the installed capacity of natural gas in 2025.

Capacity from natural gas is projected to increase by a factor of 1.6 in the timeframe 2015-2040, from 77 GW in 2015 to 91 GW in 2025, and up to 121 GW in 2040, thereby exhibiting a CAGR of 1.9%.

Oil-fired power plants will remain much in the same range as for 2015, increasing with a moderate CAGR of 0.2%, thus showing an overall stagnation from 16 GW in 2015 to 16 GW in 2040. This illustrates the declining importance of oil for the power sector in ATS.

In view of the impacts of the RE targets in ATS, RE is projected to experience a substantial increase, growing with a CAGR of 6.7% and thus multiplying installed RE capacity by a factor of 5.1 from 50 GW in 2015 to 142 GW in 2025, and to 252 GW in 2040. Total RE will then comprise the largest share of installed power capacity in ASEAN, representing 42.8% of the total installed capacity in 2040 (from 24.3% in 2015). RE technologies are followed by coal with 33.3% and natural gas with 20.6% in 2040. Oil shares will have a marginal contribution with 2.8% of total installed capacity by 2040. Detail on RE is illustrated in **Figure 46** and **Figure 47**.

Figure 46. **Installed RE Capacity Projections in ATS by Technology**

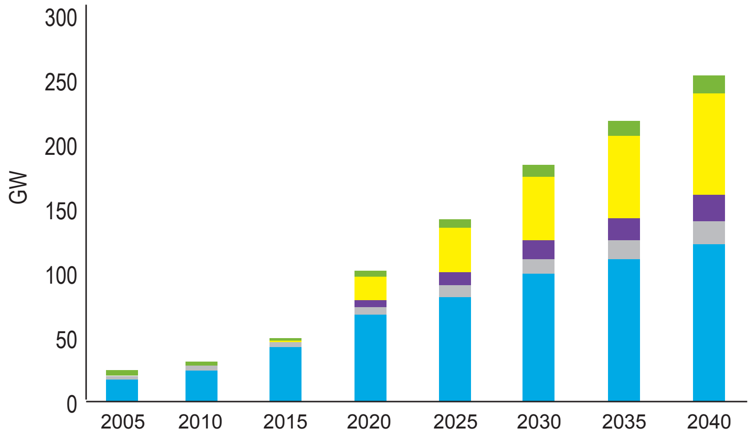
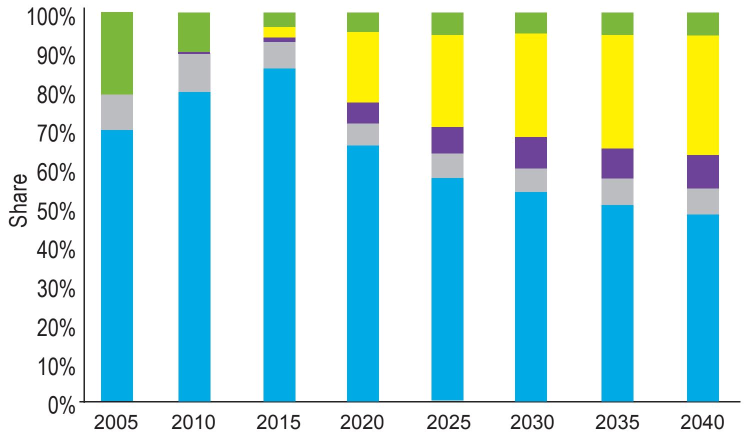
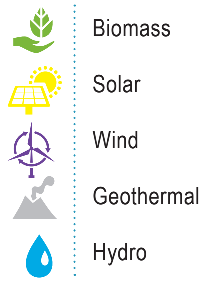


Figure 47. **Installed RE Capacity Projections in ATS by Technology-share**





Similar to BAU, hydro is projected to remain the dominant renewable technology, expanding installed capacity by a factor of 2.8 from 43 GW in 2015 to 121 GW in 2040, growing by a CAGR of 4.3%. The growth rate of hydro is the lowest among the renewable technologies, meaning that the share of hydro among installed renewable capacity will be reduced to one half of its initial value, from 85.7% in 2015 to 48.3% in 2040.

Geothermal will experience a similar increase as compared to BAU. It will grow with a CAGR of 7.0% and increase by a factor of 5.4 during the projection period. Starting from 3 GW in 2015, the installed geothermal capacity will grow to 9 GW in 2025 and double from 2025 to 2040 to reach 18 GW in 2040. The share of geothermal capacity in ATS is projected to remain small and approximately constant with a value of 7.0% during the projection period.

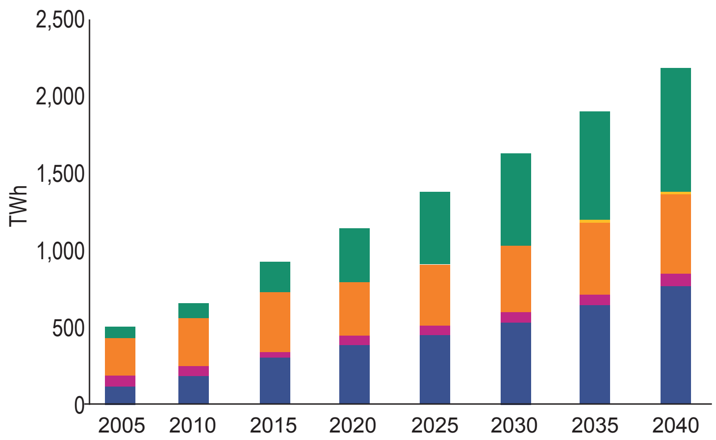
Biomass is projected to experience a high growth of about 8.4% annually and thus expand its capacity from 2 GW in 2015 to 14 GW in 2040, growing by a factor of 8.4. Starting from a low value in 2015, biomass capacity is expected to represent 5.6% of the total renewable installed capacity in 2040.

Solar PV is projected to be the second largest RE technology installed in ASEAN power systems, with 78 GW in 2040. Starting from a value of 1.3 GW in 2015, it expands its capacity by a factor of 59.5. Due to an impressive CAGR of 17.8%, solar PV will increase its share from 2.6% of total installed renewable capacity in 2015 to 23.9% in 2025, increasing further to 30.8% in 2040.

The second highest CAGR of 15.1% in the installed renewable capacities in ATS is projected for wind energy, which will grow by a factor of 33.5 from 0.6 GW in 2015 to 10 GW in 2025 and 21 GW in 2040. Thereby, wind will become the third largest RE source in the ASEAN power system, representing 8.1% of total capacity in 2040.

Power generation is illustrated in **Figure 48** and **Figure 49**, where a shift from the formerly dominant natural gas to coal and renewable energies is evident. The overall power generation is projected to increase by a factor of 2.3 from 927 TWh in 2015 to 1,373 TWh in 2025, and to 2,166 TWh in 2040. This represents a difference of 472 TWh regarding the overall generation compared to BAU and underlines the efforts undertaken in the field of EE

Figure 48. **Generation Projections in ATS by Technology**



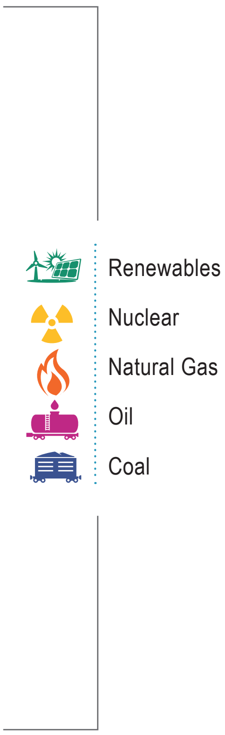
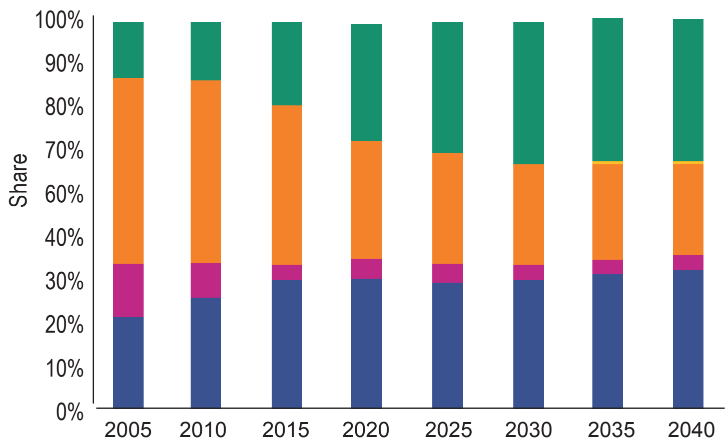


Figure 49. **Generation Projections in ATS by Technology-share**



Concomitant with developments in the installed power capacity, electricity generation from natural gas will increase by a factor of 1.3 from 381 TWh in 2015 to 507 TWh in 2040. While still growing by a CAGR of 1.1%, the share of natural gas in the power generation mix will reduce from 41.1% in 2015 to 23.4% in 2040.

Power generated from coal is projected to grow by a factor of 2.5 from 308 TWh in 2015 to 451 TWh in 2025, and to further increase to 777 TWh in 2040. Expanding by a CAGR of 3.8%, the share of coal in the power mix will grow from 33.3% in 2015 to 35.9% in 2040.

In ATS, RE will become the largest power source in 2025 with an overall generation of 463 TWh, which will further increase to 790 TWh in 2040 (36.5% of total generation). Altogether, renewable technologies are projected to expand by a factor of 3.9, exhibiting a high CAGR of 5.6% until 2040. This demonstrates a clear shift from natural gas towards RE, while coal maintains its important role in the power sector.

The landscape of the different RE sources is illustrated in **Figure 50** and **Figure 51**. Hydro is projected to remain dominant in ATS producing 146 TWh in 2015, 265 TWh in 2025, and up to 380 TWh in 2040. While hydro will rise by a factor of 2.6, reflecting a CAGR of 3.9% during the projection period, its share is still projected to decrease from 76% in 2015 to 48% in 2040, due to higher growth rates of other RE technologies.

Figure 50. **Generation Projections in ATS by RE Technology**

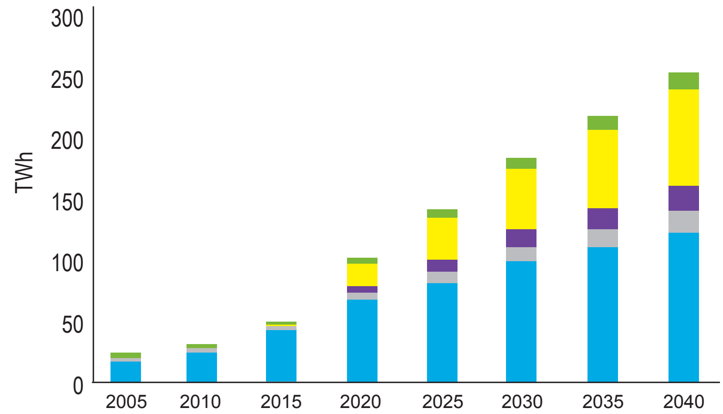
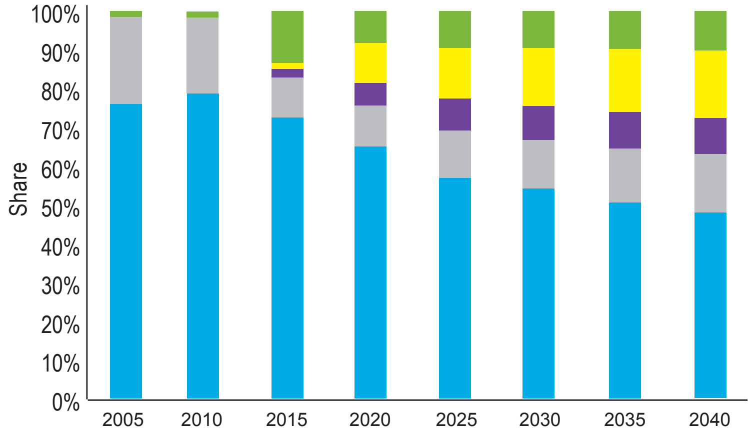
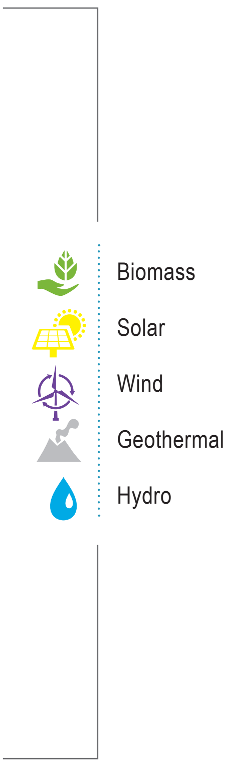


Figure 51. **Generation Projections in ATS by RE Technology-share**





In 2015, solar PV accounted for only 3 TWh electric power generation but it is projected to grow strongly by a CAGR of 16.0% until 2040. The projections indicate that it will contribute 61 TWh in 2025 and 137 TWh in 2040, which implies growth by a factor of 40.5 compared to the 2015 level. The share of PV in total renewable power produced is projected to be the second highest after hydro with 17.4% in 2040. Although the installed capacity of solar PV is between four and five times that of wind, geothermal or biomass, the power output is less than twice as high as the output of these technologies. This can be explained by the low capacity factor of solar PV. Geothermal and biomass are more suitable technologies to provide baseload power.

Geothermal electricity generation is projected to multiply by a factor of 5.7 from 21 TWh in 2015 to 119 TWh in 2040. Growing by a CAGR of 7.2% it will become the third largest renewable technology with a share of 15.1% in the total renewable generation.

Power generation from wind energy and biomass is projected to increase from 4 TWh and 27 TWh in 2015 to 74 TWh and 79 TWh, respectively, in 2040. Consequently, wind energy will represent 9.4% and biomass 10.0% of the total renewable power generation in 2040. For both technologies, high CAGR of 12.5% and 4.5% are achieved, corresponding to an overall increase in power generation by factors of 18.9 and 3.0, respectively.

APS. The long-term projection of APS is based on figures contained in analysis presented in the 2016 report *Renewable Energy Outlook for ASEAN: a REmap Analysis* (IRENA & ACE, 2016), while the exact path of the development of each technology in each country follows the electricity demand as projected in *AEO5*. Due to inherent differences (resulting from differing framework parameters and methodology) between the electricity demand projections between *AEO5* and *ASEAN REmap*, the development of installed capacities in *AEO5* does not exactly correspond to the *REmap* publication. The total installed power capacity is projected to grow from 205 GW in 2015 to 349 GW in 2025, and to 580 GW in 2040.

Credit: ACE

Figure 52 shows the development of the installed power capacity by technology for ASEAN during the period 2005-2040, while **Figure 53** illustrates the shares by technology in the same period.

Figure 52. **Installed Capacity Projections in APS by Technology**

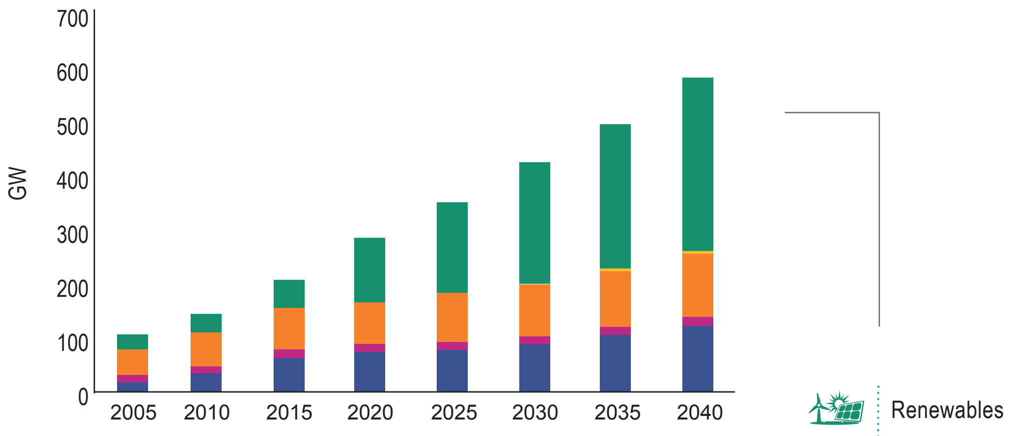
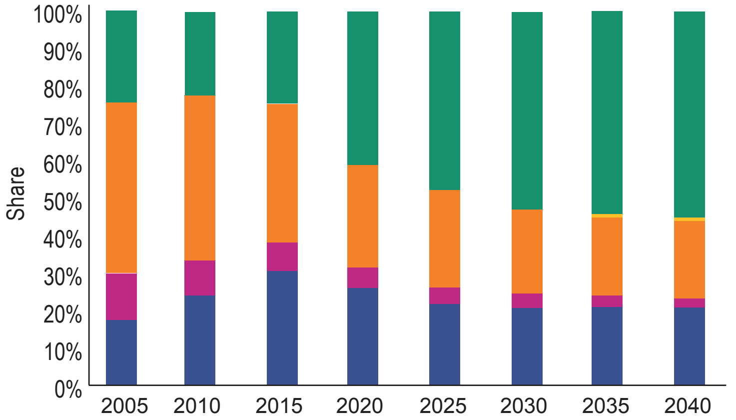


Figure 53. **Installed Capacity Projections in APS by Technology-share**



Installed capacity from coal increases by a factor of 2.0 from 63 GW in 2015 to 78 GW in 2025, and to 124 GW in 2040. This growth reflects a CAGR of 2.7%.

Natural gas installed capacity will grow with a CAGR of 1.7%, increasing its value by a factor of 1.5 from 77 GW in 2015 to 91 GW in 2025, and up to 118 GW in 2040.

The capacity of oil plants is projected to decrease by a yearly rate of -0.33% from 16 GW in 2015 to 15 GW in 2040, leading to a decrease of 5% as compared to the 2015 value.

In contrast, RE will increase considerably by a factor of 6.4 between 2015 and 2040. Having a total installed capacity of 50 GW in 2015, RE capacity will increase to 166 GW in 2025 and even further to 320 GW in 2040, projected with a CAGR of 7.7%. Details of RE are illustrated in **Figure 54** and **Figure 55**.

Figure 54. **Installed Capacity Projections in APS by RE Technology**

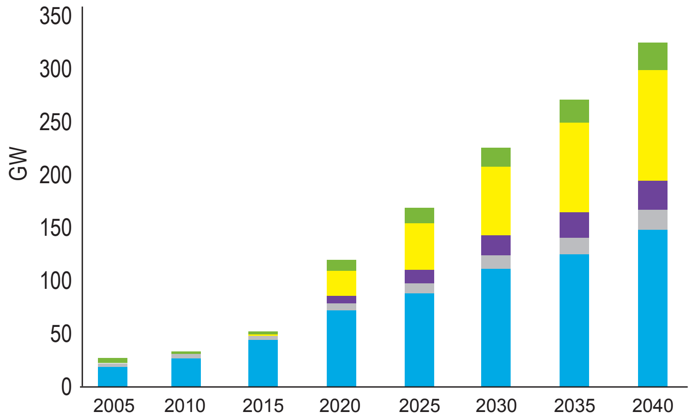
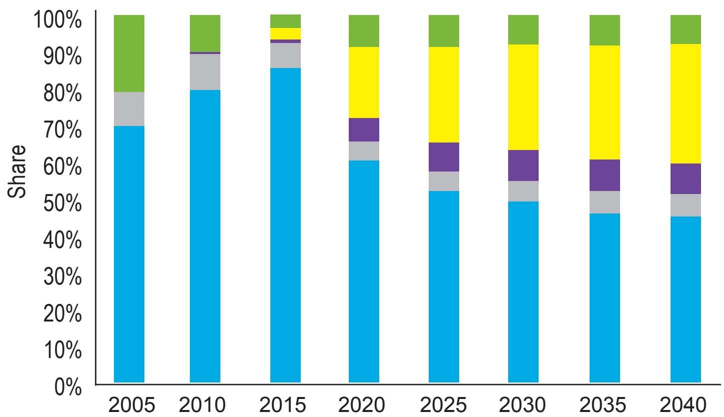
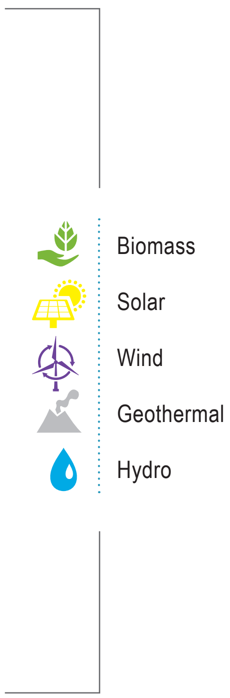


Figure 55. **Installed Capacity Projections in APS by RE Technology-share**





Starting with a low value of total installed capacity, solar PV is projected to experience the highest growth with a CAGR of 19.1% and thus growing by a factor of 78.7, from 1.3 GW in 2015 to 43 GW in 2025, and further to 103 GW in 2040.

Solar PV is followed by wind and biomass, which are projected to grow between 2015 and 2040 with CAGR of 16.4% and 11.1%, respectively. Wind will increase its capacity by a factor of 44.5 from 2015 to 2040, from 0.6 GW in 2015 to 13 GW in 2025, and to 27 GW in 2040. Biomass is projected to grow by a factor of 13.8 from 2 GW in 2015 to 15 GW in 2025, and further to 26 GW in 2040.

Hydro will grow with a CAGR of 5.0% and expand its capacity by a factor of 3.4 from 43 GW in 2015 to 87 GW in 2025, and further to 145 GW in 2040. Hydro is therefore projected to remain the largest renewable technology,

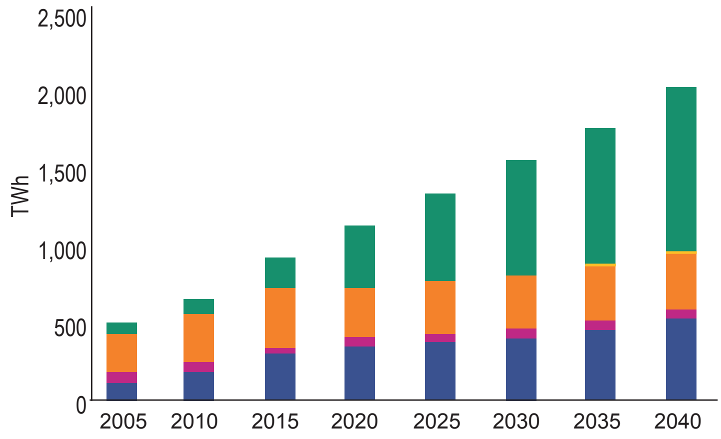
representing 45.2% of total renewable installed capacity in 2040. Solar PV will represent a 32.1% share in 2040, reflecting a still higher growth rate during the projection period.

Wind and biomass are projected to increase their shares from 1.2% and 3.7% in 2015 to 8.5% and 8.0% in 2040, respectively. In terms of installed capacity, geothermal will be the least installed renewable technology in APS in 2040, representing 6.1% compared to 6.7% in 2015.

Figure 56 and **Figure 57** show the power generation from fossil fuels as well as RE during the projection period until 2040 in TWh and its shares.

Power generation from oil-fired power plants is expected to grow by a moderate CAGR of 2.3% which implies an expansion by a factor of 1.7 from 37 TWh in 2015 to 64 TWh in 2040. The share of oil based generation is projected to decrease from 4.0% in 2015 to 3.1% to 2040.

Figure 56. **Generation Projections in APS by Technology**



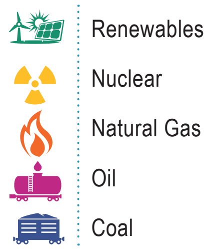
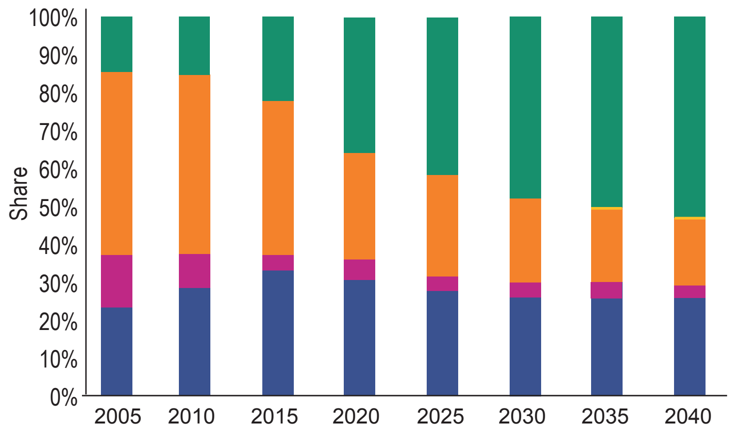


Figure 57. **Generation Projections in APS by Technology-share**

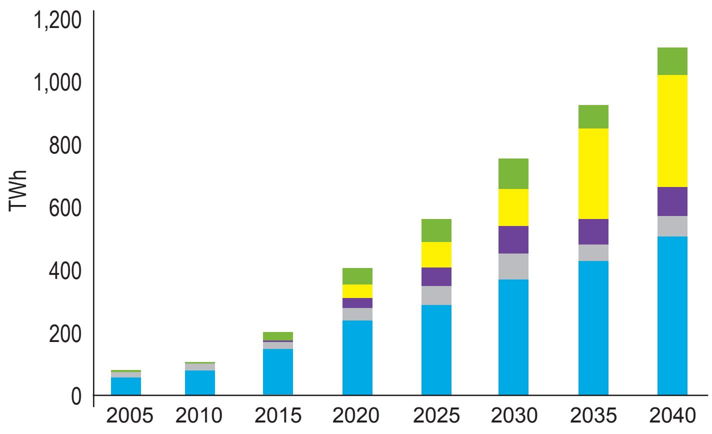


Natural gas-based power generation is projected to decrease, with a CAGR of 0.2% until 2040. However, as total electricity generation increases massively over the projection period, and the volume of power generated from natural gas remains constant, its share is projected to drop from 41.1% in 2015 to 26.1% in 2025, and to 17.8% in 2040.

Coal-based power generation is expected to increase by a factor of 1.7 from 308 TWh in 2015 to 373 TWh in 2025, and further to 527 TWh in 2040. Growing by a CAGR of 2.2%, it is projected to be the second largest power source behind RE with a share of 25.8% in 2040.

Power generation by renewable energies, consisting of hydro, solar PV, wind, biomass and geothermal energy, is projected to increase by a factor of 5.3 from 201 TWh in 2015 to 558 TWh in 2025, and to 1,060 TWh in 2040, which corresponds to a CAGR of 6.9%. Details on RE are illustrated in **Figure 58** and **Figure 59**.

Figure 58. **Generation Projections in APS by RE Technology**



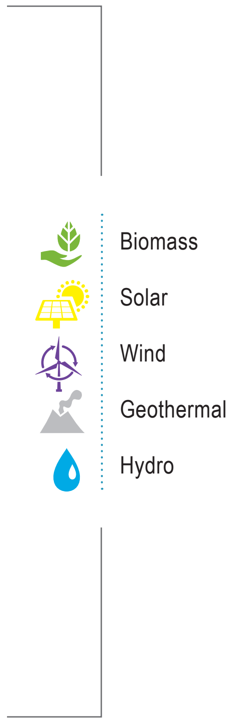
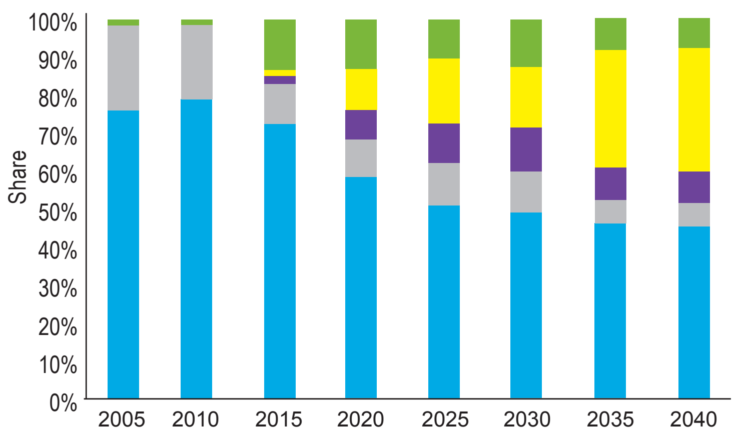


Figure 59. **Generation Projections in APS by RE Technology-share**



Hydro-based generation is projected to increase by a factor of 3.4 from 146 TWh in 2015 to nearly 500 TWh in 2040, which corresponds to growth reflecting a CAGR of 5.0%. However, the importance of hydro among the RE will decrease, with the share of hydroelectric generation declining from 72.6% in 2015 to 46.7% in 2040. Nevertheless, hydro will remain the major pillar with regard to RE generation in APS.

Geothermal energy and biomass-based electricity generation will grow by CAGR of 7.5% and 6.6%, respectively.

Expanding by a factor of 6.1 and 4.9, respectively, both technologies will reach generation volumes of 130 TWh in 2040. Both geothermal energy and biomass will increase their shares in total renewable power generation to 12.2% in 2040.

Power generation by wind energy will increase by a factor of 28.9 from 4 TWh in 2015 to 113 TWh in 2040. Although growing with the second highest CAGR of 14.4%, wind power is projected to contribute least, compared to the other RE technologies. In 2040, it is expected to reach a share of 10.7% in 2040, while its share was only 2.0% in 2015.

Power generation from solar PV is projected to increase by the highest CAGR of all RE technologies, namely 17.6% between 2015 and 2040. Accordingly, solar power will increase by a factor of 57.6 reaching 192 TWh in 2040, starting from 3 TWh in 2015. Similar to ATS, solar PV will be the second biggest renewable power source after hydro, with an increase in share from 1.7% in 2015 to 18.1% in 2040.

Comparison of Scenarios. Comparing the three projections in installed capacity – BAU, ATS and APS – the change in paradigms between the scenarios becomes clear. To better illustrate the long-term differences of each scenario, **Figure 60** presents total installed capacity of non-RE technologies and **Figure 61** presents total installed capacity of RE technologies to 2040 for BAU, ATS and APS.

Figure 60. **Total Capacity All Scenarios by Non-RE**

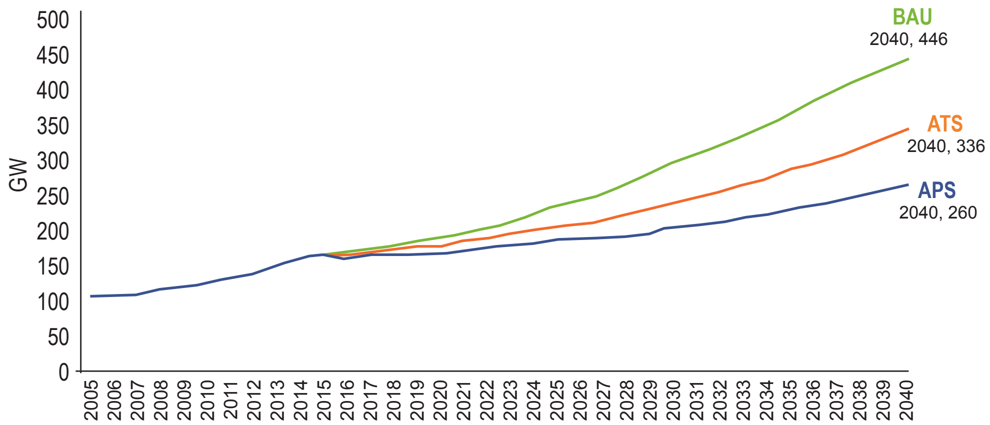
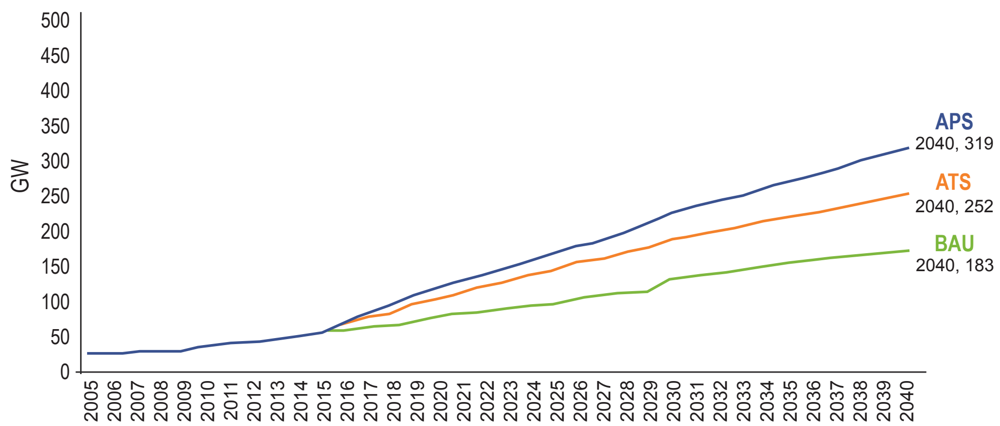


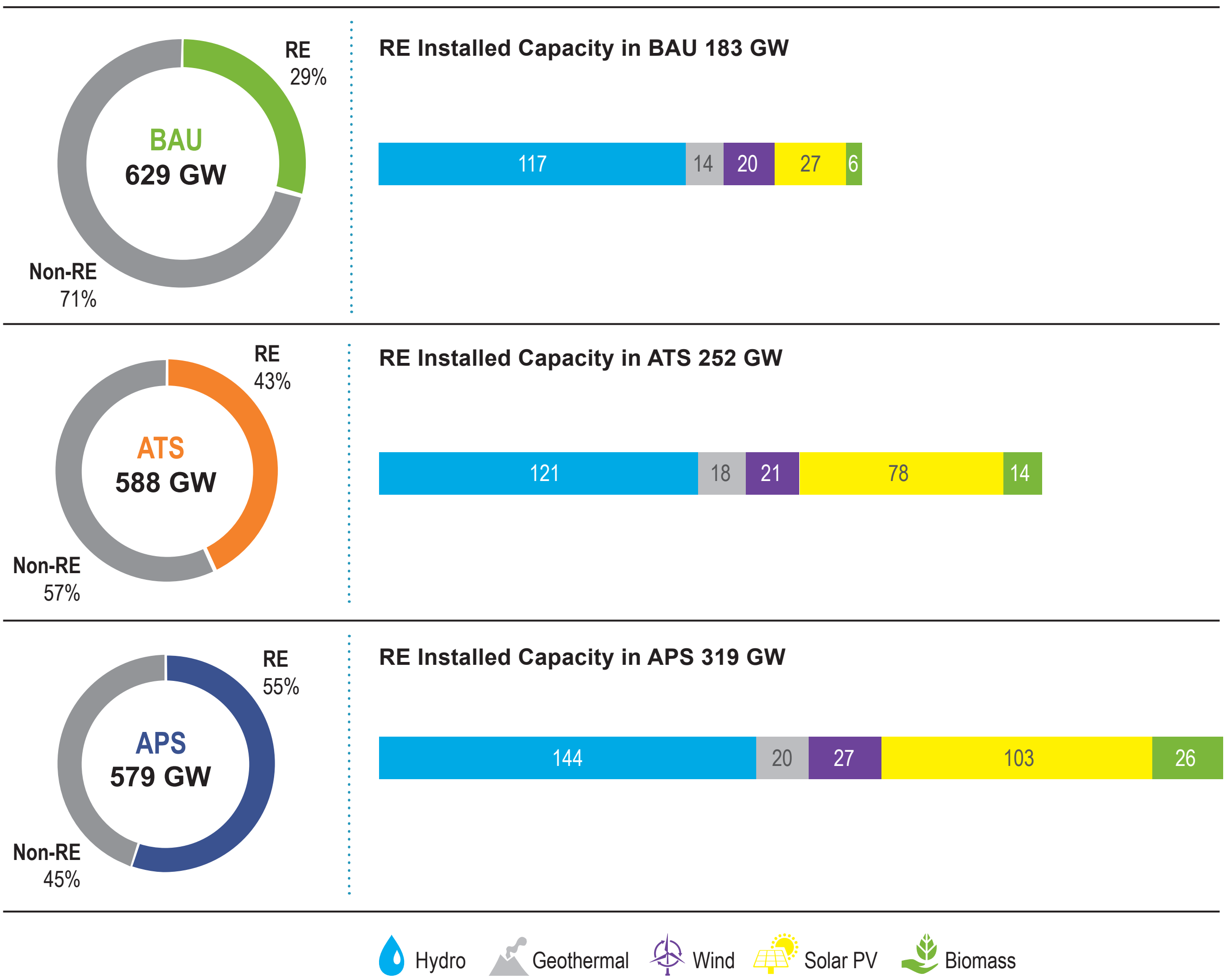
Figure 61. **Total Capacity All Scenarios by RE**



Detailed composition of capacity, particularly with the breakdown on RE is illustrated in **Figure 62**. In BAU, total installed capacity in 2040 is projected at 629 GW, of which RE comprise a share of 29% and conventional fossil fuels 71%. Hydro represents almost 64% of installed RE technology, followed by 15% solar PV, 11% wind, 7% geothermal and 3% biomass. In ATS, total installed capacity in 2040 is projected to be 588 GW, with a 43% share of RE and a 57% share of conventional fossil fuels. Total installed power capacity from RE will be 252 GW, of which hydro represents roughly one half (48%) and solar PV one third (31%). Wind, geothermal and biomass will comprise shares of 8%, 7% and 6%, respectively. In APS, total installed capacity in 2040 is the lowest (579 GW), but it shows the highest share of RE technologies (55%) by far. The total installed RE capacity will thus rise to 319 GW and will have the most diverse capacity mix among the renewable technologies. Hydro will represent 45%, followed by solar PV with 32%, wind (9%), biomass (8%) and geothermal (6%).

Therefore, APS represents the most ambitious scenario regarding the transition towards implementing low-carbon technologies in the power sector.

Figure 62. **Capacity Composition 2040 All Scenarios**



Taking power generation into account, a comparison of the scenarios is illustrated in **Figure 63** for total generation by non-RE and **Figure 64** for total generation by RE.

Figure 63. **Total Generation All Scenarios by Non-RE**

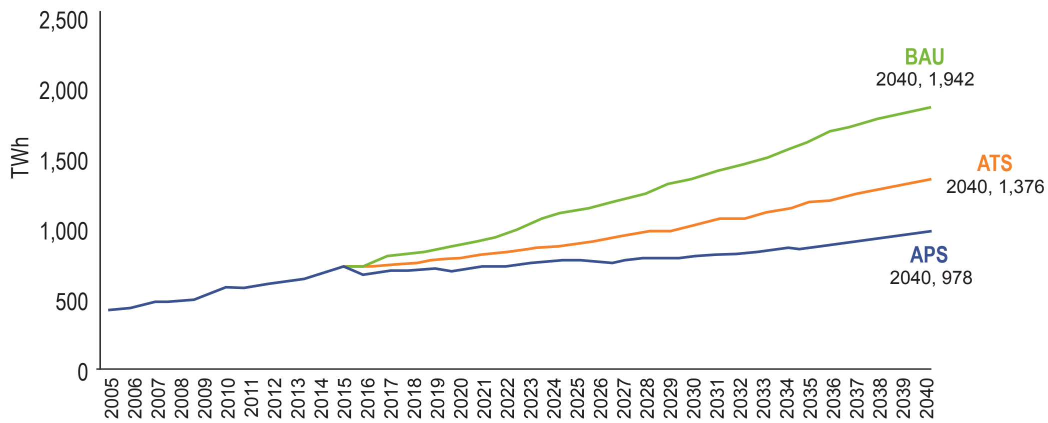
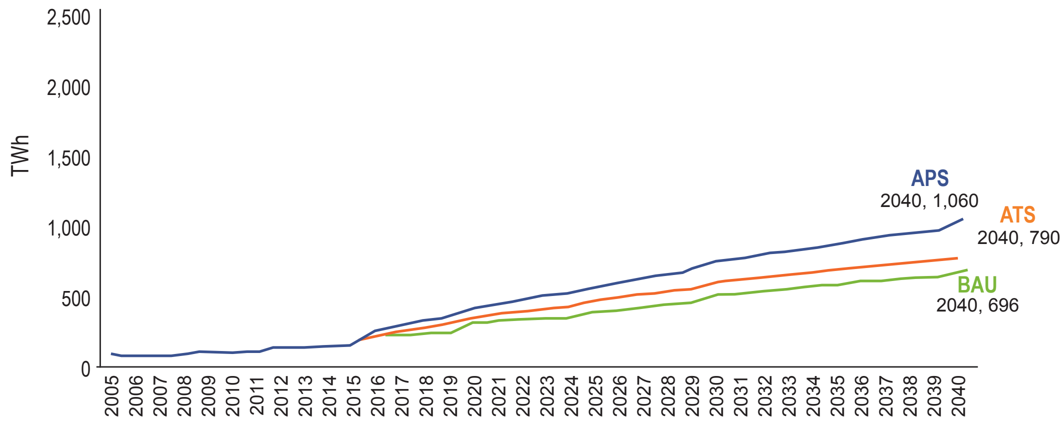
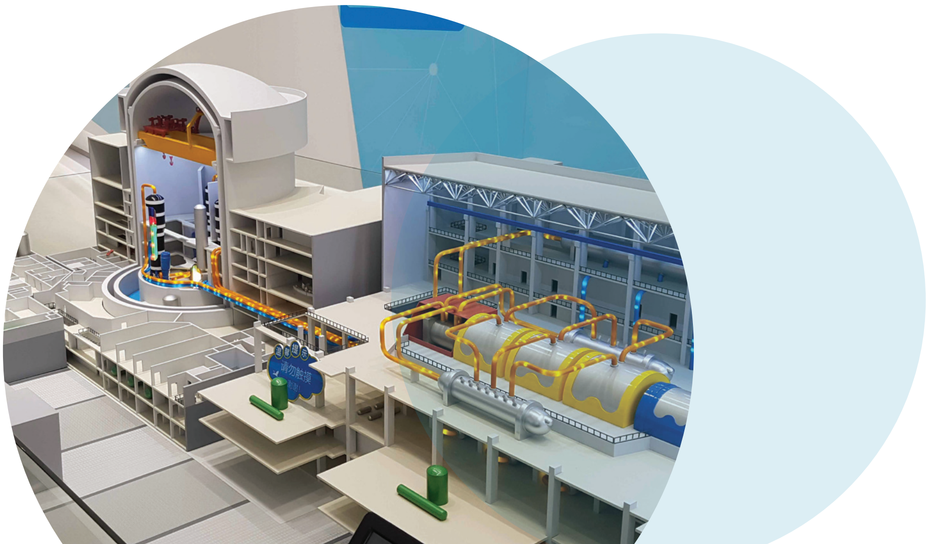


Figure 64. **Total Generation All Scenarios by RE**



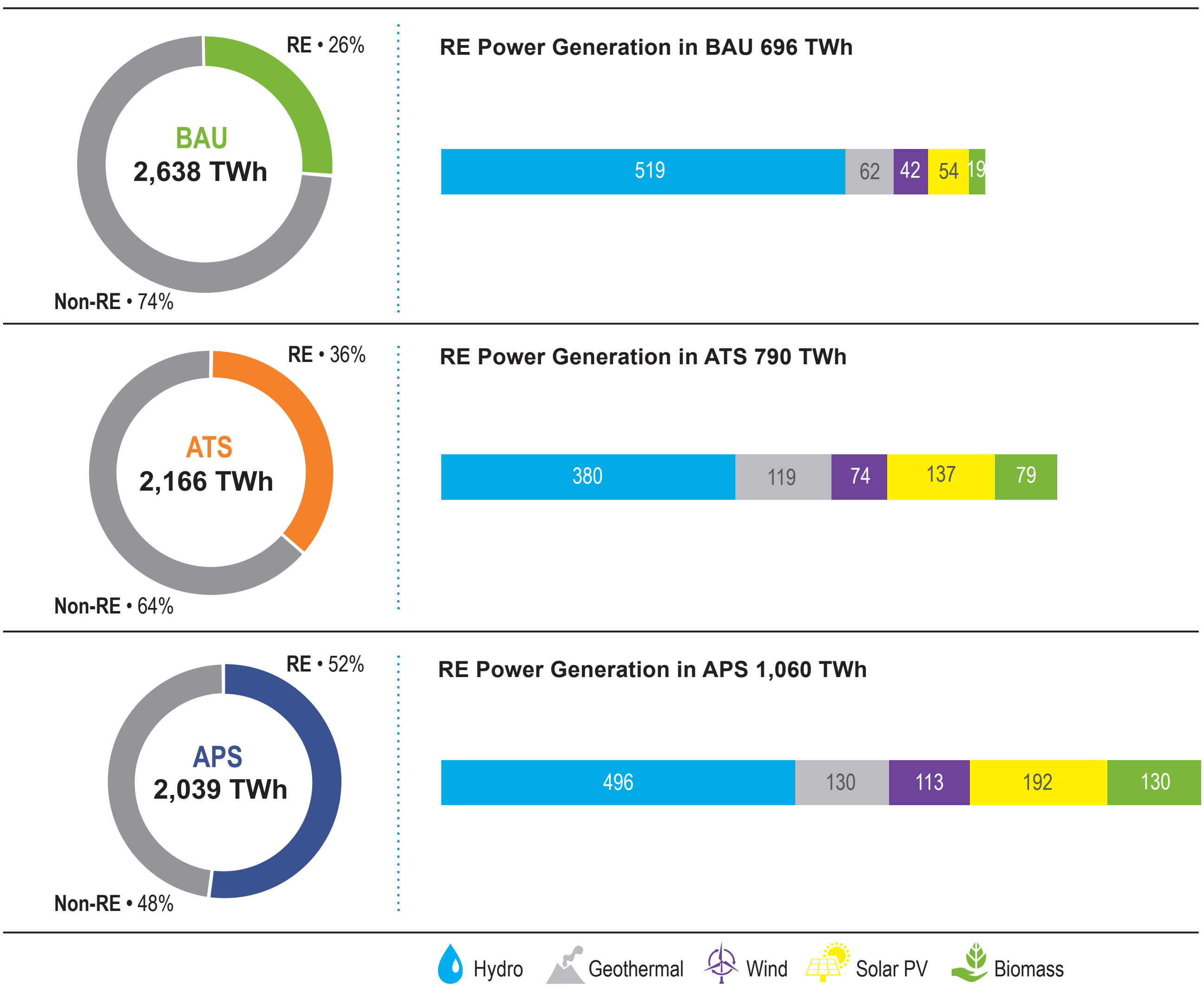


Credit: ACE

Furthermore, the detailed composition of power generation, particularly considering the breakdown of RE is illustrated in **Figure 65**. In BAU, the total projected power generation is about 2,638 TWh in 2040, with RE comprising a share of 26% and conventional power a share of 74%. The power-mix in RE is not projected to change significantly as compared to 2015. Hydro will keep a dominant role among RE with a 75% share of capacity. It will be followed by geothermal with 9%, solar PV (8%), wind (6%) and biomass (3%). In view of the EE targets reached in ATS, a significantly lower total power generation is required in APS (2,166 TWh) while the implementation of national targets on RE will lead to a higher power generation from RE (790 TWh), representing a higher share (36.5%) of total generation.

Among RE, hydro maintains the dominant share with 48% of total generation, followed by solar PV (17%), geothermal (15%), biomass (10%) and wind (9%). As for APS, total electricity output is further lowered to 2,039 TWh whereas the power generation from RE reaches 1060 TWh, representing 52% of total generation. While hydro maintains the dominant share with 47%, solar PV represents 18% followed by geothermal and biomass (12% each) and wind (11%). In conclusion, BAU has the highest projected power generation in total, and from fossil fuels. In contrast, while in ATS the total power generation is lowered and shows a shift from natural gas to coal and RE, APS reflects a strong transition towards low carbon power generation backed by a high RE share.

Figure 65. **Generation Composition 2040 All Scenarios**



Furthermore, BAU represents a switch from the currently dominant technology to coal. Reaching the national EE and RE targets in ATS depicts a power mix which is more evenly distributed between fossil fuels and RE technologies. In contrast, APS represents a shift away from fossil fuels with a strong commitment towards RE. Table 6 provides an overview of the installed renewable capacity by country in 2040 in the BAU, ATS and APS scenarios, as well as presenting the distribution of renewable technologies in each country.

Table 6. AMS RE Figures in 2040 All Scenarios

AMS	Target Description
Brunei Darussalam	• BAU: 0.02 GW (2% of total capacity) of RE consisting of 53% solar and 47% biomass. • ATS: 0.2 GW (17% of total capacity of GW) of RE consisting of 95% solar and 5% biomass. • APS: 0.5 GW of RE consisting of 88% solar, 9% wind, 2% biomass.
Cambodia	• BAU: 3.7 GW (56% of total capacity of 6.8 GW) of RE consisting of 99% hydro and 1% biomass. • ATS: 4 GW (62% of total capacity of 6 GW) of RE consisting of 99% of Hydro and 1% biomass. • APS: 6 GW of RE consisting of 71% hydro, 22% solar, 6% wind, 1% biomass.
Indonesia	• BAU: 63 GW (23% of total capacity of 273 GW) of RE consisting of 40% hydro, 12% geothermal, 17% wind, 28% solar, 3% biomass. • ATS: 100 GW of RE consisting of 33% hydro, 12% geothermal, 5% wind, 51% solar. • APS: 109 GW of RE consisting of 30% hydro, 11% geothermal, 8% biomass, 47% solar, 4% wind.
Lao PDR	• BAU: 29 GW (82% of total capacity of 37 GW) of RE consisting of 80% hydro and 15% wind. • ATS: 29 GW of RE consisting of 84% Hydro, 12% wind, 6% solar. • APS: 33 GW of RE consisting of 79% hydro and the remainder solar.
Malaysia	• BAU: 8 GW (18% of total capacity of 47GW) RE consisting of 85% hydro, 3% solar, 11% biomass. • ATS: 11 GW of RE consisting of 68% hydro, 15% solar, 16% biomass. • APS: 26 GW of RE consisting of 49% hydro, 7% biomass, 43% solar, no wind, 0.9% geothermal.
Myanmar	• BAU: 4.8 GW (80% of total capacity of 6 GW) of RE consisting of 100% hydro. • ATS: 24 GW of RE consisting of 83% hydro, 12% solar, 4% wind. • APS: 24 GW of RE consisting of 83% hydro, 13% solar, 4% wind.
Philippines	• BAU: 19 GW (29% of total capacity of 67 GW) of RE consisting of 57% hydro, 29% geothermal, 7% wind, 4% solar, 4% biomass. • ATS: 18 GW of RE consisting of 42% hydro, 31% geothermal, 20% wind, 3% solar, 4% biomass. • APS: 23 GW of RE consisting of 31% geothermal, 26% solar, 27% hydro, 8% wind, 8% biomass.
Singapore	• BAU: 0.3 GW (6% of total capacity of 14 GW) of RE consisting of 80% biomass and 20% solar. • ATS: 0.3 GW of RE consisting of 80% biomass and 20% solar. • APS: 5 GW of RE consisting of 81% solar, 10% wind, 9% biomass.
Thailand	• BAU: 19 GW (20% of total capacity of 96 GW) of RE consisting of 85% hydro, 4% wind, 10% solar, 1% biomass. • ATS: 23 GW of RE consisting of 36% hydro, 13% wind, 27% solar, 25% biomass. • APS: 29 GW of RE consisting of 38% solar, 25% biomass, 26% hydro, 11% wind.
Vietnam	• BAU: 33 GW (41% of total capacity of 83GW) of RE consisting of 75% hydro, 7% wind, 15% solar, 4% biomass. • ATS: 46 GW of RE consisting of 50% hydro, 13% wind, 31% solar, 7% biomass. • APS: 64 GW of RE with 52% hydro, 25% solar, 18% wind, 5% biomass.
ASEAN	• BAU: 183 GW of RE (29% of total 629 GW), consisting of 64% hydro, 7% geothermal, 11% Wind, 15% solar, 3% biomass. The share variable RE in total installed capacity is 7%. • ATS: 252 GW of RE (43% of total 588 GW) consisting of 48% hydro, 7% geothermal, 8% wind, 31% solar, 6% biomass. The share of variable RE in total installed capacity is 17%. • APS: 320 GW of RE (55% of total 580 GW) consisting of 45% hydro, 6% geothermal, 9% wind, 32% solar, 8% biomass. The share of variable RE in total installed capacity is 22%.


Credit: ACE

Chapter 3
APAEC Targets

APAEC Targets

This chapter analyses the energy indicators from the three scenarios and examines their development against the APAEC targets, namely:

- Energy Efficiency and Conservation: to achieve the aspirational target of reducing EI by 20% by 2020 in the medium-term, and 30% by 2025 in the long-term based on 2005 levels.
- Renewable Energy: to achieve the aspirational target of increasing the RE component to 23% by 2025 in TPES.

HIGHLIGHTS

- *This projection shows that ASEAN is well on track to reach EI target. In particular, the medium-term (2020) component of the target is reached in all scenarios, exceeding the target by 5% in BAU, 8% in ATS and 9% in APS. In the long-term (2025) component , the energy intensity is reduced by 29% in 2025 in BAU, thereby missing the target with a gap of 1%. However, it exceeds by 5% and 8% in ATS and APS, respectively.*

- *Reaching the RE target will require stronger efforts than currently foreseen by AMS. In the BAU scenario, ASEAN will reach only 12.6% of RE in TPES by 2025. In the ATS scenario, a share of 17.5% is projected to be achieved. Thus, more ambitious national targets in EE and RE than currently issued are required. The APS scenario is conceived to reach the 23% share by 2025 and thus provides a possible path that could be followed by AMS to reach the APAEC RE targets.*

- *Both the EI and the RE target components of APAEC 2016-2025 are complementary. Thus, reaching the RE target component is facilitated if TPES is reduced by fostering EE. In view of ASEAN being well on track to reach the EI target component, ASEAN could consider tightening the EI target to further reduce TPES which could contribute to achieving the RE target.*

3.1 ENERGY INTENSITY TARGET

Energy intensity (EI) is a measure of the energy efficiency (EE) performance of an economy. It is calculated as units of energy use per unit of GDP. In practice, two options are commonly used to calculate EI: (1) Total Primary Energy Supply per Gross Domestic Product (TPES/GDP), to see the energy saving trend for the country, commonly known as primary EI and (2) Total Final Energy Consumption per Gross Domestic Product (TFEC/GDP), which is commonly known as final EI, to see energy saving trend by sector.

EI has been used to compare energy use across different industries, as well as to understand how energy consumption changes as a country develops its industries and economy. A country whose economy is based on banking and trading will use less energy per unit of GDP than one whose economy is based on steel making and ore processing. By taking the structure of the economy into account, energy intensities can monitor changes in EE, which in turn may be linked to changes in technologies, fuel mix and consumer preferences or behaviour.

Selecting which intensity depends on how one defines “energy use”. It can refer to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport (TPES). It can also refer to use of energy by end-users, after transformation from one form to another (end-use fuels), and excluding transport to customers, own-use and losses (TFEC).

Thus, primary EI is an economy-wide EI because it accounts for the entire economy of the country. It is an aggregation of the intensity of the four-major energy consuming end-use sectors (transport, industry, residential buildings, and commercial buildings) and the electricity producing sector.
Final EI is a sector EI because it is calculated at the end-use level. It corresponds to the energy consumed per unit of GDP by final consumers for energy using applications. The final EI accounts for only the EE improvements at the final consumer level. It excludes EE improvements during energy conversion particularly in the power sector. Usually final EI decreases less than the primary EI.

There is also a discussion as to whether the GDP of individual AMS are converted to a common currency using market exchange rates or purchasing power parity (PPP).

This can dramatically change EI improvement calculations. The PPP approach converts currencies at a rate based on how much they buy compared to a US dollar, rather than the rate that would be offered at a bank. It could be argued that, for purposes of calculating energy intensities, PPP is the more appropriate method for converting currencies. PPP is superior for calculating energy intensities because an economy’s energy use should be fundamentally related to how much its GDP will buy, rather than how much it would be worth if it were converted to US dollars at a bank. Market exchange rates can be subject to dramatic fluctuations, which could cause energy intensities to fluctuate dramatically if GDP were valued at market exchange rates, even if the way the economy uses energy has not changed. Market exchange rates also tend to assign lower values to the GDPs of fast-growing economies. EI improvement for a grouping of countries will typically be much larger if calculated using PPP than if calculated using market exchange rates. It is therefore appropriate to use PPP because of its relative stability, and because it is the actual purchasing power of GDP that drives an economy’s energy use.

It is difficult to find a definition of EI that is suitable as an indicator of regional EE, but in the context of providing the reference analysis, ASEAN has selected the calculation for EI as TPES per GDP in which GDP is defined as PPP in constant 2005 USD value.

Figure 66. **Projections on APAEC EI Target**

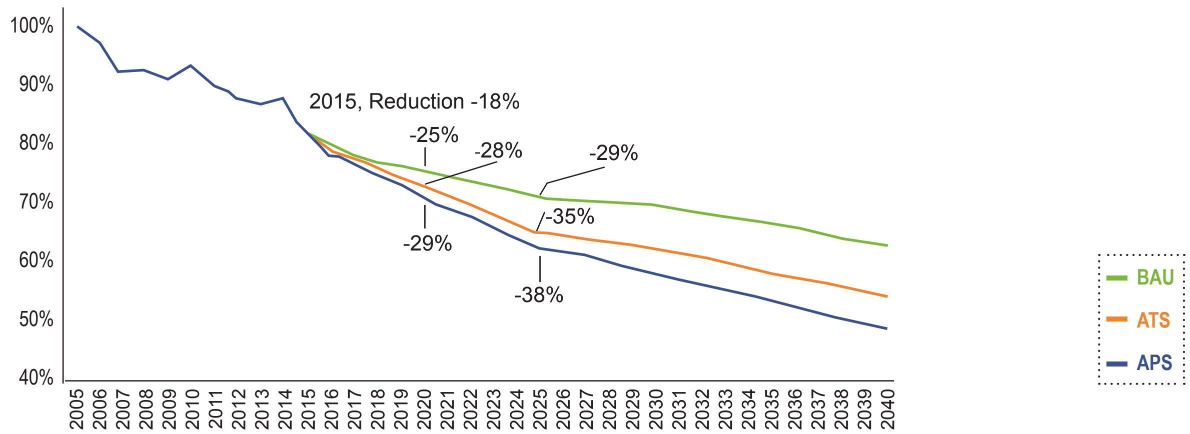


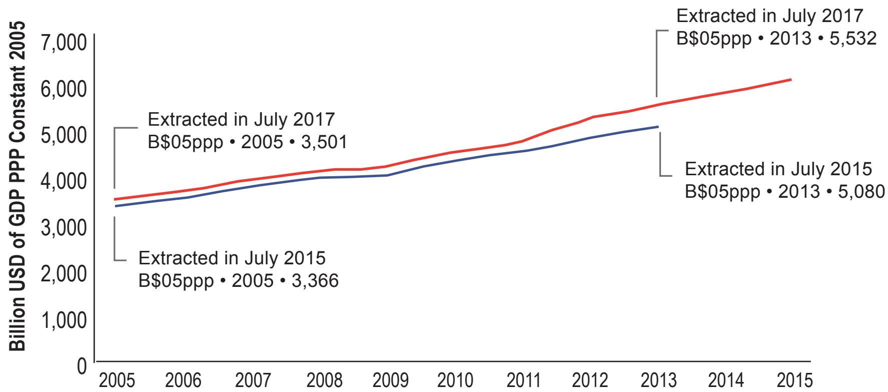
Figure 66 presents the development of EI in the timeframe 2005-2040 for ASEAN, calculated as TPES in Mtoe per 1,000 constant 2005 USD in PPP. The number is indexed as the 2005 value to correspond to 100%. Considering the historical period, EI shows a decrease of 18% from 100% in 2005 to reach 82% in 2015. For the projection period 2015-2040, EI shows a decreasing trend in all scenarios. This reflects the fact that the primary energy requirements grow more strongly than the GDP, leading to a decrease in EI.

This projection shows that ASEAN is well on track to reach the target. In particular, the medium-term (2020) component of the target is reached in all scenarios, exceeding the target by 5% in BAU, 8% in ATS and 9% in APS. Furthermore, the long-term (2025) component , the energy intensity is reduced by 29% in 2025 in BAU, thereby missing the target with a gap of 1%. However, it exceeds by 5% and 8% in ATS and APS, respectively.

Notably, in *the 4th ASEAN Energy Outlook (AEO4)* projection, reaching the APAEC 2016-2025 EI target would be a challenge, thus requiring greater efforts in EE during the projection period 2013-2035. In contrast, *AEO5* projects that ASEAN is well on track to reach the APAEC 2016-2025 EI target. While the difference in these findings might be surprising and appear contradictory, there are several reasons leading the difference:

- While the methodology of *AEO5* is similar to that of *AEO4*, several methodological improvements have been considered in *AEO5* as compared to *AEO4* (as noted in the methodological framework chapter).
- The most important variables that contribute to the differences between the two results concern data. Historical data on both TPES and GDP have been subject to revisions, thereby providing a new benchmark against which the ASEAN EI target is measured.

Figure 67. **Resulting from the Date of Data Retrieval**



While all of these factors contribute to different findings in *AEO4* as compared to *AEO5*, the major factor is historical GDP data updating. **Figure 67** illustrates ASEAN GDP in million USD 2005 in PPP in the historical timeframe 2005-2015 for two-time series: the time series used within *AEO4*, retrieved through Enerdata from the World Bank's database in 2015, and the time series used in AEO5, retrieved from the same source in 2017. Of note, ASEAN's GDP as used in *AEO4* is lower than ASEAN's GDP as used in *AEO5*. Additionally, the difference in both time series is higher for 2012-2015, leading to a stronger reduction in EI when referring to the time series retrieved in 2017 to compute EI.

As mentioned previously, EI is computed by dividing TPES by GDP. A lower value for EI is thus obtained if the denominator (GDP) is higher in the time series. Additionally, a trend towards a greater reduction in EI is obtained if the GDP grows more strongly during the timeframe as compared to the base year (2005) of the APAEC 2016-2025 EI target. A higher value of the GDP, and a stronger growth of GDP between 2005 and 2015, both lead to a greater reduction in EI in AEO5 as compared to *AEO4*.

As outlined by World Bank (2017), revisions to national account estimates over time are common, and usually result in an upward adjustment of data over time, noting that improved data sources at a later point of time increase the coverage of economic activity, and giving new weight to growing industries, more accurately reflect their contributions to the economy.

Nevertheless, it is important to note that while ASEAN has been showing progressive development in tapping its potential on EE, there is still room for collaboration among AMS to optimise it.

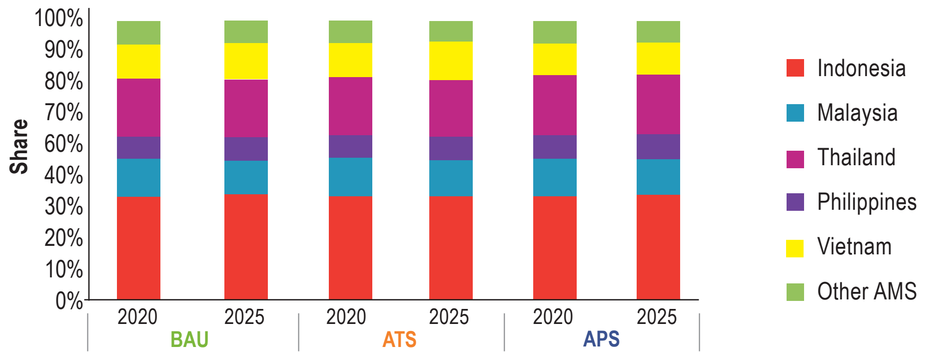
"The accuracy of national accounts estimates and their comparability across countries depend on timely revisions to data on GDP and its components. The frequency of revisions to GDP data varies: some countries revise numbers monthly, others quarterly or annually, and others less frequently. Such revisions are usually small and based on additional information received during the year. However, in some cases larger revisions are required because of new methodologies and changes to the base year. The new base year should represent normal operation of the economy – it should be a year without major shocks or distortions. Comprehensive revisions of GDP data usually result in upward adjustments as improved data sources increase the coverage of the economy and as new weights for growing industries more accurately reflect their contributions to the economy…" (World Bank, 2017)[8]

Credit: ACE

[8]Excerpt from article "Why do countries revise their national accounts?", available online: *https://datahelpdesk.worldbank.org/knowledgebase/articles/680284-why-do-countries-revise-their-national-accounts* (date of access 31/07/2017)

Figure 68 presents the distribution of TPES by AMS and scenarios for the corresponding years of the APAEC EI target components, 2020 and 2025. The small differences across scenarios and time in the relative share of the contribution by AMS to the total TPES in ASEAN depend on the impact of nationally differing EE and RE targets across AMS in the combined ASEAN TPES. Notably, for both years and over all scenarios, TPES is distributed in a similar manner. Indonesia contributes a value of 37-38%, Thailand 20-21%, Malaysia 12-14%, Vietnam 11-13%, the Philippines 8-9% and the rest of ASEAN 8%. Being the biggest contributors to TPES, Indonesia, Thailand, Malaysia, Vietnam and the Philippines are the most important contributors to reaching the APAEC 2016-2025 EI component.

Figure 68. **AMS Distribution in Achieving EI Target**

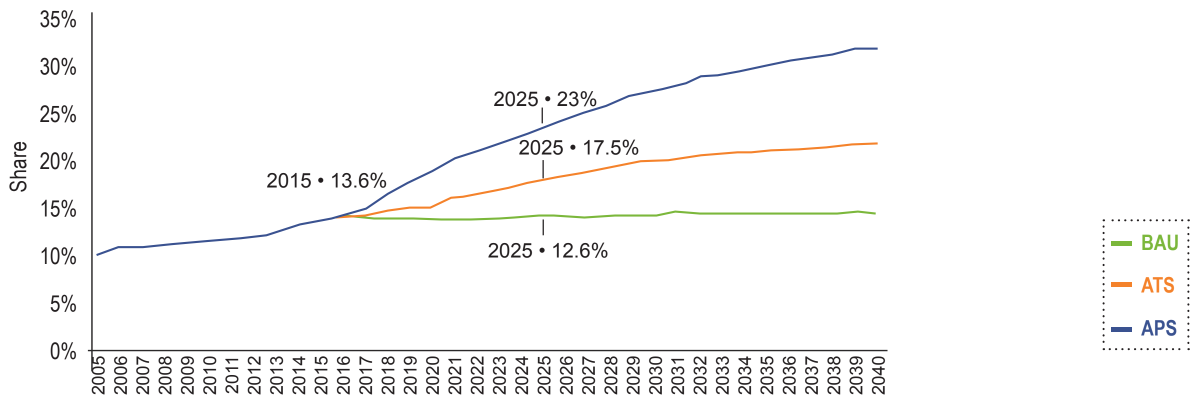


3.2 RENEWABLE ENERGY TARGET

As stated in APAEC 2016-2025, ASEAN has the aspirational target to increase the share of RE to 23% by 2025 in TPES. This target includes different sources of RE in the energy system, in particular hydro of all sizes, but excludes traditional biomass.

In 2015, it is estimated that the share of RE in TPES was 13.6%. In the historical period, i.e. between 2005 and 2010, the share of RE in TPES was below 10%, and showed an increasing trend over time, reaching a value of slightly over 10% in 2010 and 13.6% in 2015. As for the projection period, all three scenarios show an increasing trend over time, as illustrated in **Figure 69**. This does not imply that the share of renewable cannot reach higher levels, but that the projections based on framework parameters and targets reach their limits.

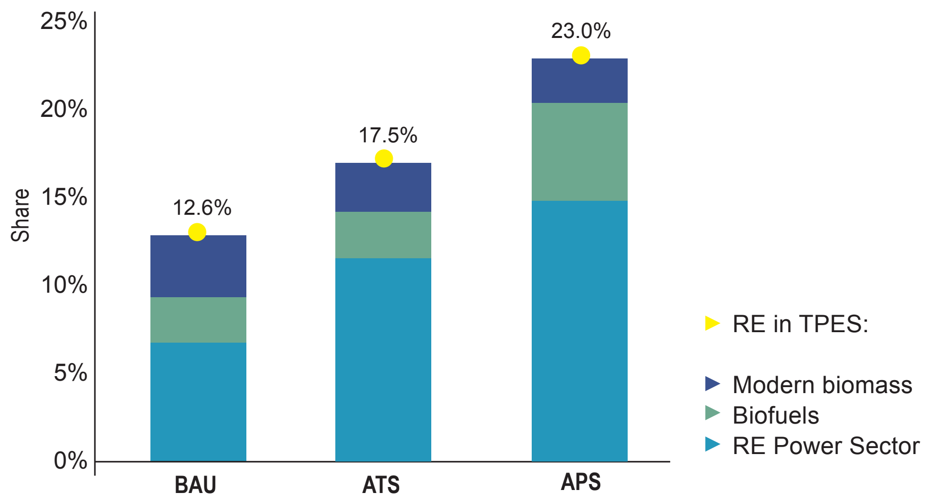
Figure 69. **Projections on APAEC RE Target**



In BAU, the share of RE in TPES increases only slightly over time, saturating at a value of 12.6% in 2025, and continuing a slightly increasing development until 2040. With a target of 23% in 2025, BAU thus represents a gap of more than 10%. In ATS, i.e. the scenario reaching all the national targets of AMS in EE and RE, the share of RE in TPES reaches a value of 17.5% in 2025, still representing a gap of 5.5% to the APAEC RE target of 23% in 2025. The evolution of the share also shows a greater increase but continues with a decreasing slope over time. In APS, the share of RE in TPES is designed to reach 23% in 2025 and thereby meet the target requirements. By definition and in the conception of the scenario, APS was designed so that the APAEC 2016-2025 RE target is met. Of note, the shape of the graph is similar to that of BAU and ATS, but it shows that stronger efforts in increasing the share of RE in TPES are needed in the years up to 2025 as opposed to BAU and ATS. The following sections of this chapter elaborate on the exact composition of the target, and the contribution of the power sector, as well as the distribution by RE technologies and countries in 2025 in order to meet the target.

In BAU 2025, the 12.6% RE share is composed of 6.6% from RE generation in the power sector, 2.5% by biofuels and 3.5% by other RE in TFEC (comprising modern biomass, and biogas). Of note, modern biomass refers to biomass used in TFEC sectors other than traditional biomass. Biomass-fuelled power plants are however considered in the power sector. In ATS it reaches a share of 17.5% in 2025 (with 2.5% for biofuels and 3.2% for modern biomass) but while biofuels and modern biomass contribute similarly to BAU, RE electricity in the power sector represents a share of 11.7% of TPES. APS shows, in the conception of the scenario, a share of 23% of RE in TPES in 2025. The power sector contributes the most, with 15%, followed by biofuels with 5.5% and modern biomass with 2.5%. The detailed composition of this is illustrated in **Figure 70**.

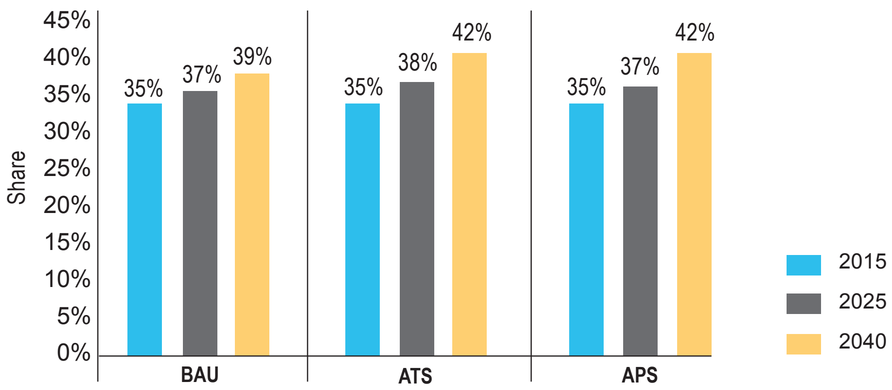
Figure 70. **Distribution of 2025 APAEC RE Target**



The share of RE-power generation in TPES contributes the most to reaching the target, i.e. an increase from 7% in BAU to 12% in ATS, and 15% in APS. In contrast, the contribution of biofuels and modern biomass remain similar over the scenarios. Due to its prominence, the relevance of the power sector to fulfil the target is discussed in more detail in the following section.

RE Power Generation. Figure 71 illustrates the share of total power generation, i.e. the primary energy required for electricity generation divided by the overall TPES, for the years 2015, 2025 and 2040 and all scenarios. Of note, among scenarios and time, the share of the power sector is in the range of between 35% in 2015 and 42% in 2040. This highlights that even if ASEAN's power sector was fully based on RE, only a fraction of TPES would be covered by RE. The rest of TPES would refer to other fuels, mainly oil products in the transport and agricultural sectors, as well as natural gas and other fuels in the industrial sector, and LPG, kerosene and traditional biomass in the residential sector, for example.

Figure 71. **Power Sector Input as Share of TPES**



Further, **Figure 72** illustrates the share of renewable power in the total power generation for the years 2015, 2025 and 2040 in BAU, ATS and APS, respectively. It is noteworthy that in all three scenarios, the share of RE increases over time. In 2015, a share of about 21% is depicted, stemming mostly from large hydro-based power plants. In ATS and APS the share of RE in the power sector increases significantly due to very high growth rates of renewable capacities (6.7% and 7.7% CAGR from 2015-2040 in ATS and APS for the total RE power capacity growth), combined with the EE targets, which lead to a reduced demand for electricity. As for 2025, the APAEC target year, implementing the national targets of AMS in ATS leads to a share of 33.7% of renewable electricity among total electricity, while APS shows a share of 41.8%.

Figure 72. **RE Power Generation Share of Total Generation**

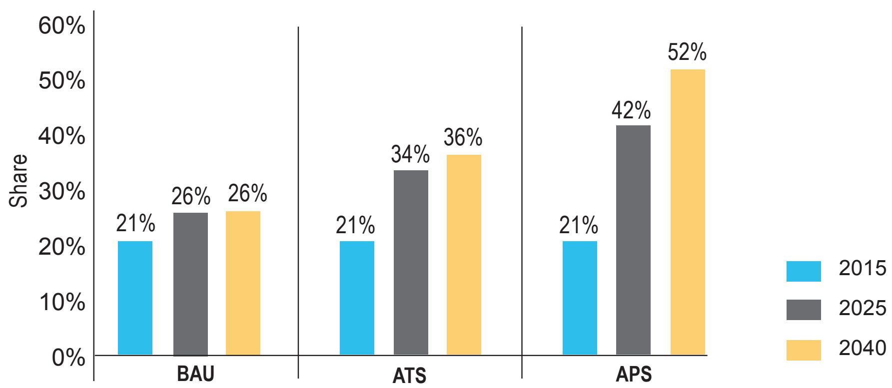
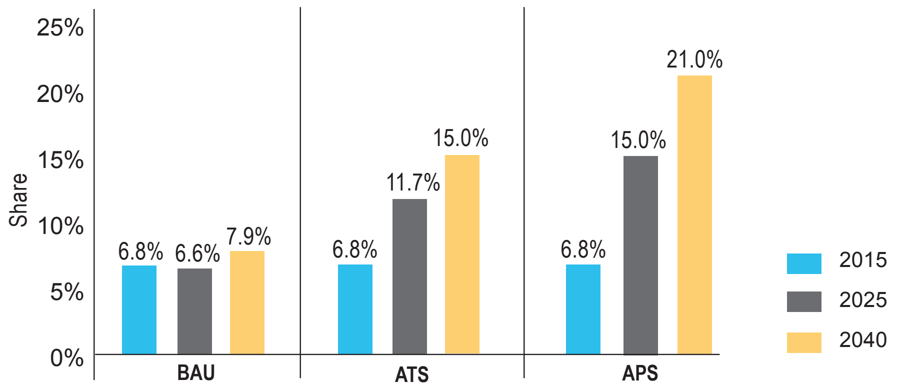


Figure 73 illustrates the share of RE electricity in power sector to TPES in BAU, ATS and APS. In BAU, the share of RE power in TPES decreases from 6.8% in 2015 to 6.6% in 2025 then increases to 7.9% in 2040. In ATS, the contribution of RE power generation to TPES is projected at 11.7% in 2025 and about 15.0% in 2040.

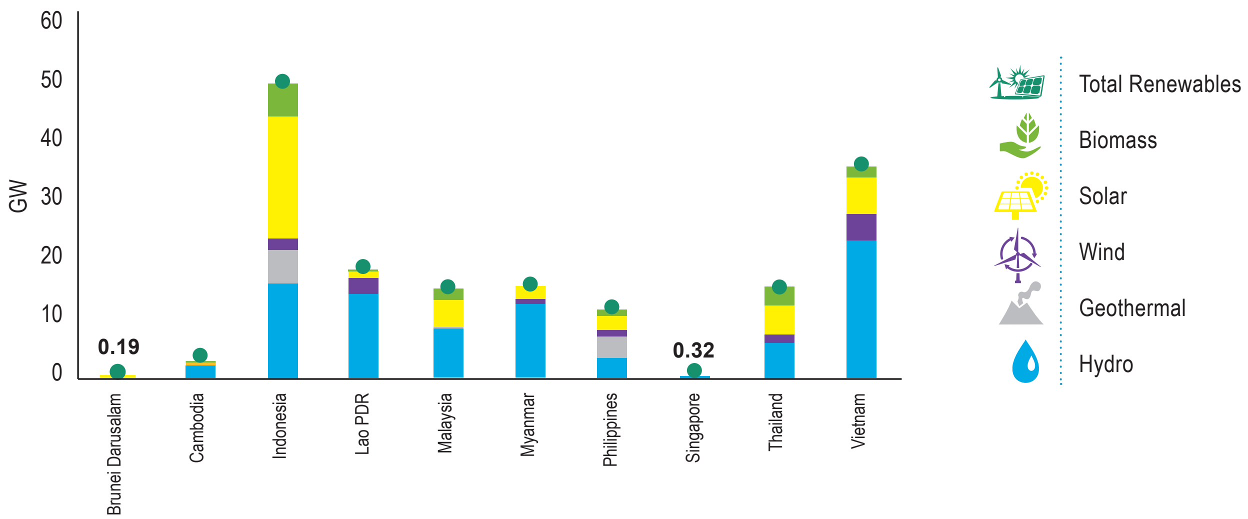
Figure 73. **RE Power Generation Share of TPES**



Power Sector Composition. In *AEO5*, the long-term projection up to 2040 of the power sector in APS, i.e. the scenario designed to meet the APAEC 2016-2025 targets, is based on the *ASEAN REmap* results. It considers the country specific potentials for each technology and contains figures on the long-term development of renewable technologies in ASEAN. Of note, the existing *REmap* comprises projections until 2030. As for *AEO5*, 2040 values were derived by projecting the technology specific growth rates as specified in the projection period of REmap.

A total of 165 GW of RE capacity is to be installed in ASEAN in order to reach the 14.9% share of RE in TPES by 2025 and thus meet the APAEC RE target of 23% by 2025 as modelled in APS. **Figure 74** illustrates the composition of RE capacities in every AMS as designed to meet the regional target.

Figure 74. **Composition of Targeted AMS RE Installed Capacity in 2025**

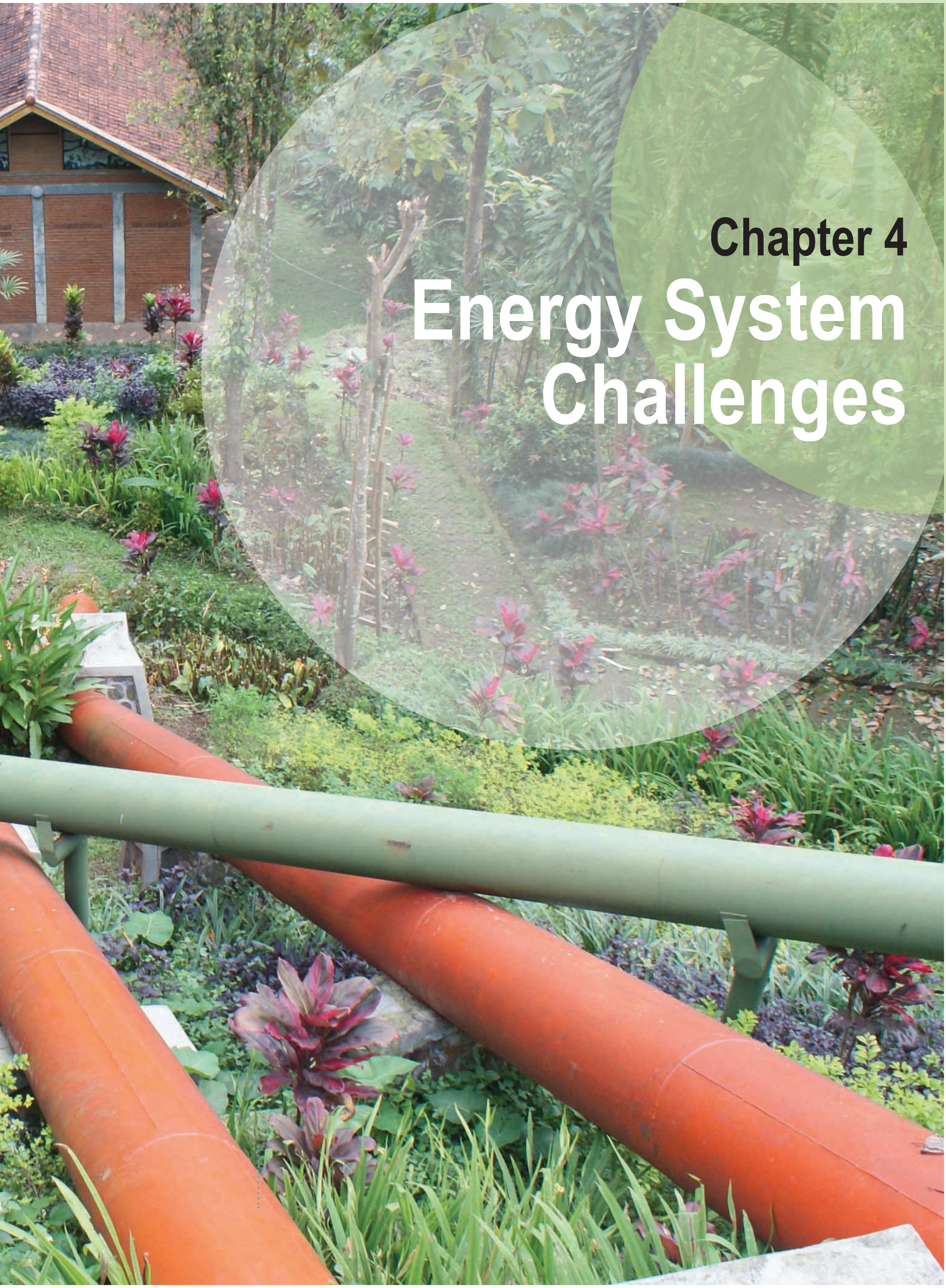


Indonesia, being the largest country, has 30.0% of installed capacity, followed by Vietnam with 21.6%, Lao PDR with 11.1%, Myanmar with 9.5%, Thailand with 9.4%, Malaysia with 9.2%, the Philippines with 7.1%, and Cambodia with 1.8%. Meanwhile, Singapore and Brunei Darussalam, will also contribute to meeting the target with shares of 0.2% and 0.1% respectively.

In conclusion, despite the analysis above, it may be perceived that reaching the EI target component of the APAEC 2016-2025 target is not crucial. However, it must be understood that both EI and the renewable components of APAEC 2016-2025 are complementary. While considering the EI component of the APAEC 2016-2025 target, the impression could emerge that little effort is required in EE in order to meet the target. However, the impact of energy saving due to EE as well as implementing RE technologies in the power sector is subject to effects of interaction and overlap with each other. Increasing EE and thus more strongly reducing EI leads to a reduction in the demand for electricity. This reduces the overall TPES, as fossil fuel-based generation is reduced with a multiplier effect. This is the case in view of the fact that reducing one unit of electricity generated from fossil fuels results in approximately three units of primary energy reduction, due to the 30-35% overall efficiency of conversion in the power sector. While the EI component of the APAEC 2016-2025 target is projected to be easily reached in ATS, the RE component is only met in APS. APS however is calculated based on the assumption that strong efforts in EE are present. These efforts reduce the overall demand of electricity and increase the relative share of RE technologies in the power sector, as well as in TPES as compared to a case where less effort in EE is present.

Credit: ACE


Credit: ACE



Chapter 4
Energy System Challenges

Energy System Challenges

Based on the results in Chapter 2, this section analyses the challenges faced by ASEAN regarding Energy Supply Security, Emissions and Power Sector Investments.

HIGHLIGHTS

- *ASEAN is a major producer of coal, oil and natural gas. The primary production of coal shows a slightly increasing trend, and oil and natural gas show a decreasing trend over the projection period of 2015 to 2040.*
- *In 2015, coal production was 434 Mtce, with Indonesia producing nearly 90% and Vietnam 7%. Coal production is projected to be 487 Mtce by 2040. During the whole projection period, ASEAN as a region produces more coal and thus the region has a net surplus in coal production.*
- *Over the projection period, oil production decreases at an average rate of 1.4% per year and lands at only 70% of the 2015 level, which corresponds to 1.6 Mbbl/d or 85 Mtoe in 2040. While the primary production of crude oil in ASEAN steadily declines until 2040, the primary requirements of crude oil are expected to rise in all three scenarios.*
- *Natural gas production in ASEAN is currently still above the primary requirements. However, the projection in all scenarios show that the projected production of natural gas will not meet the projected demand. Demand will exceed production in 2020 in BAU, 2025 in ATS and 2029 in APS. By 2040, ASEAN will be a net importer of natural gas. In BAU, imports are 4 times larger than in APS, reflecting the clear benefits from enhancing EE and RE to ASEAN's import dependency.*
- *Refining capacity is projected to increase from its current level of 3.7 mbbl/d to 6 mbbl/d in 2025 and 7.7 mbbl/d in 2040. This development already reflects the capacity expansion in many AMS, as well as long-term considerations of future expansions incorporated in AEO5. Reaching EE targets identified in the scenarios can also yield a substantially reduced import dependency.*
- *In BAU, CO_2 emissions in the region will increase 2.4 times to reach 3,460 Mt CO_2eq in 2040. Considerable savings of 23% in ATS and 35.6% in APS can be achieved. Decomposition analysis shows that while emissions will be driven by economic and demographic growth, substantial improvements in EI due to enhanced EE and the uptake of RE can help ASEAN to cope with this challenge.*
- *A total of USD 550.6 billion is needed for power sector investment from 2015 to 2040. However, injecting more RE through ATS and APS will require less investment than in BAU, i.e. -4% and -1% respectively.*

4.1 SUPPLY SECURITY

Primary Production. Figure 75 presents the projected primary production of coal, oil and natural gas in the ASEAN region for the timeframe 2000-2040. Notably, ASEAN is a major producer of coal, oil and natural gas. For the projection period 2015-2040, the primary production of coal shows a slightly increasing trend, and oil and natural gas show a decreasing trend.

In 2015, ASEAN produced 434 million tonnes of coal equivalent (Mtce), with Indonesia producing nearly 90% and Vietnam 7%. After significant increases in the primary production of coal in the historical period 2000-2016, only a slight increase is foreseen for the period 2016-2040. This development is heavily attributable to Indonesia's plans to cap its coal production at 400 million tonnes per year starting in 2019, according to Indonesia's new Energy Plan (RUEN). Meanwhile, Vietnam, as the second largest producer in the region, is projected to slightly increase its production 3.6% every year on average. In all, as illustrated in **Figure 76**, the combined regional production is expected to reach a level of 487 million tonnes of coal in 2040 to serve regional neighbours and beyond.

Figure 75. **Primary Production of Fossil Fuels in ASEAN**

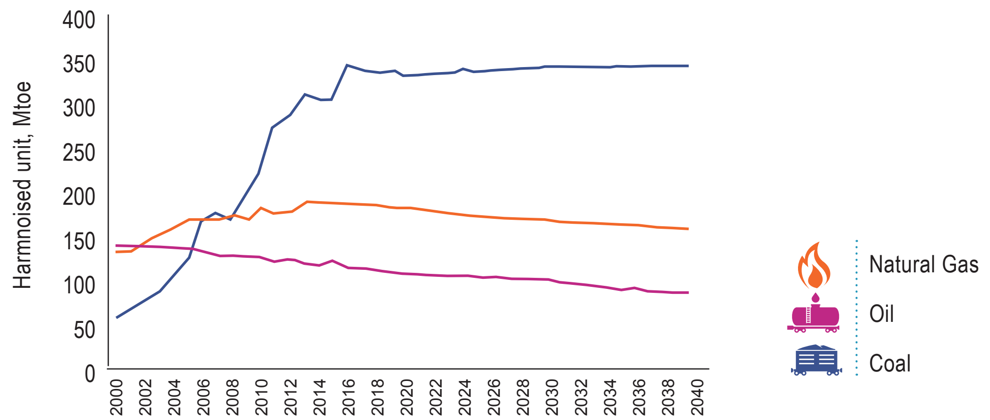
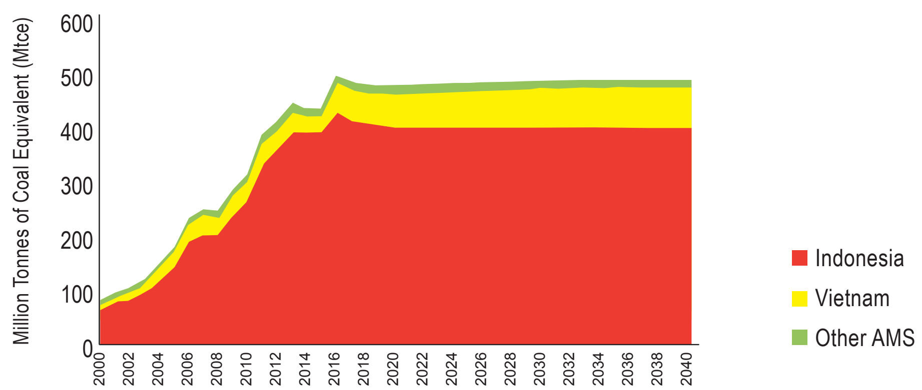
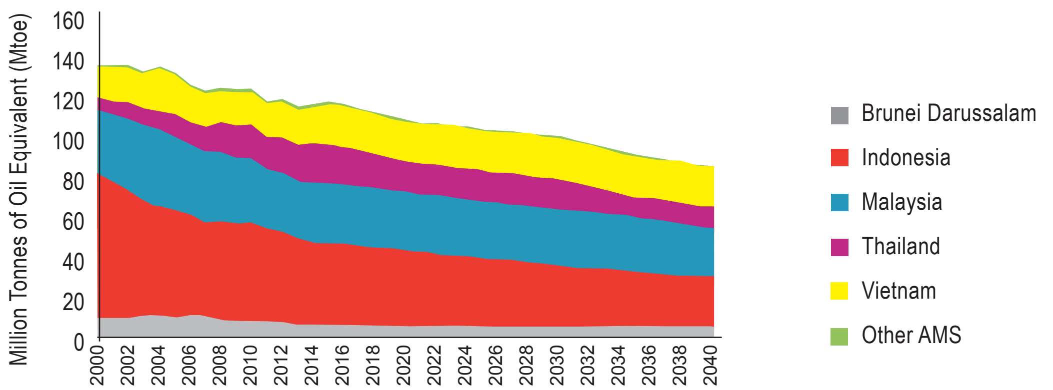


Figure 76. **AMS Coal Production**



Oil is produced by several AMS. In 2015, the combined ASEAN oil production corresponded to 2.4 million barrels of oil per day, with the majority contributed by Indonesia and Malaysia at 35% and 25%, respectively. As the region is expecting to rely mainly on mature oil fields, the primary production of oil shows a steadily decreasing trend until 2040. Over the projection period, oil production decreases at an average rate of 1.4% per year and lands at only 70% of the 2015 level, which corresponds to 1.6 Mbbl/d in 2040. **Figure 77** shows an overall decreasing trend in oil production for the last decade, which is mainly due to a reduction of oil production in Indonesia.

Figure 77. **AMS Oil Production**

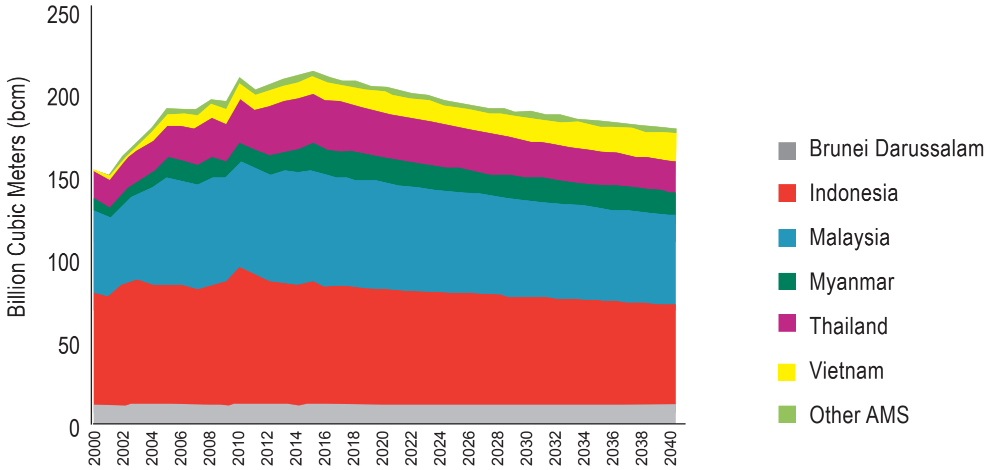


Natural gas is produced by several AMS in ASEAN. In 2015, the region's combined primary production was approximately 205 billion cubic metres (bcm) of natural gas, with 35% produced by Indonesia, 30% by Malaysia, 15% by Thailand, 8% by Myanmar, 6% by Brunei Darussalam, and 5% by Vietnam. The region has seen no significant discovery after the East Natuna D-Alpha gas field, the expected single largest resource in the region. However, as Natuna D-Alpha is still not in the production, the combined total future primary production of natural gas will decrease by 0.6% on average every year.

Credit: ACE

Figure 78 shows the projected primary production of natural gas in AMS. Although overall gas production in the region is expected to decrease from its current level until 2040, trends vary. Annual production in Brunei Darussalam is anticipated to be stable in the projection period, a slightly decreasing trend is expected for Indonesia, while Vietnam, on the contrary, is projected to increase its production.In 2040, production is expected to reach only 87% of the present level, which corresponds to 177 bcm.

Figure 78. **AMS Natural Gas Production**



Reserves Depletion

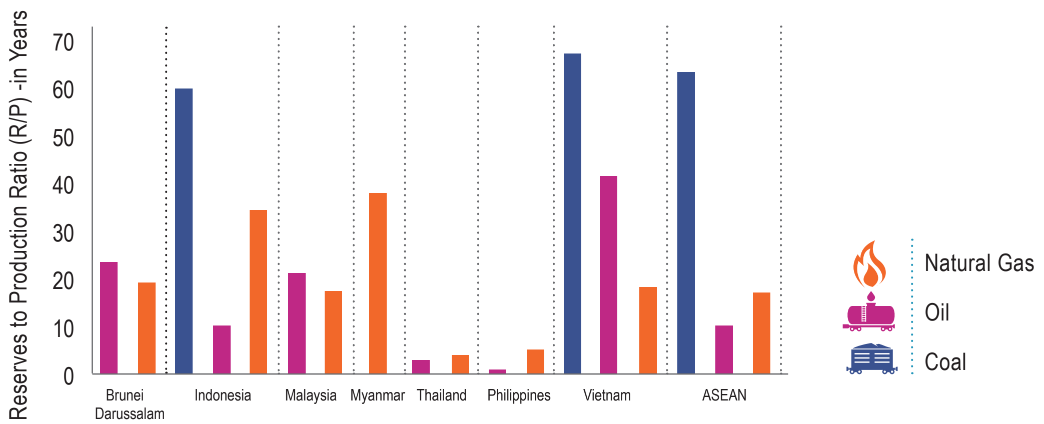
Reserves depletion is calculated as the reserves to production ratio (R/P) and indicates the years until the reserves would be depleted if no additional resources are discovered. It is not a guide to long-term production potential, which depends on the underlying recoverable resource base, but it is one reference in considering the supply security challenges. In reality, new reserves often become available due to new discoveries as well as to technological improvements in extraction technology which make access to formerly unavailable reserves possible. Additions to future reserves therefore depend on the price development of fossil fuels. These drive exploration activities and determine the economic viability of extraction, as well as technological developments. These factors are however difficult to forecast. The R/P ratio is thus commonly used to show the theoretical time until reserves are depleted without assuming future additions.

ASEAN has abundant fossil fuels reserves. The largest reserves of coal are located in Indonesia, representing about 80% of the region’s total reserves. Smaller reserves of lignite are present in Thailand and Lao PDR.

Vietnam holds 18% of the hard coal reserves in the region. The largest share of the overall 11 billion tonnes of crude oil reserves in ASEAN is located in Malaysia, Vietnam and Indonesia. Natural gas reserves amount to 6.8 trillion cubic metres for the overall region and are located mainly in Indonesia and Malaysia and, to a smaller extent, Vietnam. However, given the current rate of production, the region is expected to see depletion of reserves in the coming decades.

The variation of possible timeframes for resources depletion is illustrated in **Figure 79.** With abundant reserves, coal is expected to deplete only in 66 years. If no new reserves are added, the depletion of gas reserves in ASEAN can be anticipated within the next few decades, and for some AMS the gas reserves might be depleted much earlier (i.e. for Thailand within the next five years). It can also be expected that oil reserves in ASEAN will deplete within the next four decades. However, in most AMS, the oil reserves will probably be exhausted in even shorter periods (i.e. 10 years or less in Indonesia, the Philippines and Thailand).

Figure 79. **Reserves to Production Ratio of ASEAN's Fossil Fuels**



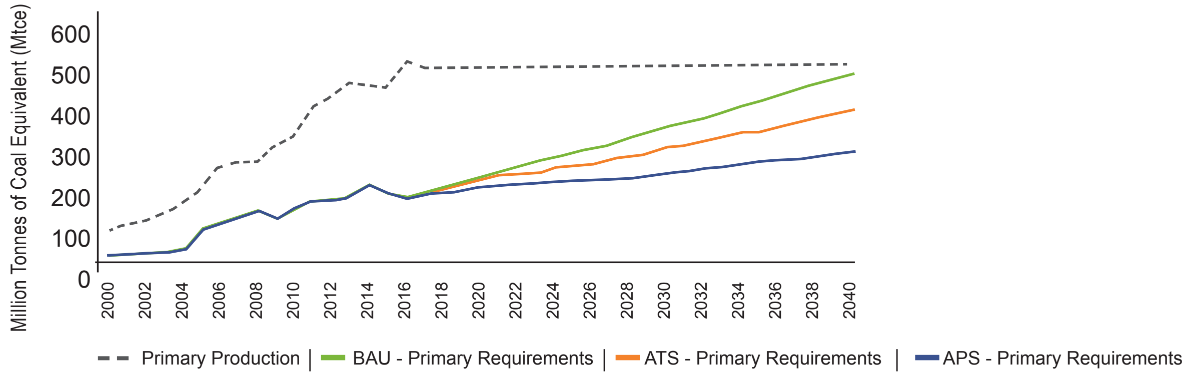
Export/Import Dependency. To examine the potential of exporting or importing primary energy carriers, the primary production of each fossil fuel is compared to the requirements for fuel arising in the different scenarios.

Coal primary requirements are the highest in BAU, reaching a value of 462 Mtce in 2040. In ATS, reaching the national targets on EE and RE, ASEAN will only require 375 Mtce of coal in 2040, resulting from a reduced final demand for coal in the industry as well as a reduced electricity demand in the residential, commercial and industrial sectors. The even more ambitious EE and RE targets in APS lead to an even lower value of 272 Mtce of coal production by 2040.

During the whole projection period, ASEAN as a region produces more coal (reaching 487 Mtce in 2040) than its primary requirements (462 Mtce in BAU, 375 Mtce in ATS and 272 Mtce in APS) and thus the region has a net surplus in coal production.

Figure 80 highlights the corresponding surplus production of coal resulting in each scenario. With a nearly constant production over the projection period 2015-2040 and increasing domestic requirements, the surplus production constantly reduces over the projection period. However, the figure clearly illustrates the effect of reaching the EE and RE targets in ATS and APS, which leads to a substantially reduced domestic coal demand and thus makes substantial volumes of coal available for exports. As at 2040, only 25 Mtce would be available for exports in the absence of substantially improved EE and RE. In contrast, if AMS reach their nationally determined targets, 112 Mtce will be available for exports in 2040, and 2,015 Mtce in the case that the ASEAN regional EE and RE targets are reached. As a major producer, Indonesia would mostly benefit from these exports.

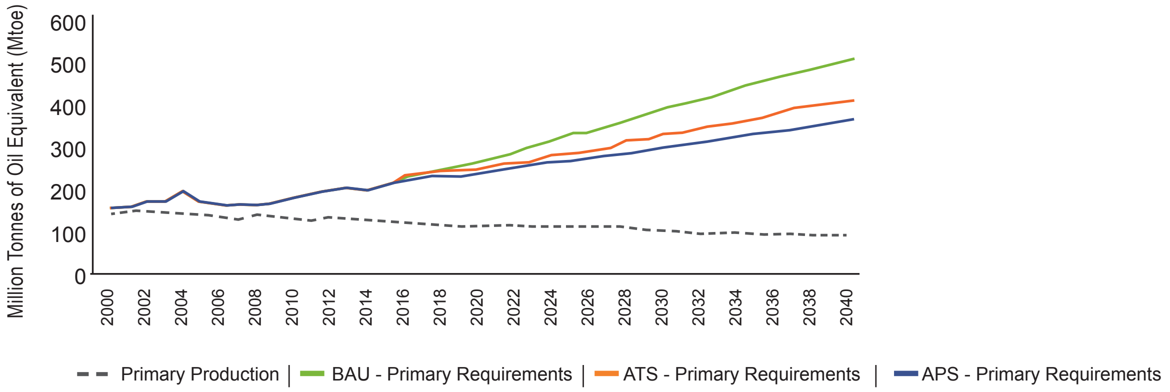
Figure 80. **Production and Requirements on Coal All Scenarios**



For oil, **Figure 81** illustrates that while the primary production of crude oil in ASEAN steadily declines until 2040, the primary requirements of crude oil are expected to rise in all three scenarios. As ASEAN is already a net importer of crude oil, significant additional imports of crude oil will be required in all scenarios. However, in the more ambitious scenarios that assume the implementation of EE and RE targets and corresponding policies (ATS and APS) the import dependency could be reduced considerably. In 2040 the overall production of crude oil in ASEAN is expected to reach 85 Mtoe. In BAU the primary requirements of oil in ASEAN in 2040 are projected to reach 505 Mtoe.

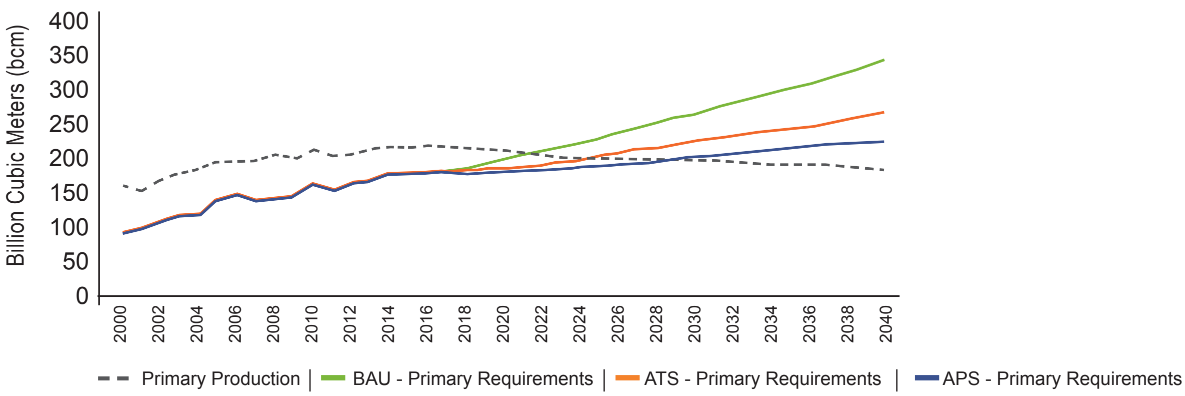
During the whole projection period, ASEAN as a region produces more coal (reaching 487 Mtce in 2040) than its primary requirements (462 Mtce in BAU, 375 Mtce in ATS and 272 Mtce in APS) and thus the region has a net surplus in coal production.

Figure 81. **Production and Requirements on Oil All Scenarios**



Natural gas production in ASEAN currently is still above primary requirements. However, **Figure 82**. shows the primary production of natural gas in the ASEAN region and contrasts it with the primary requirements of natural gas arising from the different scenarios. The graph clearly illustrates that the projected production of natural gas will not meet the projected demand in all scenarios. In BAU demand will exceed production in 2022. Given the reduced demand in ATS, this point can be delayed until 2025, and APS can postpone it until 2029. However, in all three scenarios it becomes clear that, against the background of the anticipated energy strategy, there will be a strong import dependency for natural gas in the future. With limited availability to import natural gas via pipelines, this dependency will have to be covered by future LNG imports. Concretely, the primary production is projected to reach 177 bcm by 2040. This contrasts with primary requirements of 339 bcm in BAU, 263 bcm in ATS and 220 bcm in APS. Thus, the net imports required amount to 43 bcm in BAU, 68 bcm in ATS and 162 bcm in BAU. Hence, BAU imports are 4 times bigger than in APS, reflecting the clear benefits of enhancing EE and RE to reduce ASEAN's import dependency.

Figure 82. **Production and Requirements on Natural Gas All Scenarios**



Refining Requirement. Historically in the timeframe 2000-2015, ASEAN has shown a moderately increasing tendency in the refining of oil products from close to 3 mbbl/d in 2000 to 3.7 mbbl/d in 2015. As for the projection period 2015-2040, it is noteworthy that ASEAN will strongly increase refining capacity as compared to 2015, reaching 6 mbbl/d in 2025 and 7.7 mbbl/d in 2040. Several AMS are planning to increase their refining capacity through project expansion and even new construction. This increase represents more than a doubling of the refining capacity and output of refined oil products in the next 25 years.

The following five AMS have considered expanding their refining capacity, be it under government planning or private sector activity. Assumptions based on this planning were used in the modelling.

Indonesia. Notably, the main expansion in ASEAN will be driven by Indonesia. As in 2015, 10 refineries have been operated in Indonesia, providing approximately 0.9 million barrels per day (mbbl/d), equivalent to 47 Mtoe per year of refined oil products. Of these refineries, five complexes, Balongan, Balikpapan, Cilacap, Duamai, and Plaju are assumed to experience upgrades in capacity of between 125,000 bbl/d and 348,000 bbl/d, while two new refineries, Bontang and Tuban (each 300,000 bbl/d) will be built. In all, this will lead to mid-term (up to 2025) total capacity expansions of 1.1 mbbl/d. In the long-term (up to 2040), Indonesia is assumed to further increase its capacity by 650,000 bbl/d, leading to a total refining capacity of 2.7 mbbl/d (corresponding to 137 Mtoe per year) in 2040.

Malaysia. As an oil-producing country, Malaysia is also expected to experience considerable capacity expansion.

The country currently has five refineries with a combined output of approximately 400,000 bbl/d and will receive a boost in refining capacity due to the 300,000 mbbl/d RAPID petrochemicals facility, which will come online by 2020. The total capacity is therefore projected to increase to a value close to 700,000 mbbl/d. In the long-term, no further expansions are considered in Malaysia. This assumption accounts for the fact that domestic oil production is declining during the projection period.

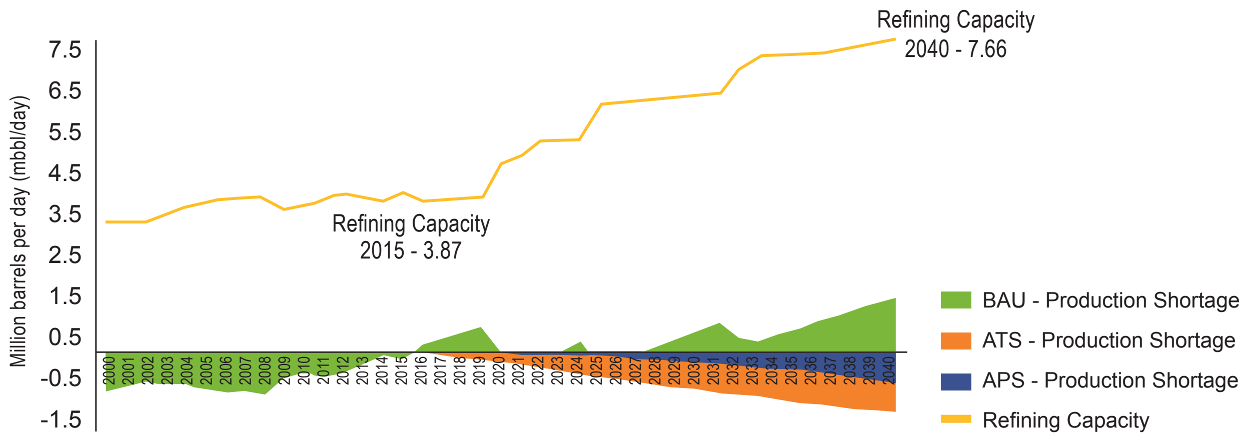
Singapore. Singapore has 3 refiners: a 605,000 bbl/d-combined facility owned and operated by ExxonMobil; a 290,000 bbl/d-facility operated by Singapore Refining Corporation; and a 500,000 bbl/d-facility owned and operated by Royal Dutch Shell. All have announced capacity expansions, although exact numbers have not been disclosed. For this *Outlook*, it is assumed that Singapore will experience a total growth of 600,000 bbl/d up to 2040.

Thailand. As at 2015, Thailand had seven refineries with a total a capacity of approximately 1.23 mbbl/d. No official expansion plans are known for Thailand. This outlook assumes a moderate growth in refining capacity between 2015 and 2040, with the total capacity reaching 1.5 mbbl/d in 2040. The expansion reflects first the growing demand for refined oil products in the projection period, second the fact that domestic oil production is declining, and third that the reserves to production ratio is only five years, and thereby the lowest among all AMS.

Vietnam. Vietnam is a relatively minor oil producer (20 Mtoe or 0.4 mbbl/d in 2015). Notably it used to export the totality of its oil production and import the totality of refined oil products. In order to reduce the import dependency on oil products and benefit from domestic refining activities, Vietnam commissioned its first refinery in 2009, which came online in 2015 with an annual capacity of 126,000 bbl/d. As for the projection period, Vietnam will further increase its capacity with two new refineries, Nghi Son in Thanh Hoa with 164,000 bbl/d capacity, and Long Son at Ba Ria-Vung Tau with 195,000 bbl/d capacity. Both refineries are projected to come online in 2020, operated by PetroVietnam.

Figure 83 presents the future total of ASEAN refining capacity contrasted with the demand for oil products in ASEAN in BAU, ATS and APS. As for BAU, ASEAN's projected expansions in refining capacity follow the trend of increasing demand for oil products. In the mid-term (up to 2025), ASEAN's expansions correspond to the increase in demand for oil products. In the long-term (after 2025), demand surpasses the refining capacity, implying a shortage in domestic capacity to provide oil products and indicating the possible need to import oil products. In ATS and APS however, in view of the effect of reaching the corresponding EE and RE targets, the projected refining capacity expansions will surpass the domestic demand for oil products. This means that refined oil products could be exported during the projection period.

Figure 83. **Refining Surplus/Shortage All Scenarios**

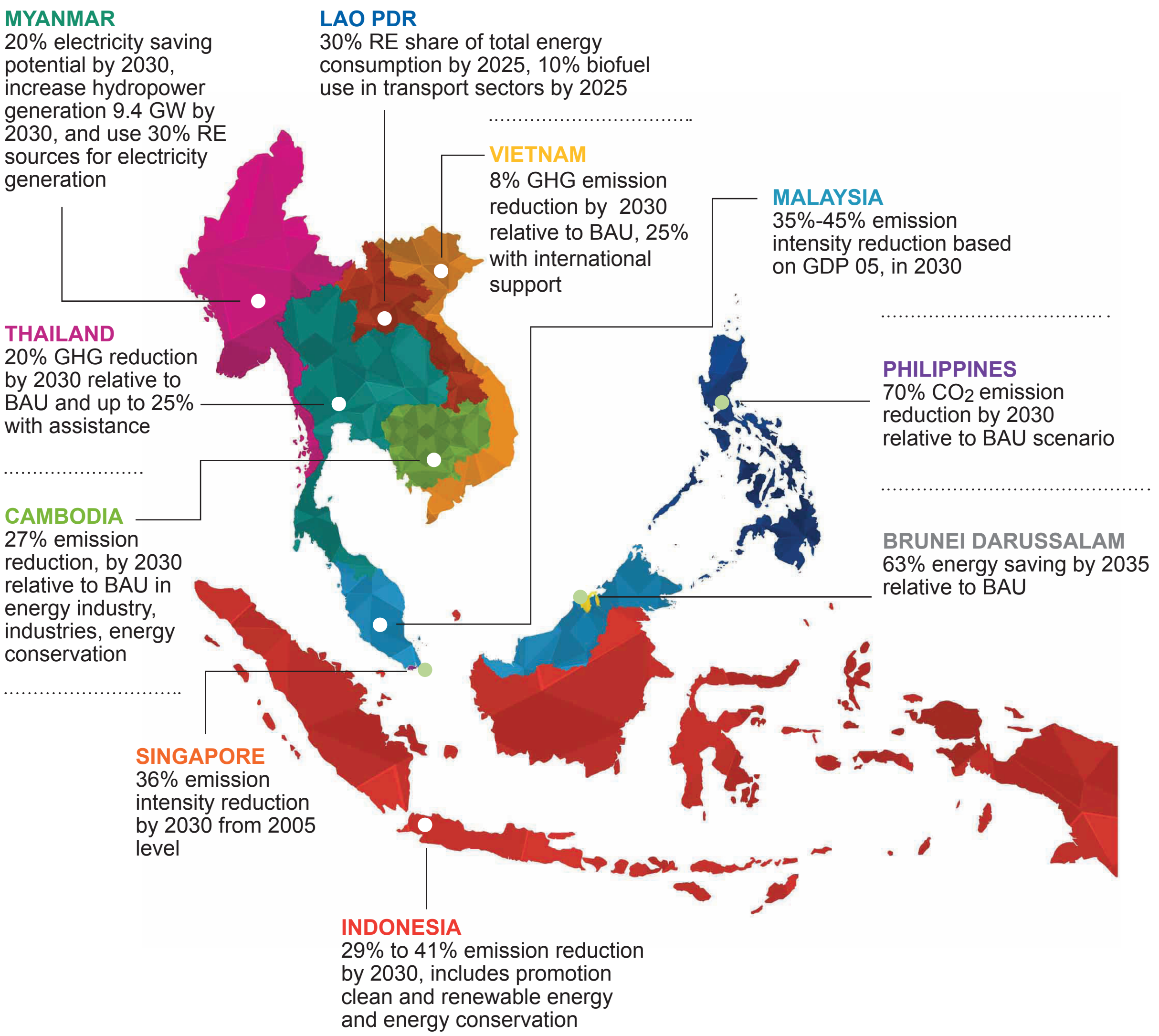


4.2 GHG Emissions

National Commitments. AMS have prepared and submitted their Intended Nationally Determined Contributions (INDCs) for the Paris Agreement adopted by the 21st Conference of Parties of the United Nations Framework Convention on Climate Change (UNFCCC), held in Paris in 2015. The specification in which targets or measures to counteract greenhouse gas (GHG) emissions vary substantially from country to country, and most of them cover all sectors, not energy only. The Paris Agreement entered into force on 4 November 2016. All 10 AMS, with the exception of Myanmar, have ratified the Paris Agreement, transforming these into Nationally Determined Contributions (NDCs), which they are now obliged to meet. **Figure 84.** shows the energy related target only as part of AMS (I)NDCs.

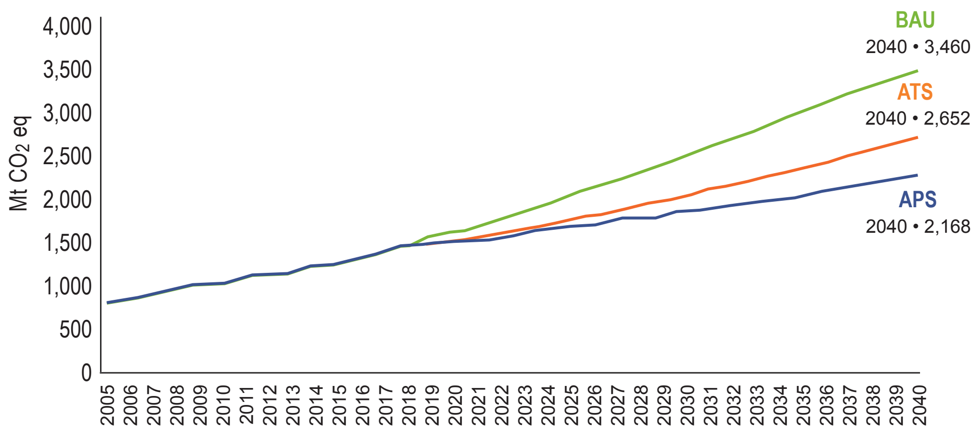
At regional level, ASEAN itself does not define specific value on regional commitment for carbon-dioxide (CO_2) emission reduction. However, the direction of APAEC 2016-2025, particularly in setting actions on clean energy such as reducing EI by 20% in 2020 based on the 2005 level, increasing the component of RE to 23% by 2025 in ASEAN energy mix, and enhancing the image of coal through the promotion of clean coal technologies (CCT) as well as encouraging civilian nuclear energy, is leading to significant CO_2 emissions reduction in the region.

Figure 84. **Energy Related Targets on AMS (I)NDC**



Emission Projection. Emissions in this *Outlook* refer only to the results from all types of energy conversion processes in the power sector, as well as in the residential, commercial, industrial, agricultural and transport sectors. It does not include potential emissions resulting from land use changes (e.g. deforestation or intensification of agricultural activities) and waste processing. Nonetheless, these sectors could have a significant impact on the development of the overall emissions in the region, especially in Member States that foresee a strong increase in future biofuel production.

Figure 85. **Projection on Emissions All Scenarios**

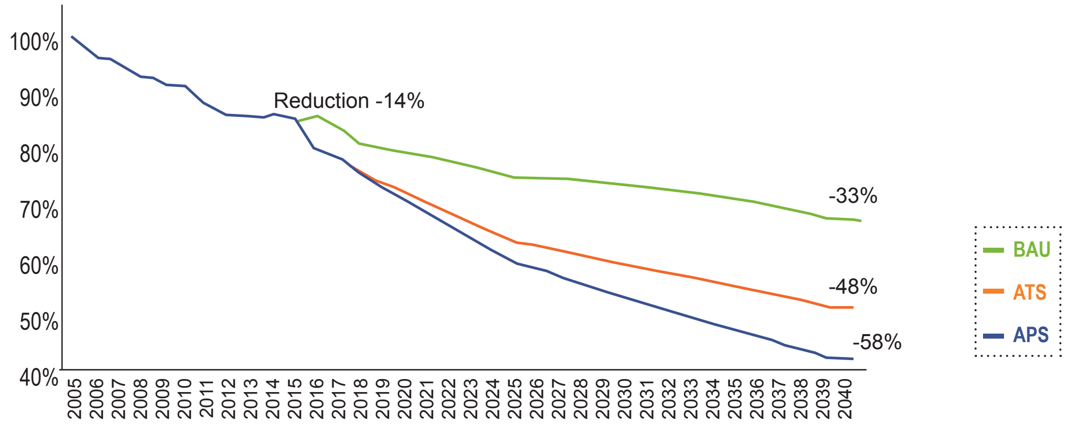


In 2015, fossil fuels accounted for three quarters of the energy demand that produced 1,446 million tonnes of CO_2 equivalent (Mt CO_2eq). As fossil fuels remain dominant, the region is expected to see the growth of energy-related CO_2 emissions, but at a different pace depending on the scenario. This is illustrated in **Figure 85**. Assuming no significant change in the future development of ASEAN energy systems, emissions in the region will increase 2.4 times to reach 3,460 Mt CO_2 eq in 2040 given the high growth in the share of fossil fuels. Reaching EE targets lead to both a lower demand in TFEC sectors and hence reduced emissions as well as a reduced demand for electricity, which impacts on the emissions attributable to the power sector. Implementing more RE in the power sector to replace fossil fuel-based generation is expected to lower emissions. Under ATS, the CO_2 emissions in the region will only grow 1.8 times to reach a total of 2,652 Mt CO_2eq in 2040, 23% lower as compared to BAU. In progressive efforts, where the share of fossil fuels supplies only two thirds of the energy demand, ASEAN is expected to reduce emissions further to only 2,168 Mt CO_2eq in 2040, or only grow 1.5 times from 2015, corresponding to a decline by 35.6% compared to BAU.

Credit: ACE

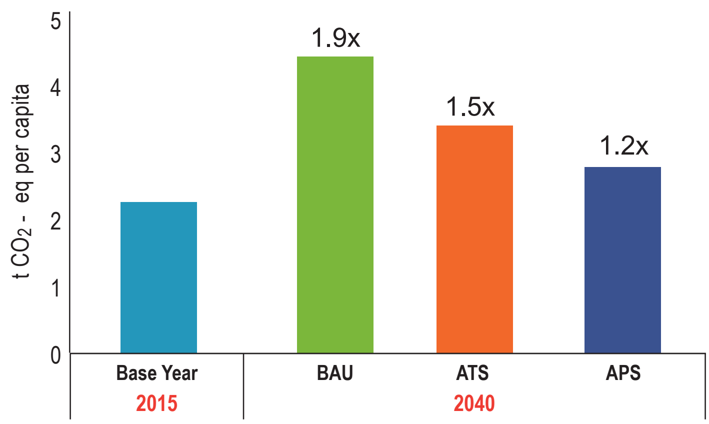
As GDP is expected to grow during the period, the projection sees the significant potential to reduce carbon intensity (CO_2 per GDP) in the region, as illustrated in **Figure 86**. Indexed to a 2005 level, in 2015 ASEAN was already producing 14% less CO_2 for every single dollar generated. All projection scenarios expect that the region will be able to cut emissions from their economic activities further, with 33% reduction for BAU, 48% for ATS and 58% for APS in 2040.

Figure 86. **Carbon Intensity (CO_2/GDP) Projections All Scenarios**



In terms of CO_2 per capita emission, the number is projected to almost double in BAU, from 2.3 tCO_2eq per person in 2015 to 4.4 tCO_2eq per person in 2040. In 2040, in ATS, the projected per capita emissions will reach a level of 3.4 tCO_2eq, showing a 21% reduction from BAU. The high ambition level of APS is reflected in significantly lower per capita emissions to only 2.8 tCO_2eq in 2040, which implies a reduction of one third as compared to BAU per capita emission level. The projections highlight that, especially in those AMS with more ambitious energy savings targets, a continuation of these efforts until 2040 would contribute significantly to a reduction of future CO_2 emissions. It is also important to note that, as **Figure 87** shows, even with a progressive plan in APS implemented in the energy system, it is not possible for the region to reduce future levels of CO_2 emissions to the 2015 level, or lower.

Figure 87. **Projection on Emissions per Capita**



Decomposition Analysis. In order to analyse the drivers of CO_2 emissions in ASEAN, a decomposition analysis is provided. The CO_2 decomposition analysis allows the evaluation of the contribution of an array of factors on the impact of total CO_2 emissions. The analysis provided is well-known as Kaya-Identity analysis[9] and is analogous to the findings presented in the IPCC assessment reports. The development of CO_2 emissions is expressed as consequential to the development of four underlying factors: population (POP), per capita GDP (GDP/POP), primary energy intensity (TPES/GDP), and carbon intensity (CO_2/TPES).

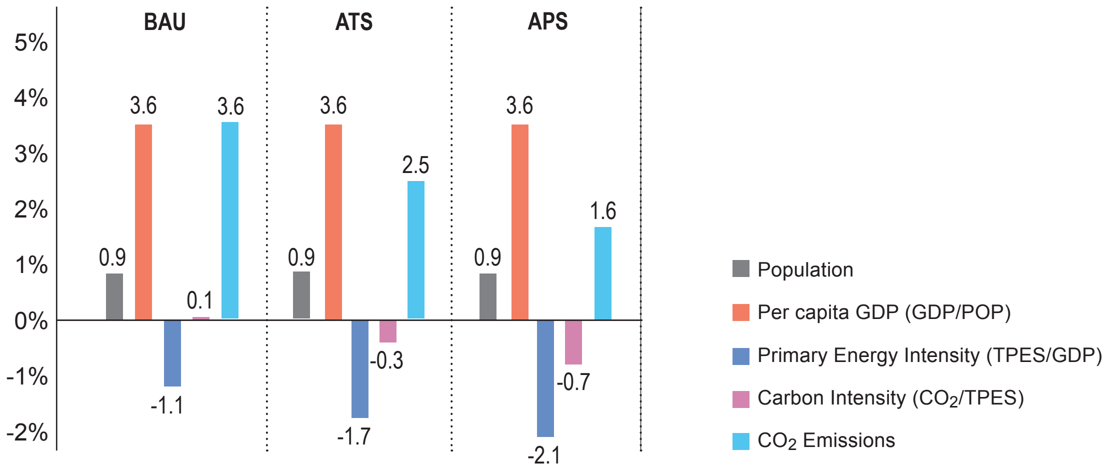
Thus, the analysis is based on expressing the level of energy related CO_2 emissions as the product of these four indicators:

CO_2 = Population * per capita GDP * energy intensity * CO_2 intensity

CO_2 = POP * GDP/POP * TPES/GDP * CO_2/TPES

All scenarios indicate that the energy-related CO_2 emissions in ASEAN will increase during the projection period, but ATS and APS show that increased EE and RE efforts result in substantially reduced emission values. **Figure 88** shows CO_2 decomposition analysis using Kaya-Identity to evaluate the four contributing factors to CO_2 emissions.

Figure 88. **Kaya-Identity Analysis All Scenarios**



In all scenarios, GDP growth and population growth are the same at 4.5% and 0.9% on average each year, respectively. The growth of GDP (PPP constant 2005) per capita is therefore assumed to be 3.6% on average in each year during the projection timeframe. With variations in EE and RE efforts, substantial improvements in EI and carbon intensity lead to reduced CO_2 emissions in ATS and APS as compared to BAU. EI shows values of -1.1%, -1.7% and -1.21% in BAU, ATS and APS, respectively, reflecting that even in BAU the reduction in EI is projected to contribute to reducing overall CO_2 emissions from energy conversion. As for the carbon intensity, ASEAN can also reduce future CO_2 emissions by improving EE and RE. While EE leads to a lower demand for electricity, increasing RE offsets carbon intensive technologies with low carbon technologies, thereby improving the overall carbon intensity. This is reflected in a carbon intensity of 0.01% in BAU, -0.3% in ATS and -0.70% in APS. Following BAU, and the historical past, the average ASEAN power plant's emission intensity will continue in a similar range as it does today. In contrast, implementing EE and RE will lead to a reduction of carbon intensity as compared to 2015 levels.

[9]Emissions Scenarios using Kaya-Identity Analysis. *http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=50*

In conclusion, the decomposition analysis illustrates that ASEAN CO_2 emissions will be driven by population growth as well as a substantial increase in GDP per capita. However, ASEAN can substantially reduce overall CO_2 emissions by improving EE (reducing energy intensity) and deploying more RE in the energy mix (reducing carbon intensity).

4.3 POWER SECTOR INVESTMENTS

Reaching the APAEC RE Target. Power sector is one of the most significant sectors for the region to achieve its aspirational goal of 23% share of RE in TPES by 2025. As projected, in BAU, the power sector contributes 7.0% of 12.6% RE share of TPES in 2025. In ATS it will contribute 12.0% of 17.5% and in APS up to 14.9% of 23% of TPES.

Understandably significant amount of investments is required to fulfil the growing demand on electricity. Considering the future trend on the cost, both on fossil fuel and also RE, it is very important for AMS to have proper planning on the investments for the power sector, particularly in reaching the ASEAN RE Target in the most economical way.

Table 7. details the comparison between the capacity requirement and investments for all scenarios. Within this period, ASEAN will require additional power capacity of 117.5 GW in the BAU, entailing USD 154.5 billion in investments. In ATS, 138.8 GW of additional capacity with investments of USD 201.0 billion is needed. Whereas, to reach ASEAN's 23% RE target by 2025 in APS will require an estimated total investment over the period of USD 214.3 billion to install 145.3 GW of added capacity.

Table 7. Cumulative Added Capacity and Power Sector Investments for 2016-2025

Fuel Types		Additional Capacity (GW)[10]			Investment (USD billion)[11]		
		BAU	ATS	APS	BAU	ATS	APS
Fossil Fuels	Coal	56.2	32.2	14.8	61.4	34.5	15.3
	Oil	0.9	0.2	-	0.9	0.2	-
	Natural Gas	17.7	14.8	14.2	12.3	10.4	9.9
Renewables	Hydro	26.3	39.1	43.9	53.0	78.9	88.5
	Geothermal	2.4	5.3	5.9	8.4	18.8	21.2
	Wind	4.9	9.0	12.3	6.6	12.1	16.5
	Solar	8.8	32.5	41.5	10.3	38.3	48.8
	Biomass	1.2	5.9	12.7	1.4	7.8	14.0
Total		**117.5**	**138.8**	**145.3**	**154.5**	**201.0**	**214.3**
Yearly (Average)		**11.8**	**13.9**	**14.5**	**15.4**	**20.1**	**21.4**

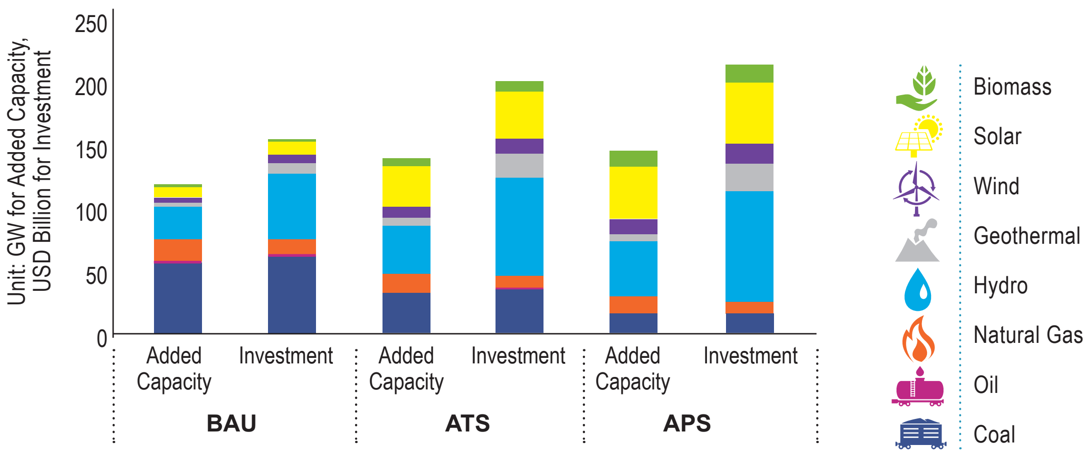
[10] Power Development Plans (PDP) of the AMS that was used to project the future installed capacity already considered the future retirement of the power plants. With this, the assumptions of the Additional Capacity includes both the new and decommissioned installation.

[11] The technology-specific investments are based on data taken from the 'World Energy Outlook' (*http://www.worldenergyoutlook.org/weomodel/investmentcosts/*). As no specific reference is made to ASEAN, the specific investments refer to the figures given for South Asia assuming learning rates from WEO. The investment was calculated based on capital cost, without considering operation & maintenance cost and decommissioning cost.

As illustrated further in **Figure 89**, about 51.6% of the investments in BAU is allocated for the construction of 43.6 GW of RE power plants, expecting to contribute 28.9% of the total RE installed capacity in 2025. However, coal is still dominant with the highest cumulative investments of 39.8% amounting to USD 61.4 billion. On the average, for BAU, ASEAN is projected to allocate USD 15.4 billion annually, or about 0.6% of its GDP in 2015.

For ASEAN to gear itself in achieving the individual national targets in ATS, they have to inject a cumulative amount of USD 201.0 billion during this period. Compared with BAU, an additional cumulative investment of USD 46.5 billion is needed. RE will account for 77.6% of the total investments. In this scenario, the RE share can be increased to 41.2% of its installed capacity in 2025. Hydro will be the major option for RE investments in ASEAN with a total investment of USD 78.9 billion followed by solar at USD 38.3 billion. There is a significant reduction of about 43.9% or amounting to USD 26.9 billion in the coal investments by the region in ATS as compared to BAU. On the average, ASEAN is projected to require USD 20.1 billion annually, or about 0.8% of its GDP in 2015.

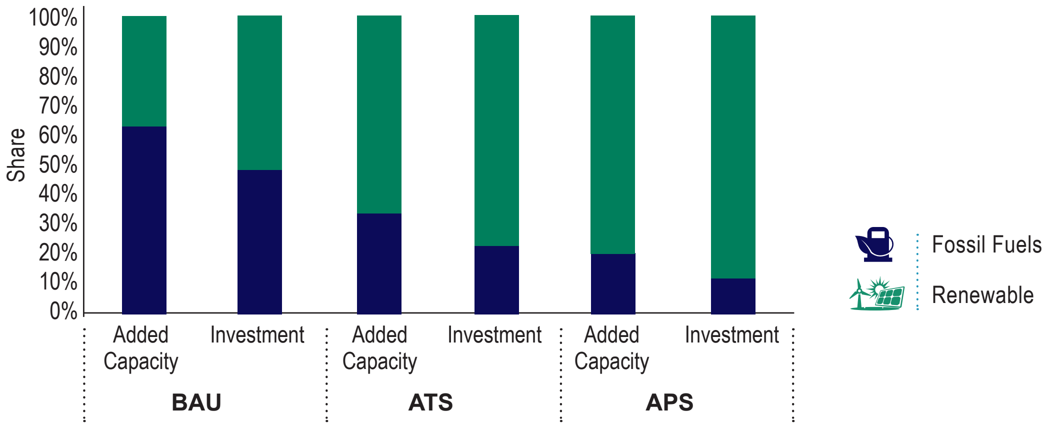
Figure 89. **Cumulative Added Capacity and Power Sector Investments for 2016-2025**



In ATS, ASEAN is projected to reach only 17.5% of RE share in TPES by 2025 which falls short of the 23% in the APAEC target. It is envisaged apart from completely ensuring that ATS is reached, further investments need to be allocated. The incremental cost of APS is USD 1.3 billion annually as compared to ATS. An additional investment USD 3.31 billion annually is needed for RE, of which USD 1.99 billion annually for fossil fuels is redirected to RE. All of these efforts are expected to assist the region to achieve its target of 23% of RE in TPES, amounting to 47.5% of installed capacity from RE. On average, for APS, ASEAN is projected to allocate USD 21.4 billion annually, or about 0.9% of its GDP in 2015.

Figure 90. clearly indicates for the APAEC period in spite of the downward trend of the solar cost, it still will not be cost competitive with fossil fuel technology especially coal. As such, the investments required for the same MW is about 1.8 times on the average compared to fossil fuel technology.

Figure 90. **Share Comparison of Capacity and Investments 2016-2025**



Beyond APAEC Horizon. Table 8. illustrates the cumulative added capacity and power sector investments (total and annual average) for BAU, ATS and APS over the projection period (2026-2040) beyond APAEC timeline (2016-2025). As previously highlighted in Chapter 2.3, energy efficiency applied in ATS and APS contributes to power demand reduction. From 2026 to 2040, ASEAN will add 306.6 GW of electricity in BAU. With energy efficiency initiatives in ATS, the additional installed capacity could reduce up to 20.4% as compared to BAU, which could then further decrease up to 24.9% in APS.

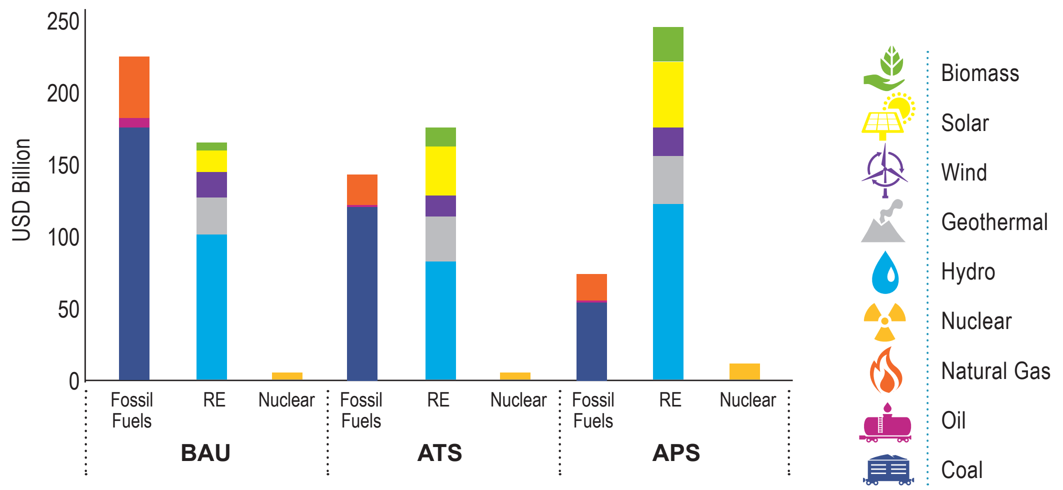
Table 8. Cumulative Added Capacity and Power Sector Investments for 2026-2040

Fuel Types		Additional Capacity (GW)			Investment (USD billion)		
		BAU	ATS	APS	BAU	ATS	APS
Fossil Fuels	Coal	147.5	100.7	45.7	177.0	120.8	54.9
	Oil	5.4	1.3	-	5.4	1.3	0.5
	Natural Gas	61.6	29.9	26.8	43.1	21.0	18.8
Renewables	Hydro	48.4	39.7	58.1	101.6	83.4	122.0
	Geothermal	7.9	9.5	10.3	26.4	31.9	34.8
	Wind	14.2	10.9	14.3	18.3	14.1	18.6
	Solar	17.0	43.8	59.8	13.2	33.9	46.3
	Biomass	2.6	6.3	11.1	5.5	13.3	23.6
Nuclear	Nuclear	2.0	2.0	4.0	5.6	5.6	11.2
Total		306.6	244.1	230.3	396.1	325.2	330.6
Yearly (Average)		20.4	16.3	15.4	26.4	21.7	22.0

The cumulative investments needed for additional power plant capacities in BAU beyond the APAEC timeline is USD 396.1 billion comprising of investments for fossil fuels, RE and nuclear which could become part of the energy mix. The nuclear option depends very much on the national policy directions taken within the present APAEC period. **Figure 91.** shows the continued trend in BAU i.e. 57.9% of the investments will be allocated for fossil fuel technology, mostly for coal. In this scenario, within the RE investments, hydro remains the major option with 24.4% of the investments, while the combined investment for solar PV and wind is 7.1%.
The investment requirements in ATS is 20% less than BAU with a higher share of RE. More than half of cumulative investments in ATS is for RE, of which 20.4% is for hydro. The investment for non-hydro renewable is around USD 93.0 billion of which the share of solar PV and geothermal make up 70.7% of the said investment.

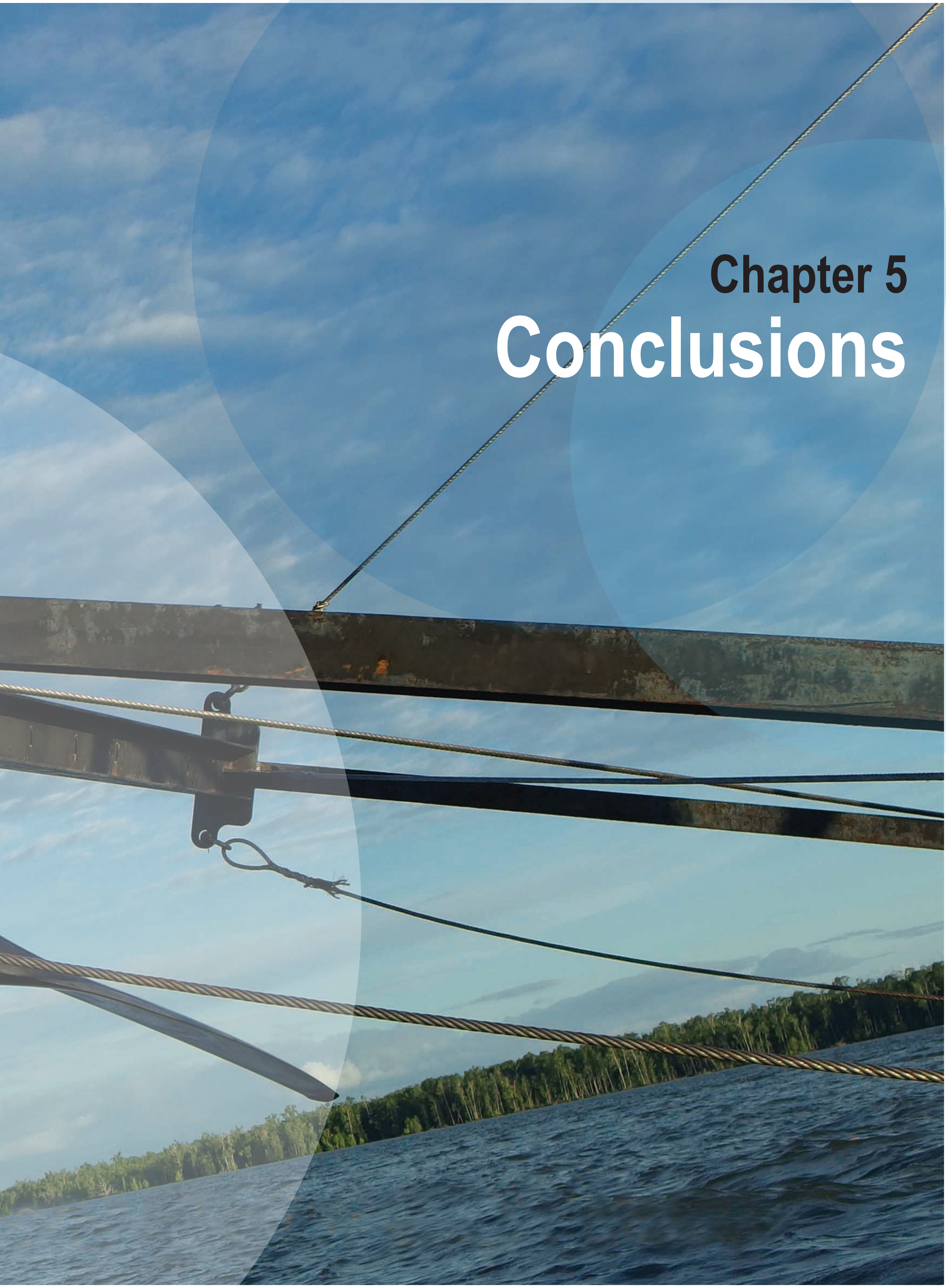
In APS, the investment for fossil fuel technology drops to 22.4%. Hydro remains the biggest share with 37.0% of total cumulative investments. Due to more ambitious target applied in APS, investments for solar PV account for 14.0% of USD 330.6 billion invested beyond APAEC timeline, followed by geothermal and biomass. Nuclear will have a higher share in APS compared to ATS amounting to an increase of investment of USD 5.6 billion by 2040.

Figure 91. **Composition of Cumulative Power Investments 2026-2040**



To reach the APAEC target, ASEAN needs to further increase the total installed capacity by another 1.7% from the ATS. This requires the commitment for higher investments in the power sector. If these are achieved during the APAEC period by 2025, the required amount of the investments for ATS and APS are significantly lower than BAU beyond 2025. This finding proves that for ASEAN to integrate more RE in achieving sustainability, additional investment from BAU is not required in the long term.

Credit: ERI@N & OceanPixel Pte Ltd.



Chapter 5
Conclusions

5.1 KEY FINDINGS

AEO5 aims to provide policymakers and energy communities in the region with an understanding of future energy trends and challenges in ASEAN. Specifically, the scenario philosophy chosen in *AEO5* aims to provide answers to the following questions:

- **BAU**: What are the consequences to energy demand and supply, as well as CO_2 emissions, if ASEAN continues to follow past practice, primarily to use fossil fuels to meet growing energy needs.
- **ATS**: What are the implications for energy demand and supply, as well as CO_2 emissions if AMS attain their officially issued EE and RE national targets?
- **APS**: What efforts are required from each AMS on EE and RE to meet the regional APAEC 2016-2025 targets?

The main findings relate to the total final energy demand, the power sector, the primary energy supply, challenges to reserves, and environmental challenges, as well as the APAEC 2016-2025 EI and RE targets. These are summarised below.

TFEC will increase constantly in ASEAN during the projection period 2015-2040. Substantial savings can be achieved in ATS and APS.

- In BAU, TFEC is projected to reach the highest growth among all scenarios, with a CAGR of 3.6% and reaching 1,046 Mtoe by 2040. This projection reflects how ASEAN's energy demand will develop if the expected economic and population growth materialises, but in absence of ambitious EE policies which could drive energy demand down in years ahead, even in the event of continuing economic prosperity.
- In ATS, in view of the combined national EE targets, ASEAN could lower its TFEC to 856 Mtoe. This represents savings of 18.1% in 2040, i.e. reaching the 81.9% level of BAU.
- In APS, TFEC could reach a value of 771 Mtoe in 2040, reflecting 26.3% of savings in that year, and representing a 73.7% level as compared to BAU. These savings could materialise as the result of maintaining the ambition level of currently issued EE targets over the whole timeframe 2015-2040.
- The importance of traditional biomass as a share of residential TFEC in 2040 is projected to decrease in ASEAN across all scenarios, from 65% in 2015 to 48% in BAU, to 46% in ATS, and to 44% in APS.

TPES will considerably increase during the projection period. Substantial savings can be achieved in ATS and APS.

- In BAU, TPES is expected to rise from 627 Mtoe in 2015 to 1,450 Mtoe by 2040, growing by a CAGR of 3.4%. This number reflects how the ASEAN TPES would develop if the expected economic and population growth materialises, but in absence of ambitious EE and RE policies. Oil keeps its dominant share in TPES, with a nearly unchanged value of 35% over the projection period. In contrast, coal grows with the highest CAGR of 4.3% to reach a share of 22.7% in 2040, while starting with an initial share of 18.5% in 2015. ASEAN TPES in 2040 is composed of 78.6% fossil fuels, 13.5% RE sources, 6.4% traditional biomass, and others are the remainder.
- In ATS, TPES is expected to rise to 1,249 Mtoe in 2040, reflecting a CAGR of 2.8%. TPES in 2040 represents 86.1% of BAU level and hence, savings of 13.9% by 2040 can be achieved by reaching the nationally issued AMS EE and RE targets. Oil is projected to nearly keep its share among TPES, reaching a value of 33% in 2040. Coal, as in BAU, has the highest growth rate among fossil fuels, with a CAGR of 3.4%. Starting from a share of 18.5% in 2015, coal's share rises to reach 21.5% in 2040. TPES in 2040 is composed of 73.2% fossil fuels, 21.4% RE sources, and traditional biomass is the remainder.
- In APS, TPES is expected to reach 1,123 Mtoe in 2040, reflecting a CAGR of 2.4% during the projection period. TPES in 2040 represents 77.4% as compared to BAU level and hence savings of 22.6% by 2040. Oil will grow with a CAGR of 1.7%. Coal is projected to expand with a moderate CAGR of 2.1%, and will contribute with a share of 18.5% to TPES in 2040. TPES in 2040 comprises of 64.3% fossil fuels, 31.8% RE sources, and the rest is traditional biomass.

A substantial increase in installed power capacity is required to cope with the strongly rising electricity demand in ASEAN. However, enhanced efficiency can lower installed capacity requirements substantially. Renewable power generation can play an important role in dealing with ASEAN's rising power demand.

- In BAU, coal-based plants will rise in capacity from 63 GW in 2015 to 267 GW in 2040, while oil will reach 21 GW and natural gas is projected to reach 156 GW by 2040. A total installed capacity from RE of 183 GW in 2040 is projected to be covered by hydro with 64.0%, solar PV with 14.8%, wind energy with 10.8%, geothermal with 7.4%, and biomass with 3.1%. The share of variable RE in total installed capacity is projected to be 29.2% by 2040.
- In ATS, coal power plants are projected to experience considerable growth and are thus projected to reach 196 GW. Capacity from natural gas is projected to increase from 77 GW in 2015 to 91 GW in 2025 and up to 121 GW in 2040. Oil fired power plants will remain much in the same range as for 2015, showing a near overall stagnation from 16 GW in 2015 to 17 GW in 2040. In 2040, the total installed RE capacity will be 252 GW, of which hydro represents roughly one half (48.3%) and solar PV one third (30.8%). Wind, geothermal and biomass will comprise shares of 8.1%, 7.2% and 5.6%, respectively. The share of variable RE in total installed capacity is projected to be considerably higher than in BAU, representing 42.8% in 2040.
- In APS, installed capacity from coal will increase by a factor of 2.0 from 63 GW in 2015 to 78 GW in 2025 and to 124 GW in 2040. Natural gas installed capacity will reach 118 GW in 2040, and oil plant capacity is projected to decrease by a yearly rate of -0.3% from 16 GW in 2015 to 15 GW in 2040. The total installed RE capacity will rise to 320 GW and have a diverse capacity mix among renewable technologies. Hydro will represent 45.2%, followed by solar PV with 32.1%, wind with 8.5%, biomass with 8.0%, and geothermal with 6.1%. The share of variable RE in total installed capacity is projected to be higher than in BAU and ATS, representing 55.2% in 2040. Therefore, APS represents the most ambitious scenario regarding the transition towards implementing low-carbon technologies in the power sector.

Electricity demand and supply is projected to rise considerably in ASEAN in the years ahead. However, enhancing EE leads to savings of 0.8% per year in ATS and 1% per year in APS.

- In BAU, total power generation is highest for generation from fossil fuels, with 2,638 TWh. This considerable increase reflects on the one hand ASEAN´s expected economic prosperity, while as well a general shift among energy carriers in the final energy demand towards electricity. The strongly growing industrial sector, as well as both the commercial and residential sector exhibit trends of an increased demand for electricity among the relative distribution of demanded energy carriers. Total generation from RE amounts to 696 TWh and consists of 74.5% hydro, 9.0% geothermal, 7.7% solar PV, 6.1% wind, and 2.8% biomass.
- In ATS, there is a significant saving in electricity generation of 472 TWh, or 17.9% as compared to BAU, reflecting the impact of the combined EE targets among AMS. In addition, the impact of RE targets on renewable power generation leads to an increase of 94 TWh or 13.5% of RE power generation in 2040 as compared to BAU. Total generation from RE amounts to 790 TWh by 2040 and consists of 48.1% hydro, 17.4% solar PV, 15.1% geothermal, 10.0% biomass, and 9.4% wind.
- APS shows a further reduced demand for electricity, reaching nearly 600 TWh or 23% as compared to BAU by 2040. For APS, there is a large shift towards RE power generation, with 1,060 TWh as opposed to 696 TWh in BAU, representing an increase of 364 TWh or 52.3% by 2040 as compared to BAU. Total generation from RE is composed of 46.7% hydro, 18.1% solar PV, 12.2% geothermal and biomass, and 10.7% wind.

ASEAN is well on track to reach the APAEC 2016-2025 EI target. Stronger efforts in EI could be targeted by AMS.

- As stated in APAEC 2016-2025, ASEAN has the aspirational target to reduce EI by 20% by 2020 as a medium-term target and 30% by 2025 as a long-term target based on the 2005 level.
- The medium-term (2020) component is reached in all scenarios, exceeding the target by 5% in BAU, 8% in ATS and 9% in APS.
- In the long-term (2025) component , EI is reduced by 29% in 2025 in BAU, thereby missing the target with a gap of 1%. However, it exceeds by 5% and 8% in ATS and APS, respectively.

As stated in APAEC 2016-2025, ASEAN has the aspirational target to increase the share of RE to 23% by 2025 in the energy mix. Reaching the APAEC 2016-2025 RE target component will require stronger efforts than currently foreseen by AMS.

- In BAU, ASEAN will reach a share of only 13% RE in TPES by 2025. In ATS, i.e. by reaching the officially declared EE and RE targets of AMS, a share of 17% is projected. Thus, more ambitious national targets in EE and RE than currently issued are required by AMS if ASEAN is to reach a share of 23% RE in TPES by 2025.
- APS is conceived to reach a 23% share by 2025 and thus provides a possible path in all sectors that could be followed by AMS to reach the APAEC RE targets. RE in the power sector will contribute the most to reaching the ASEAN RE target. The share of RE in the power sector as a fraction of TPES is projected to be 15% in APS by 2025, corresponding to 165 GW of RE capacity, consisting of 52% hydro, 26% solar, 8% wind, and 6% geothermal. In APS, RE in the final energy consumption sectors (biofuels, modern biomass, biogas, etc.) will account for the remainder 8% to reach the APAEC RE target component. In particular, AEO5 projects 5.5% contribution from biofuels and 2.5% contribution from other RE sources in TFEC.

Both the EI and the RE targets of APAEC 2016-2025 are complementary.

- EE and RE are complementary. Thus, reaching the RE target component is facilitated if TPES is substantially reduced by fostering EE. In view of ASEAN being on track to reach the EI target component, ASEAN could consider tightening the EI target to further reduce TPES which could contribute to achieving the RE target.

Substantially increased export volumes, as well as substantially lower import volumes, can be achieved by reaching higher EE and shifting towards RE, reflecting the multiple benefits of EE and RE.

- Total production of coal is projected to be 487 Mtce by 2040. Contrasting this production with the primary requirements in BAU (462 Mtce), ATS (375 Mtce) and APS (272 Mtce), substantially increased export volumes can be freed by reaching the ambitious EE and RE policies as considered in the scenario modelling.
- Total primary production of natural gas is projected to decrease by 0.6% per year after 2015, reaching 85.7% of the present production level in 2040 (which corresponds to 177 bcm). By 2040, ASEAN will be a net importer of natural gas. However, BAU imports are four times bigger than in APS, reflecting the clear benefits of enhancing EE and RE to ASEAN's import dependency.
- Total primary production of crude oil is projected to decrease to 85 Mtoe in 2040. In BAU, oil primary requirements in ASEAN in 2040 are projected to reach 505 Mtoe, exceeding the production by a factor of nearly six and implying minimum oil imports of 420 Mtoe. In ATS, demand exceeds production by a factor of 4.8 (409 Mtoe in 2040), and minimum oil imports of 324 Mtoe would be required. In APS, the demand in 2040 is estimated at 360 Mtoe which would exceed the production capacity by a factor of 4.2 and entail a reduced import volume of crude oil of 275 Mtoe. In conclusion, although oil import dependency will increase in all scenarios, substantial improvements in import dependency can be achieved by enhancing EE and RE.

Refining capacity is projected to increase in ASEAN, both in the medium- as well as in the long-term. Enhanced EE will lead to substantially reduced requirements of minimum imports.

- Refining capacity is projected to increase from its current level of 3.9 Mbbl/d to 6.1 Mbbl/d in 2025 and 7.7 Mbbl/d in 2040. This development already reflects announced capacity expansion, as well as long-term considerations of future expansion incorporated in *AEO5*. Reaching EE targets in the scenarios also yields a substantially reduced import dependency. Concretely, in BAU, demand surpasses refining capacity by 1.2 Mbbl/day (~62 Mtoe) in 2040, whereas in APS, refining capacity surpasses demand by 1.5 Mbbl/d (~77 Mtoe).

GHG related emissions from energy conversion will increase in the years ahead, mainly driven by economic and population growth. ASEAN can substantially reduce GHG emissions by enhancing EE and RE. GHG emissions from energy conversion are projected to grow during the whole projection period.

- Considerable savings of 23% in ATS can be achieved, reaching a 77% level as compared to BAU. In addition, 37% savings can be reached in APS, attaining a 63% level as compared to BAU by 2040.
- Decomposition analysis allows accounting for the factors driving GHG emissions up and down in the years to come. Following the widespread Kaya-Identity analysis, *AEO5* decomposes the development of GHG emissions considering four factors: prosperity (economic growth expressed in per capita GDP), population growth, EI and CO_2 emissions, and the intensity of the economy (carbon intensity).
- The results of this analysis show that emissions will be driven up by a future increase in economic prosperity and population growth. However, the figure can be substantially reduced by improvements in EI due to enhanced EE as well as reduced GHG emission by the uptake of RE.
- Thus, AMS can substantially reduce their emissions from energy production by enhancing EE and RE and thereby contribute to meeting their nationally determined contributions as declared for COP21.

Significant efforts are needed from the power sector in contributing to the APAEC RE target. To reach APAEC target, ASEAN needs to continue with its EE efforts while ensuring the needed investments to integrate more RE by 2025. In the longer term beyond 2025, a 55.2% RE in the 2040 installed capacity mix can be sustained with significantly lower investments than BAU.

- For APAEC period, ASEAN will require additional power capacity of 117.5 GW in the BAU, entailing USD 154.5 billion in investments. In ATS, 138.8 GW of additional capacity with investments of USD 201 billion is needed. Whereas, to reach ASEAN's 23% RE target by 2025 in APS will require an estimated total investment over the period is USD 214.3 billion to add 145.3 GW capacity.
- Beyond the APAEC period, ASEAN will require additional power capacity of 306.6 GW in the BAU, entailing USD 396.1 billion in investments. In ATS, 244.1 GW of additional capacity with investments of USD 325.2 billion is needed. Whereas, APS will require an estimated total investment over the period is USD 330.6 billion to add 230.3 GW capacity.
- Assuming ASEAN reaches the RE target during the APAEC period, the required amount of investment for ATS and APS would be significantly lower than BAU beyond 2025. In APS, there is a reduction of 16.5% in investment as compared to BAU. This will contribute to 55.2% of RE in the total installed capacity in 2040. This finding proves that ASEAN's goal for integration and sustainability of RE can be achieved with lesser investment in the long term.

Credit: ACE

5.2 RECOMMENDATIONS

The main features of *AEO5* are the strongly increasing primary and final energy demands, as well as the rising electricity demand, especially in BAU. Following this rise in demand, the consumption of fossil fuels will grow strongly with important implications for ASEAN economies, supply security and local as well as global environment impacts. As reflected in this *Outlook*, current ASEAN energy policies, both at the regional and national levels in ATS and APS are aiming to counter such impacts (for further details on current EE and RE policies, see Annex B – Current EE and RE Policies). The following recommendations point to specific actions to enforce achieving, in particular, the APAEC targets.

1. **Enhance synergies between EE and RE targets.** Fossil fuels still achieve comparatively high growth rates in this Outlook, in particular coal. EE and RE are major strategies to mitigate the penetration of fossil fuels while opening up opportunities for local manufacturing. The Outlook shows that AMS are close to achieving stated EE targets. This is an improvement compared to the situation found in *AEO4*. This is partly due to improving efficiency in the economy, and partly due to lower economic growth as expected in *AEO4*. This context can be used to enhance achievement of the APAEC RE target. Improving EE and reducing EI leads to lower requirements of power capacity and generation. ASEAN is well on track to reach the APAEC 2016-2025 EI target, but stronger efforts will be required to reach the RE target. Hence, ASEAN could consider tightening the EI target component and thereby help reach the RE target component.

2. **Implement stronger policies in both EE and RE to reach both the EI and RE components of the APAEC 2016-2025 targets:**
   a. Regarding EE, stronger cooperation in the introduction and harmonisation of labelling and minimum energy performance standards could be targeted by AMS, as well as rationalise subsidy in electricity tariff, introduce ToU (Time of Use) tariff.
   b. Regarding RE, region needs to impose carbon pricing, consider electricity market reforms, rationalise electricity tariff subsidy and stronger consideration of auctions as an incentive to foster competition as well as more strongly deploy RE capacity in the power sector could also be targeted by AMS (for further details see Annex C – RE Auction). But this new market requires comprehensive in-depth study especially on regulatory and pre-emptying anti-competitive behaviour if any. Strongly coordinated policies with respect to the electricity infrastructures and electricity markets could contribute to achieving APAEC RE targets, as identified in *AEO4*. These policies will become more important in the next years given the strong decline of costs for RE and energy storage. This is reflected in this *Outlook*, in particular in APS, under which RE reach a share of about 50% in power generation by 2040. However, further developments are difficult to predict and could occur even faster than supposed for APS. Investment in fossil fuels and their infrastructures should therefore carefully scrutinise the ongoing developments to avoid stranded investments and to seize opportunities for ASEAN economies. Carbon tax needs to be introduced as well to provide social cost of energy.

Developing such policies could benefit significantly from strong cooperation and harmonisation across AMS, including on legal aspects, testing procedures, and market organisation, for example. Holistically, the framework should also address intermittency issues with regard to RE applications which may warrant dedicated amount of spinning reserve from fossil fuel and large hydro plants to arrest sudden loss of RE power from the grid.

3. **Formulate RE policies beyond the power sector.** While RE in the power sector contributes most to the target achievements, reaching the APAEC targets will require not only focusing on the power sector, but also focusing on RE in the final energy consumption sectors. Fostering the demand-side use of RE, such as modern biomass, biogas and biofuels, should additionally be targeted by AMS. Enforcing strong sustainability criteria in the production of biofuels must also be considered in order to guarantee environmental benefits from their increased use.

4. **Improve data availability.** While this *Outlook* has considerably improved the database for the projections, improving data availability at AMS level should be a continuing effort. Moreover, information credibility and accessibility needs to be improved significantly to be effective in long-term policy formulation as well. Developing harmonised energy indicators could support AMS efforts to improve their statistical database. Improvements could provide more detailed data on end-uses to allow building harmonised bottom-up demand models for all AMS. With the rise of RE share, time-resolved models for the electricity sector which consider interconnections of AMS and options such as energy storage, the technology mix etc. are also required. Analysis of the impacts of single policies is also a field where further work would provide benefits.

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Annex

Annex A – ASEAN Overview Tables

Total Primary Energy Supply	Absolute, Mtoe							
	2005	2015	2020	2025	2030	2035	2040	2005
Total	**455**	**627**	**744**	**916**	**1,086**	**1,263**	**1,450**	**100%**
Coal	54	116	150	190	232	278	329	12%
Oil	176	207	263	323	382	445	505	39%
Natural gas	112	149	162	201	233	266	305	25%
Nuclear	-	-	-	-	-	1	3	0%
Hydro	7	18	24	30	39	43	51	1%
Geothermal	9	12	21	29	35	44	54	2%
Others Renewables	27	55	48	60	70	81	92	6%
Traditional Biomass	71	67	71	78	83	89	94	16%
Others	-	3	4	6	11	15	18	0%

Total Final Energy Consumption	Absolute, Mtoe							
	2005	2015	2020	2025	2030	2035	2040	2005
Total	**306**	**427**	**526**	**653**	**780**	**912**	**1,046**	**100%**
Industry	96	123	156	201	246	293	340	31%
Transportation	79	124	159	203	244	288	331	26%
Residential	95	104	117	135	154	174	196	31%
Commercial	14	25	32	41	49	58	67	5%
Agriculture	6	9	11	13	16	19	22	2%
Non-energy use	17	41	51	61	70	80	91	6%
Total	**306**	**427**	**526**	**653**	**780**	**912**	**1,046**	**100%**
Coal	23	30	31	41	51	62	73	7%
Oil	137	168	245	303	359	416	472	45%
Natural Gas	21	44	54	70	85	102	121	7%
Electricity	38	82	93	118	146	176	207	12%
Biofuels	0	14	9	15	21	29	39	0%
Traditional Biomass	69	66	71	78	83	89	94	23%
Others	18	24	24	29	34	38	41	6%

Power Generation	Absolute, TWh							
	2005	2015	2020	2025	2030	2035	2040	2005
Total	**500**	**927**	**1,184**	**1,481**	**1,864**	**2,219**	**2,638**	**100%**
Coal	118	308	445	570	712	876	1,062	24%
Oil	69	37	53	60	69	82	92	14%
Natural gas	240	381	388	497	579	666	772	48%
Nuclear	-	-	-	-	-	8	16	0%
Hydro	55	146	239	304	388	441	519	11%
Geothermal	17	21	25	33	41	51	62	3%
Other Renewables	1	34	34	49	75	95	115	0%

Emissions	Absolute, Mt-CO2eq						
	2005	2015	2020	2025	2030	2035	2040
Total	**1,002**	**1,446**	**1,745**	**2,151**	**2,556**	**3,000**	**3,464**

Business-as-Usual Scenario (BAU)

Share, %						CAGR, %			
2015	2020	2025	2030	2035	2040	2005-2015	2015-2025	2025-2040	2015-2040
100%	**100%**	**100%**	**100%**	**100%**	**100%**	**3.3%**	**3.9%**	**3.1%**	**3.4%**
19%	20%	21%	21%	22%	23%	7.9%	5.1%	3.7%	4.3%
33%	35%	35%	35%	35%	35%	1.6%	4.6%	3.0%	3.6%
24%	22%	22%	21%	21%	21%	2.9%	3.1%	2.8%	2.9%
0%	0%	0%	0%	0%	0%	-	-	-	-
3%	3%	3%	4%	3%	4%	10.7%	5.2%	3.6%	4.2%
2%	3%	3%	3%	3%	4%	2.6%	9.3%	4.3%	6.3%
9%	6%	7%	6%	6%	6%	7.3%	0.8%	2.9%	2.0%
11%	10%	8%	8%	7%	6%	-0.6%	1.5%	1.3%	1.4%
1%	1%	1%	1%	1%	1%	-	5.8%	7.6%	6.9%

Share, %						CAGR, %			
2015	2020	2025	2030	2035	2040	2005-2015	2015-2025	2025-2040	2015-2040
100%	**100%**	**100%**	**100%**	**100%**	**100%**	**3.4%**	**4.3%**	**3.2%**	**3.6%**
29%	30%	31%	32%	32%	32%	2.5%	5.0%	3.6%	4.1%
29%	30%	31%	31%	32%	32%	4.7%	5.0%	3.3%	4.0%
24%	22%	21%	20%	19%	19%	0.9%	2.6%	2.5%	2.5%
6%	6%	6%	6%	6%	6%	6.1%	4.9%	3.4%	4.0%
2%	2%	2%	2%	2%	2%	4.5%	4.1%	3.5%	3.7%
10%	10%	9%	9%	9%	9%	9.1%	4.0%	2.7%	3.2%
100%	**100%**	**100%**	**100%**	**100%**	**100%**	**3.4%**	**4.3%**	**3.2%**	**3.6%**
7%	6%	6%	7%	7%	7%	2.8%	3.1%	3.9%	3.6%
39%	46%	46%	46%	46%	45%	2.0%	6.1%	3.0%	4.2%
10%	10%	11%	11%	11%	12%	7.6%	4.7%	3.8%	4.1%
19%	18%	18%	19%	19%	20%	7.9%	3.7%	3.8%	3.8%
3%	2%	2%	3%	3%	4%	-	0.8%	6.7%	4.3%
15%	14%	12%	11%	10%	9%	-0.5%	1.6%	1.3%	1.4%
6%	5%	5%	4%	4%	4%	3.1%	2.0%	2.1%	2.1%

Share, %						CAGR, %			
2015	2020	2025	2030	2035	2040	2005-2015	2015-2025	2025-2040	2015-2040
100%	**100%**	**100%**	**100%**	**100%**	**100%**	**6.4%**	**4.8%**	**3.9%**	**4.3%**
33%	38%	39%	38%	39%	40%	10.0%	6.3%	4.2%	5.1%
4%	5%	4%	4%	4%	4%	-6.1%	5.1%	2.9%	3.8%
41%	33%	34%	31%	30%	29%	4.7%	2.7%	3.0%	2.9%
0%	0%	0%	0%	0%	1%	-	-	-	-
16%	20%	21%	21%	20%	20%	10.2%	7.6%	3.6%	5.2%
2%	2%	2%	2%	2%	2%	2.5%	4.7%	4.3%	4.4%
4%	3%	3%	4%	4%	4%	41.6%	-7.2%	14.0%	5.0%

CAGR, %			
2005-2015	2015-2025	2025-2040	2015-2040
3.7%	**4.1%**	**3.2%**	**3.6%**

Total Primary Energy Supply	Absolute, Mtoe							
	2005	2015	2020	2025	2030	2035	2040	2005
Total	**455**	**627**	**720**	**839**	**970**	**1,103**	**1,249**	**100%**
Coal	54	116	142	165	196	230	269	12%
Oil	176	207	249	284	324	366	409	39%
Natural gas	112	149	153	177	194	213	237	25%
Nuclear	-	-	-	-	-	2	3	0%
Hydro	7	18	19	23	28	30	33	1%
Geothermal	9	12	32	48	65	82	103	2%
Others Renewables	27	55	56	75	95	113	131	6%
Traditional Biomass	71	67	71	72	73	73	72	16%
Others	-	3	(3)	(5)	(6)	(5)	(7)	0%

Total Final Energy Consumption	Absolute, Mtoe							
	2005	2015	2020	2025	2030	2035	2040	2005
Total	**306**	**427**	**495**	**577**	**667**	**758**	**856**	**100%**
Industry	96	123	146	176	208	240	275	31%
Transportation	79	124	148	175	205	235	267	26%
Residential	95	104	111	119	129	141	154	31%
Commercial	14	25	30	36	42	48	54	5%
Agriculture	6	9	10	12	14	16	18	2%
Non-energy use	17	41	49	59	68	78	88	6%
Total	**306**	**427**	**495**	**577**	**667**	**758**	**856**	**100%**
Coal	23	30	29	36	43	50	58	7%
Oil	137	168	230	269	310	351	394	45%
Natural Gas	21	44	51	62	75	88	103	7%
Electricity	38	82	86	104	123	144	167	12%
Biofuels	0	14	8	13	19	25	33	0%
Traditional Biomass	69	66	68	69	69	70	71	23%
Others	18	24	22	25	27	29	29	6%

Power Generation	Absolute, TWh							
	2005	2015	2020	2025	2030	2035	2040	2005
Total	**500**	**927**	**1,138**	**1,269**	**1,627**	**1,877**	**2,166**	**100%**
Coal	118	308	387	451	541	649	777	24%
Oil	69	37	64	62	65	73	77	14%
Natural gas	240	381	343	397	425	457	507	48%
Nuclear	-	-	-	-	-	8	16	0%
Hydro	55	146	224	265	323	351	380	11%
Geothermal	17	21	38	56	76	96	119	3%
Other Renewables	1	34	83	141	197	244	291	0%

Emissions	Absolute, Mt-CO2eq						
	2005	2015	2020	2025	2030	2035	2040
Total	**1,002**	**1,446**	**1,594**	**1,812**	**2,071**	**2,345**	**2,656**

AMS Targets Scenario (ATS)

Share, %						CAGR, %			
2015	2020	2025	2030	2035	2040	2005-2015	2015-2025	2025-2040	2015-2040
100%	**100%**	**100%**	**100%**	**100%**	**100%**	**3.3%**	**3.0%**	**2.7%**	**2.8%**
19%	20%	20%	20%	21%	21%	7.9%	3.6%	3.3%	3.4%
33%	35%	34%	33%	33%	33%	1.6%	3.2%	2.5%	2.8%
24%	21%	21%	20%	19%	19%	2.9%	1.8%	2.0%	1.9%
0%	0%	0%	0%	0%	0%	-	-	-	-
3%	3%	3%	3%	3%	3%	10.7%	2.3%	2.4%	2.4%
2%	4%	6%	7%	7%	8%	2.6%	15.2%	5.1%	9.0%
9%	8%	9%	10%	10%	11%	7.3%	3.1%	3.8%	3.5%
11%	10%	9%	8%	7%	6%	-0.6%	0.8%	0.0%	0.3%
1%	0%	-1%	-1%	0%	-1%	-	-	-	-

Share, %						CAGR, %			
2015	2020	2025	2030	2035	2040	2005-2015	2015-2025	2025-2040	2015-2040
100%	**100%**	**100%**	**100%**	**100%**	**100%**	**3.4%**	**3.0%**	**2.7%**	**2.8%**
29%	30%	30%	31%	32%	32%	2.5%	3.6%	3.0%	3.3%
29%	30%	30%	31%	31%	31%	4.7%	3.5%	2.9%	3.1%
24%	22%	21%	19%	19%	18%	0.9%	1.3%	1.7%	1.6%
6%	6%	6%	6%	6%	6%	6.1%	3.7%	2.8%	3.1%
2%	2%	2%	2%	2%	2%	4.5%	3.2%	3.0%	3.0%
10%	10%	10%	10%	10%	10%	9.1%	3.7%	2.7%	3.1%
100%	**100%**	**100%**	**100%**	**100%**	**100%**	**3.4%**	**3.0%**	**2.7%**	**2.8%**
7%	6%	6%	6%	7%	7%	2.8%	1.7%	3.3%	2.6%
39%	47%	47%	47%	46%	46%	2.0%	4.8%	2.6%	3.5%
10%	10%	11%	11%	12%	12%	7.6%	3.5%	3.5%	3.5%
19%	17%	18%	18%	19%	20%	7.9%	2.4%	3.3%	2.9%
3%	2%	2%	3%	3%	4%	-	-0.4%	6.4%	3.6%
15%	14%	12%	10%	9%	8%	-0.5%	0.4%	0.2%	0.3%
6%	5%	4%	4%	4%	3%	3.1%	0.4%	1.0%	0.8%

Share, %						CAGR, %			
2015	2020	2025	2030	2035	2040	2005-2015	2015-2025	2025-2040	2015-2040
100%	**100%**	**100%**	**100%**	**100%**	**100%**	**6.4%**	**3.2%**	**3.6%**	**3.5%**
33%	34%	36%	33%	35%	36%	10.0%	3.9%	3.7%	3.8%
4%	6%	5%	4%	4%	4%	-6.1%	5.4%	1.4%	3.0%
41%	30%	31%	26%	24%	23%	4.7%	0.4%	1.6%	1.1%
0%	0%	0%	0%	0%	1%	-	-	-	-
16%	20%	21%	20%	19%	18%	10.2%	6.2%	2.4%	3.9%
2%	3%	4%	5%	5%	6%	2.5%	10.3%	5.1%	7.2%
4%	7%	10%	12%	13%	13%	41.6%	1.0%	14.7%	9.0%

CAGR, %			
2005-2015	2015-2025	2025-2040	2015-2040
3.7%	**2.3%**	**2.6%**	**2.5%**

Total Primary Energy Supply	Absolute, Mtoe							
	2005	2015	2020	2025	2030	2035	2040	2005
Total	**455**	**627**	**706**	**804**	**905**	**1,010**	**1,123**	**100%**
Coal	54	116	132	141	155	174	196	12%
Oil	176	207	229	250	271	294	315	39%
Natural gas	112	149	149	166	175	185	198	25%
Nuclear	-	-	-	-	-	1	5	0%
Hydro	7	18	20	25	32	35	43	1%
Geothermal	9	12	35	52	71	89	111	2%
Others Renewables	27	55	75	108	142	173	203	6%
Traditional Biomass	71	67	69	67	65	63	61	16%
Others	-	3	(3)	(5)	(6)	(6)	(10)	0%

Total Final Energy Consumption	Absolute, Mtoe							
	2005	2015	2020	2025	2030	2035	2040	2005
Total	**306**	**427**	**490**	**565**	**639**	**709**	**771**	**100%**
Industry	96	123	145	172	199	223	243	31%
Transportation	79	124	147	173	197	219	238	26%
Residential	95	104	108	114	121	128	134	31%
Commercial	14	25	30	35	41	45	50	5%
Agriculture	6	9	10	12	14	16	18	2%
Non-energy use	17	41	49	59	68	78	88	6%
Total	**306**	**427**	**490**	**565**	**639**	**709**	**771**	**100%**
Coal	23	30	29	35	41	47	51	7%
Oil	137	168	219	245	270	291	308	45%
Natural Gas	21	44	51	62	73	84	95	7%
Electricity	38	82	85	101	118	134	150	12%
Biofuels	0	14	17	31	48	64	81	0%
Traditional Biomass	69	66	66	64	63	62	60	23%
Others	18	24	23	27	27	27	27	6%

Power Generation	Absolute, TWh							
	2005	2015	2020	2025	2030	2035	2040	2005
Total	**500**	**927**	**1,135**	**1,182**	**1,557**	**1,764**	**2,039**	**100%**
Coal	118	308	351	373	407	461	527	24%
Oil	69	37	60	56	57	62	64	14%
Natural gas	240	381	321	348	347	350	364	48%
Nuclear	-	-	-	-	-	8	24	0%
Hydro	55	146	236	286	367	413	496	11%
Geothermal	17	21	41	61	82	104	130	3%
Other Renewables	1	34	126	212	297	366	435	0%

Emissions	Absolute, Mt-CO2eq						
	2005	2015	2020	2025	2030	2035	2040
Total	**1,002**	**1,446**	**1,563**	**1,706**	**1,853**	**2,012**	**2,168**

ASEAN Progressive Scenario (APS)

Share, %						CAGR, %			
2015	2020	2025	2030	2035	2040	2005-2015	2015-2025	2025-2040	2015-2040
100%	**100%**	**100%**	**100%**	**100%**	**100%**	**3.3%**	**2.5%**	**2.2%**	**2.4%**
19%	19%	18%	17%	17%	17%	7.9%	2.0%	2.2%	2.1%
33%	33%	31%	30%	29%	28%	1.6%	1.9%	1.6%	1.7%
24%	21%	21%	19%	18%	18%	2.9%	1.1%	1.2%	1.2%
0%	0%	0%	0%	0%	0%	-	-	-	-
3%	3%	3%	3%	4%	4%	10.7%	3.0%	3.7%	3.4%
2%	5%	6%	8%	9%	10%	2.6%	16.1%	5.2%	9.4%
9%	11%	13%	16%	17%	18%	7.3%	7.0%	4.3%	5.3%
11%	10%	8%	7%	6%	5%	-0.6%	0.1%	-0.7%	-0.4%
1%	0%	-1%	-1%	-1%	-1%	-	-	-	-

Share, %						CAGR, %			
2015	2020	2025	2030	2035	2040	2005-2015	2015-2025	2025-2040	2015-2040
100%	**100%**	**100%**	**100%**	**100%**	**100%**	**3.4%**	**2.8%**	**2.1%**	**2.4%**
29%	30%	30%	31%	31%	32%	2.5%	3.4%	2.3%	2.7%
29%	30%	31%	31%	31%	31%	4.7%	3.3%	2.2%	2.6%
24%	22%	20%	19%	18%	17%	0.9%	0.9%	1.1%	1.0%
6%	6%	6%	6%	6%	6%	6.1%	3.5%	2.3%	2.8%
2%	2%	2%	2%	2%	2%	4.5%	3.1%	2.8%	2.9%
10%	10%	10%	11%	11%	11%	9.1%	3.6%	2.7%	3.1%
100%	**100%**	**100%**	**100%**	**100%**	**100%**	**3.4%**	**2.8%**	**2.1%**	**2.4%**
7%	6%	6%	6%	7%	7%	2.8%	1.4%	2.6%	2.1%
39%	45%	43%	42%	41%	40%	2.0%	3.9%	1.5%	2.5%
10%	10%	11%	11%	12%	12%	7.6%	3.4%	2.9%	3.1%
19%	17%	18%	18%	19%	19%	7.9%	2.1%	2.7%	2.4%
3%	3%	5%	8%	9%	10%	-	8.7%	6.6%	7.4%
15%	13%	11%	10%	9%	8%	-0.5%	-0.2%	-0.5%	-0.4%
6%	5%	5%	4%	4%	4%	3.1%	1.0%	0.1%	0.5%

Share, %						CAGR, %			
2015	2020	2025	2030	2035	2040	2005-2015	2015-2025	2025-2040	2015-2040
100%	**100%**	**100%**	**100%**	**100%**	**100%**	**6.4%**	**2.5%**	**3.7%**	**3.2%**
33%	31%	32%	26%	26%	26%	10.0%	1.9%	2.3%	2.2%
4%	5%	5%	4%	4%	3%	-6.1%	4.4%	0.9%	2.3%
41%	28%	29%	22%	20%	18%	4.7%	-0.9%	0.3%	-0.2%
0%	0%	0%	0%	0%	1%	-	-	-	-
16%	21%	24%	24%	23%	24%	10.2%	7.0%	3.7%	5.0%
2%	4%	5%	5%	6%	6%	2.5%	11.2%	5.2%	7.5%
4%	11%	16%	19%	21%	21%	41.6%	5.6%	14.4%	10.8%

CAGR, %			
2005-2015	2015-2025	2025-2040	2015-2040
3.7%	**1.7%**	**1.6%**	**1.6%**

Annex B – Current EE and RE Policies

EE&C Policy. It has been established in some AMS since 1980 and has proven to be the key driver to achieve energy savings across all sectors and interlinked benefits concerning economic growth, energy security and environmental impact. Most governments have enacted a series of laws, acts or regulations setting priorities for energy conservation, and assigned functions or created agencies with a mandate to develop strategies and mechanisms that ensure the rational use of energy in all sectors. In addition, some AMS have established plans to promote EE, calling for energy saving targets and the implementation of EE&C measures.

For instance, Thailand's national EE policy (under Thailand's 20-Year Energy Efficiency Development Plan) set up a target to reduce final energy consumption by 30% in 2036, compared to that in 2005. Vietnam's National Energy Efficiency Programme (VNEEP), designed to improve EE in all sectors, calls for 5-8% energy savings from the 2006 level in its second phase (2001-2015). Malaysia established an energy saving target under the National Energy Efficiency Action Plan 2016-2025 to pursue a cumulative energy saving of 8% by 2025 based on the 2016 level. Indonesia's National Energy Policy (2006) aims to reach final energy savings and an energy elasticity of less than one in 2025. Singapore, under the Sustainable Singapore Blueprint (SSB), has targeted to become more resource efficient with a 35% energy intensity improvement from 2005 levels by 2030. Brunei Darussalam's target is to reduce EI by 45% by 2035. **Annex Table 1** shows the key priority sectors under the relevant regulations and policies in each AMS to promote EE for energy saving targets in all sectors.

Annex Table 1. EE Key Priorities by Sector in AMS

	SECTOR					
COUNTRY	Industry	Building	Commercial	Residential	Transport	Power Generation
Brunei Darussalam	L	M	L	M	L	L
Cambodia	L	M	M	M	L	L
Indonesia	H	H	H	L	L	L
Lao PDR	L	M	L	L	L	L
Malaysia	H	M	M	M	L	M
Myanmar	M	M	L	L	L	L
Philippines	M	M	M	L	M	L
Singapore	L	H	H	H	M	M
Thailand	H	H	H	M	M	L
Vietnam	M	M	M	M	M	M

L: Low | M: Medium | H: High

It is imperative to keep implementation moving forward, as AMS have to reach targets on EI and energy consumption reduction for 2020 and beyond. Efforts, therefore, have been directed toward increasing EE in industry, and residential and commercial buildings as prioritised sectors in almost all AMS, as well as toward increasing EE in transport and power generation sectors.

Energy management, which includes planning and operation of energy production and energy consumption, has been adopted by most AMS. While Member States like Lao PDR is still developing its rules and procedures, others like Indonesia, Malaysia, Thailand, and Singapore have already implemented advanced policies.

Buildings hold great potential for cost-effective energy savings. Successful implementation of regulations that target building design and appliance performance can directly reduce energy demand. Several AMS have applied green building codes and building certification both for government and commercial buildings. Brunei Darussalam for example, has been mandating green building certification for all government buildings, and voluntary certification for commercial buildings since 2015. Similarly, Malaysia and Thailand have been adopted building energy codes/indexes with EE measures since 2009.

Standard labelling processes are importation to ensure productive use of energy and minimise waste in order to contribute to sustainable development. Mandatory energy performance requirements and standards along with labelling have proved to be a highly cost-effective policy tool for encouraging the reduction of average energy consumption in equipment without reducing consumer choice or triggering sustained increases in price. Brunei Darussalam, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, and Thailand have implemented various standards and labelling regulation for certain appliances. The effective implementation of EE policies for appliances and equipment relies upon the use of accurate energy performance measurement standards and protocol.

RE Policy. Based on the ACE publication, ASEAN Renewable Energy Policies (2016), which identifies key elements of RE policies (i.e. target, tariff, incentive, financing and technical), most AMS have policies in place to boost RE deployment to reach specified targets, as illustrated in **Annex Table 2.**

Annex Table 2. RE Policies in AMS

POLICY	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Vietnam
RE Target	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Selling Tariffs	No	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Incentives	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Financing Support	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Permits and Licences	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Technical Aspects	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes

Malaysia, the Philippines, and Thailand are identified as the most successful AMS for RE deployment. An analysis of the key policy instruments shows that clear targets/roadmaps, specific feed in tariffs (FiTs) for different RE technologies, incentives for RE project implementers, permit and licences procedures, and technical standards (regarding grid connection) are all part of successful deployment.

To some extent, all AMS have set RE targets in their energy policies. While having high-level policy on RE targets is important, developing a clear roadmap which provides a detailed plan and timeline (short- and long-term) is essential to reaching RE targets. Thailand provides a good example with its Alternative Energy Development Plan (AEDP), which is now integrated into an overall energy policy called Tha=iland Integrated Energy Blueprint (TIEB). This sets a target of 30% RE in total energy consumption by 2036. In this connection, variable renewable energy integration, hybrid energy and storage are challenges for Thailand. In AEDP, electricity, heat and transport sectors are targeted with clear timelines and milestones, and regular monitoring, evaluation and review occurs every four years.

FiTs is one of the most widely adopted RE support policies in ASEAN, and in the world. Five AMS – Indonesia, Malaysia, the Philippines, Thailand and Vietnam – have provided FiTs policy for various RE sources, which are mostly higher than the electricity market price. The objective of FiTs is to stimulate and increase the deployment of RE technologies by providing a specified price per kilowatt-hour for electricity generation in a long-term purchase agreement, thereby providing market certainty for developers/investors. Most AMS have adapted conventional FiTs, where the fixed tariff is set for a certain period. However, Thailand has introduced a formula for FiTs which consists of fix rate throughout the project with an added variable rate which is adjusted by a standard inflation rate. Before introducing FiTs in 2016, Thailand applied the adder scheme where a defined price is added on top of the wholesale electricity price for a 7-10-year period.

Effectively designed FiTs can attract private investment to support RE expansion and local economic development. To align with specific policy goals, policymakers should differentiate FiTs by technology, project size, location and resource quality.

In some AMS, FiTs are linked with other support policies, such as tender and auction processes and net metering. For example, in Indonesia, Malaysia, and the Philippines, FITs and auctions are coupled in relation to project quota and size. Starting from 2017, Malaysia will not provide any FiTs support for solar PV and move to net metering (rooftop) and open bidding (utility scale). As RE markets evolve differently in various country contexts, policymakers can consider links between FiTs and other policies that may enhance deployment opportunities.

Tax incentives, such as tax exemptions and reductions for RE projects, have been established in most AMS as part of government efforts to attract investors, constructors, and energy companies to engage in RE development. This is an important complement to other schemes in stimulating RE investment. Combinations with other fiscal policies are also implemented in some AMS to promote and accelerate RE deployment. Attractive incentives and other financing support mechanism are considered to be highly important policies by private investors.

Indonesia, Malaysia, the Philippines, Thailand, and Vietnam have various forms of tax incentives in place such as tax exemptions and tax holidays. However, the success of RE investment stimulation also relies on FiTs or other types of incentives, therefore Member States that only have tax incentives with no fully equipped FiTs program will increase RE capacity more slowly.

Even with a relatively large number of incentives, a complicated and uncertain regulatory environment can be a substantial barrier to RE resources development, especially if combined with relatively weak institutional capacity of central and local institutions.

Credit: ACE

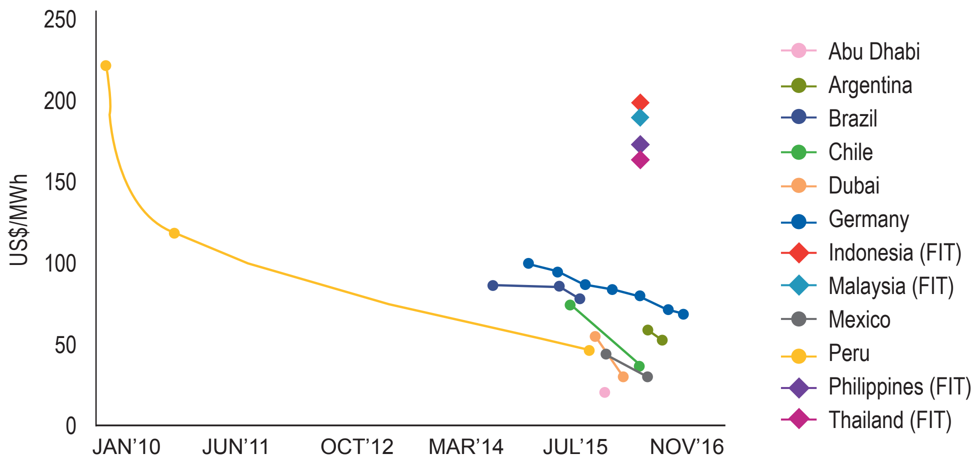

Credit: ACE

Annex C – RE Auctions

Auctions and tenders are mechanisms in which an auctioneer offers a certain good for bidding. As a market-based approach, the main goal is price determination through a competitive bidding process and the efficient allocation of the auctioned good(s) (AURES 2016). In general, project developers have more precise information on their expected cost and income than policymakers (information asymmetry). This can be solved through the mechanism of price discovery. As in the framework of RE, the auctioneer acts as the buyer and the sellers of the generated RE act as the bidders, we refer to these as "procurement auctions". Auctions give policymakers the ability to control the cost, the volume and the technologies in the RE expansion. Additionally, according to IRENA 2015, auctions can provide policymakers with the flexibility to tailor a support scheme based on their markets' needs and if well-designed, auctions should guarantee commitments and transparency in the aftermath and thus reduce risk for investors.

Success Story. Despite some difficulties in the past, a rising number of countries – currently at least 67 (IRENA 2017) – have conducted auctions as a mechanism for RE support. Recent examples have shown that well-designed auctions can indeed contribute successfully to reducing support cost for RE technologies. In 2017, Germany's offshore wind power auctions allocated around 1.5 GW for an average price of EUR 4.4/MWh. Regarding solar PV, Abu Dhabi auctioned 350 MW for an average price of USD 24.20/MWh. Another example includes Mexico's second Clean Energy Auctions, which resulted in an average price of under USD 40/MWh for PV, which is a notable result, since Mexico had only 66 MW of installed PV capacity before the first auction in 2016 and liberalised its electricity market only in 2013.

Annex Figure 1. Overview of selected results of solar PV auctions and AMS FITs,
Sources: ACE and IRENA (2017)



Although Germany's solar radiation levels are low, which leads to relatively low PV capacity factors, the recent solar power auctions in June 2017 resulted in an average price of EUR 56.6/MWh, which is almost one third of Thailand's PV feed-in tariff of around THB 56.6/MWh (approximately EUR 1.40/MWh). Among AMS, Indonesia, Malaysia and Thailand have conducted auctions in the past, aiming to move away from administratively set feed-in tariffs, with mixed results.[11] It is important to bear in mind, that auctions can only be successful if the overall economic environment is stable. Sudden changes in support policies hinder long-term investment planning. Furthermore, a clear pathway and trajectory for the auction rounds is advised.

What has to be considered in the design of auctions?

Policymakers have to take the following factors carefully into consideration when designing any auction scheme: (expected) level of competition, number of market actors, eligible technologies, and an estimation of the technologies' costs. In order to reduce the effect of an auction's possible disadvantages, policymakers should adapt the auction design to the country's specific characteristics.

The following list provides a brief overview of a variety of auction design elements policymakers should consider when introducing auctions for RE:

- Prequalification criteria: The objective is to prevent unserious bids and strategic behaviour in the auction. Furthermore, prequalification criteria should be carefully considered to ensure a high realisation rate of projects. These can consist of a material prequalification, e.g. a governmental permit, or/and a financial prequalification in the form of a bid bond. Policymakers should however bear in mind that too strict criteria might prevent actors from participating in the auction.
- Auctioned volume/product: When designing the auction, policymakers must decide whether a single-unit/project (e.g. a predeveloped offshore wind farm) or a multi-unit auction will be held, and whether the auction will be technology-specific or whether all kinds of technologies will compete against each other. Determining the appropriate auction volume must take into account the RE targets as well as the market participants.
- Ceiling price: In order to prevent overcompensation and high costs in the case of low competition, most auction formats allow for the introduction of a maximum price, above which bids are rejected. The main issue for policymakers lies in finding the correct level of the ceiling price.
- Winning selection process: Auction theory distinguishes between the static sealed-bid and the dynamic auction formats. In the first category, participants submit their bids simultaneously without knowing their competitors' prices. After sorting all the bids, and selecting the lowest bid as the auction's winner, the auctioneer has two options to determine the award price: under the first-price rule, the lowest bid wins and determines at the same time the price (pay-as-bid in the context of multi-unit auctions), or the second lowest bid determines the price (uniform pricing). In the context of dynamic auctions, ascending and descending clock auctions exist, which are usually held over several rounds and expose much more information to the participants.
- Penalties: Similar to prequalification criteria, penalties aim to ensure that projects are realised after the auction. Nevertheless, if set too high, penalties might negatively affect actor diversity and can hinder actors from participating in the auction.

A path to follow?

An innovative approach to RE auctions is currently taking place in the European Union where Member States are required to open 5% of their yearly auction volume to other members and even plan to implement common auctions between Member States. In the long-term, one can even imagine the introduction of pan-EU auctions. A similar approach could be followed in the ASEAN region, although the dispersed geography could be an obstacle to such a development. Nevertheless, multinational auctions and harmonised support mechanisms, combined with local adjustments and incentives (e.g. as in Mexico), could increase the allocative efficiency regarding RE in the region. Possible solutions to the question as to how these projects will be supported financially include an ASEAN-wide budget or national responsibility linked to the projects' sites. Given that in auctions only the least costly projects at the most profitable locations should be awarded, RES targets can therefore be achieved in the most (support) cost-efficient way.

The introduction of RE auctions – on a national or a multinational level – could assist in expanding RE deployment and investment in the ASEAN region, while controlling RES deployment capacities and overall support costs. Auctions therefore can be an appropriate mechanism to help AMS meet their increasing energy demands in an eco-friendly and sustainable manner.

[11] Presumably 'auction' could be seen in light of the existing competitive bidding framework available in countries like Malaysia and the Philippines.

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