Decarbonisation Pathways for Southeast Asia

International Energy Agency

INTERNATIONAL ENERGY AGENCY

The IEA examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 31 member countries, 11 association countries and beyond.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea
Lithuania
Luxembourg
Mexico
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Republic of Türkiye
United Kingdom
United States

The European Commission also participates in the work of the IEA

IEA association countries:

Argentina
Brazil
China
Egypt
India
Indonesia
Morocco
Singapore
South Africa
Thailand
Ukraine

Source: IEA.
International Energy Agency
Website: www.iea.org

Abstract

The International Energy Agency (IEA) and the Institute of Energy Economic, Japan (IEEJ) have developed and published long-term decarbonisation pathways for Southeast Asia and Indonesia. This paper provides a comparison of modelling approaches, quantitative drivers, and results from the IEA and IEEJ pathways, highlighting areas of agreement, as well as identifying and explaining differences, and thereby to derive implications. The IEA pathway used in the comparison is the Announced Pledges Scenario (APS) from the World Energy Outlook 2022 and the Energy Sector Roadmap to Net Zero Emissions in Indonesia. The IEEJ pathway is the net zero CO_2 emissions in 2050 or 2060 case (CN2050/2060) from the Decarbonisation of ASEAN Energy Systems: Optimum Technology Selection Model Analysis up to 2060 study.

Acknowledgements

This study was prepared by the World Energy Outlook team in the Directorate of Sustainability, Technology and Outlooks of the International Energy Agency, in cooperation with the Institute of Energy Economic, Japan.

The study was designed and directed by Brent Wanner, Head of the Power Sector Unit at the IEA. The analysis and production of the report were led and co-ordinated by Yasmine Arsalane. The work benefitted from strategic guidance by Laura Cozzi, Chief Energy Modeller of the IEA. Coordination support was provided by Toru Muta. Other IEA colleagues who contributed to this work included Daniel Crow, Davide D'Ambrosio and Ryota Taniguchi.

Valuable contributions were made by IEEJ colleagues, including guidance and analysis by Toshiyuki Sakamoto, Board Member and Director for Climate Change and Energy Efficiency Unit of IEEJ, drafting and analysis by Soichi Morimoto, and additional analysis by Seiya Endo, Hideaki Obane and Kei Shimogori. Model development and analysis were provided by Takashi Otsuki, of Yokohama National University and IEEJ.

Table of contents

Executive summary

The International Energy Agency (IEA) and the Institute of Energy Economic, Japan (IEEJ) have developed and published long-term decarbonisation pathways for Southeast Asia and Indonesia. This paper provides a comparison of modelling approaches, quantitative drivers, and results from the IEA and IEEJ pathways, highlighting areas of agreement, as well as identifying and explaining differences, and thereby to derive implications. The IEA pathway used in the comparison is the Announced Pledges Scenario (APS) from the World Energy Outlook 2022 and the Energy Sector Roadmap to Net Zero Emissions in Indonesia. The IEEJ pathway is the net zero CO_2 emissions in 2050 or 2060 case (CN2050/2060) from the Decarbonisation of ASEAN Energy Systems: Optimum Technology Selection Model Analysis up to 2060 study.[1]

The IEA and IEEJ apply unique energy modelling frameworks, differ in their regional granularity and approaches, and reflect different sets of inputs in their respective scenarios, including the policy settings by country, which can and do lead to the development of different pathways. The two decarbonisation pathways compared in this paper also reflect uncertainties around the pace of technology development, commercialisation and cost, as well as the prevailing fossil fuel prices. These differences are important considerations for the comparisons.

The IEA APS and IEEJ CN2050/2060 describe two possible decarbonisation pathways for Southeast Asia and Indonesia. Each represents a path, but not necessarily the pathway, as there are many uncertainties to consider and achieving net zero goals will involve countless decisions by people in the region and around the world. Both analyses aim to provide information to policy makers in the region and beyond on potential ways to tackle the overall challenge to reduce CO_2 emissions and fulfilling country-level ambitions to reach net zero emissions in the long term.

While the IEA and IEEJ present two distinct pathways, there are a number of shared pillars of decarbonisation, including:

- Scaling up renewable energy is central to both pathways, leading the decarbonisation of the electricity sector and for direct use in transport.
- The importance of electrification to improve the energy efficiency of many applications, including transport, and take advantage of decarbonised electricity supply.
- The strong shift away from the use of unabated coal-fired power plants, which represents the single largest source of CO_2 emissions in Southeast Asia today.

[1] The IEEJ pathway was developed in collaboration with the Economic Research Institute of ASEAN and East Asia (ERIA).

There are also several distinctions in the decarbonisation pathways described. One of the most significant is the assumption of economic growth, where the IEEJ CN2050/2060 assumes higher Gross Domestic Product (GDP) growth rate than the IEA APS. This distinction contributes to differences of projected total energy supply as well as total final consumption. Although the IEA APS and IEEJ CN2050/2060 include a very similar contribution of renewable energy, IEEJ CN2050/2060 includes greater roles for fossil fuels equipped with carbon capture, and hydrogen and ammonia in the long term. A second important difference is the extent of emissions reductions in the energy sector in order to reach net zero targets, linked to different assumptions for emissions reductions outside the energy sector, including agriculture, forestry and other land use. A critical uncertainty reflected in the two scenarios is the role of carbon dioxide removal in achieving overall climate ambitions, where the IEA APS has a more limited role than IEEJ CN2050/2060, and therefore calls for deeper decarbonisation in all sectors.

Clean energy transitions must be secure, sustainable and affordable. Energy transitions offer the opportunity to build safer and more sustainable energy systems, while maintaining energy security will require attention to both traditional and new vulnerabilities. In addition, there are many uncertainties that will influence the pathway towards net zero targets, both within and outside the energy sector. Policy makers have the most important role to play to navigate these factors and move the world closer to its climate goals. International cooperation will be critical to promote technology innovation and knowledge-sharing, including on the challenges faced, solutions developed, and policy and regulatory approaches applied. As transitions call for scaling up investment, the affordability of clean energy transitions will also depend on reducing the cost and improving the availability of capital.

Introduction to IEA decarbonisation pathways

The IEA has published the World Energy Outlook (WEO), the energy world's most authoritative source of analysis and projections, every year from 1998 through 2022. The IEA has also published five World Energy Outlook Special Reports on Southeast Asia, including the most recent Energy Sector Roadmap to Net Zero Emissions in Indonesia and Southeast Asia Energy Outlook 2022. Through energy system models of Indonesia and Southeast Asia in aggregate, complemented by areas of in-depth analysis for individual countries, the studies offer insightful prospects for the ten member countries of the Association of Southeast Asian Nations (ASEAN) – Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam.

Scenario description

The IEA explores possible trajectories for Southeast Asia's energy sector, differentiated primarily by the policies pursued by governments across the region. The **Announced Pledges Scenario (APS)** from the World Energy Outlook 2022, takes account of all the climate commitments made by governments including nationally determined contributions as well as longer term net zero emissions targets, and assumes that they will be met in full and on time. The global trends in this scenario represent the cumulative extent of the world's ambition to tackle climate change as of mid-2022.

Energy policies and climate pledges considered

In Southeast Asia, country-specific energy policies and measures, and climate pledges are represented in the decarbonisation pathways, representing the ambitions of governments and direction of travel for energy sectors and industries. For Southeast Asia, the APS reflects cross-cutting policies or pledges, as well as sector specific policies, pledges or measures.

Key policies, pledges and measures in Southeast Asia in the IEA Announced Pledges Scenario

Country	Policy, pledge or measure
Cross-cutting	
Indonesia	Net zero emissions by 2060 or before
Malaysia	Carbon neutrality target by 2050
Thailand	Net zero GHG emissions target by 2065
Viet Nam	Carbon neutrality target by 2050
Indonesia, Malaysia, Philippines and Viet Nam	Commitment to the Global Methane Pledge
Nationally determined contribution (NDC)	
Brunei Darussalam	Reduction in GHG emissions by 20% relative to business-as-usual (BAU) levels by 2030
Cambodia	Emissions reduction target of 41.7% (64.6 Mt CO_2eq) by 2030
Indonesia	Emissions reduction target of 31.89% (29% in first NDC) unconditionally and 43.2% (41% in first NDC) conditionally by 2030
Lao People's Democratic Republic (Lao PDR)	Unconditional reduction in GHG in 2030 by 60% compared to a BAU scenario
Malaysia	Reduction in economy-wide carbon intensity (against GDP) of 45% (unconditional) in 2030 compared to 2005 level
Myanmar	Total emissions reductions contributions as a part of its NDC are 244.52 million t CO_2e unconditionally, and a total of 414.75 million t CO_2e conditionally by 2030
Philippines	GHG emissions reduction and avoidance of 75%, of which 2.71% is unconditional and 72.29% is conditional, for 2020 to 2030
Singapore	Emissions reduction target of around 60 Mt CO_2e in 2030 after peaking its emissions earlier
Thailand	Reduction in GHG by 30% from the projected BAU level by 2030. The level of contribution could increase up to 40 percent, subject to adequate and enhanced access to technology development and transfer, financial resources and capacity building support
Viet Nam	GHG emissions reduction target of 15.8% (from 9%) unconditionally and 43.5% (from 27%) conditionally, compared to BAU by 2030
Electricity sector	
Indonesia	Renewable energy accounts for half (21 GW) of total power capacity addition under the National Electricity Supply Business Plan (RUPTL) 2019-2028
Viet Nam	Power Development Plan 8 proposed 19-20 GW of solar, 18-19 GW of wind, 22 GW of natural gas and 37 GW of coal-fired capacity by 2030
Buildings sector	
Viet Nam	Minimum performance standards and labelling for appliances and lighting in residential and commercial buildings
Singapore	Enhancements to minimum energy performance standards for light bulbs
Malaysia	Minimum energy performance standards and labelling for washing machines, refrigerators and air conditioners
Transport sector	
Indonesia	Government plans to phase out conventional two-wheelers from 2025 and to have 2 million electric vehicles in passenger light-duty vehicle stock by 2030
Thailand	Target for 100% zero emissions vehicle sales from 2035
Malaysia	100% of cars by 2030 to be electrified, CNG, LPG or biofuel-fuelled vehicles
Singapore	Targets to phase out passenger internal combustion engine vehicles by 2040

International cooperation and finance

International cooperation on financing clean energy transitions is a critical component of accelerating energy transitions in emerging economies, to implement plans and fulfil domestic ambitions, while opening opportunities for even faster transitions. Landmark agreements have been reached in recent months in Southeast Asia that mark major steps forward in international cooperation. In November 2022, a Just Energy Transition Partnership was launched between Indonesia and a group of leading economies, informed by IEA analysis and which targets an ambitious and equitable power sector transition in Indonesia. In December 2022, a Just Energy Transition Partnership was launched with Viet Nam, set to mobilise an initial USD 15.5 billion of public and private finance over 3-5 years to support Viet Nam's green transition. In both partnerships, ambitions were set to peak power sector emissions in 2030, followed by substantial declines in unabated coal-fired generation.

Consultation process

Consultation is a central pillar of the IEA approach to the development of energy outlooks and decarbonisation pathways, providing invaluable input to the modelling and analysis, such as technology preferences, industrial policy, market and non-market barriers, and other strategic issues. The World Energy Outlook and WEO Special Reports undergo a peer review process, inviting input from experts and thought leaders in government, industry, academia and research organisations. The IEA regularly hosts both high-level and technical workshops on many aspects of clean energy transitions, as well as events on regional issues and opportunities. For example, in support of the Indonesia Net Zero Roadmap, several technical meetings were held with counterparts from the government and relevant analytical institutions to identify critical issues, discuss key topics of analysis and preliminary analysis. The series of WEO Special Reports on Southeast Asia have been published on a regular basis since 2013 and continue to build on and develop important partnerships in the region.

Energy sector representation

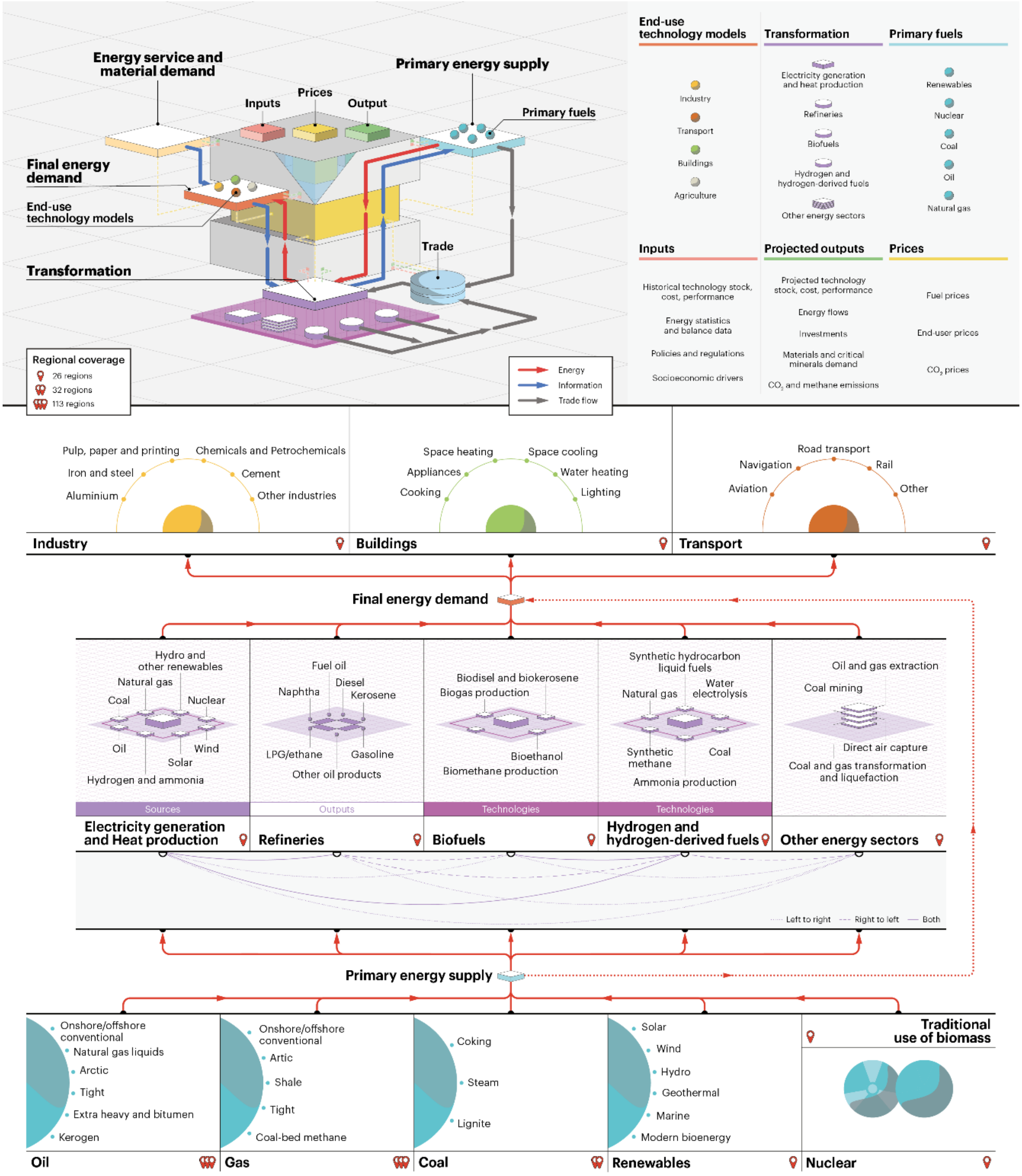
Since 1993, the IEA has provided medium- to long-term energy projections using a continually-evolving set of detailed, world-leading modelling tools. First, the World Energy Model (WEM) – a large-scale simulation model designed to replicate how energy markets function – was developed. A decade later, the Energy Technology Perspectives (ETP) model – a technology-rich bottom-up model – was developed, for use in parallel to the WEM. In 2021, the IEA adopted for the first time a new hybrid modelling approach relying on the strengths of both models to develop the world's first comprehensive study of how to transition to an energy system at net zero emissions by 2050.

Since then, the IEA has worked to develop a new integrated modelling framework: IEA's Global Energy and Climate (GEC) Model. As of 2022, this model is the principal tool used to generate detailed sector-by-sector and region-by-region long-term scenarios across IEA's publications.

The GEC Model brings together the modelling capabilities of the WEM and ETP models. The result is a large-scale bottom-up partial-optimisation modelling framework allowing for a unique set of analytical capacities in energy markets, technology trends, policy strategies and investments across the energy sector that would be critical to achieve climate goals. IEA's GEC Model covers 26 regions individually that can be aggregated to world-level results and all sectors across the energy system with dedicated bottom-up modelling for:

- **Final energy demand**, covering industry, transport, buildings, agriculture and other non-energy use. This is driven by detailed modelling of energy service and material demand.
- **Energy transformation**, including electricity generation and heat production, refineries, the production of biofuels, hydrogen and hydrogen-derived fuels and other energy-related processes, as well as related transmission and distribution systems, storage and trade.
- **Energy supply**, including fossil fuels exploration, extraction and trade, and availability of renewable energy resources.

Global Energy and Climate Model overview



Source: IEA (2022), Global Energy and Climate Model.

Key assumptions

The GEC Model is a very data-intensive model covering the whole global energy system. Much of the data on energy supply, transformation and demand, as well as energy prices is obtained from the IEA's own databases of energy and economic statistics and through collaboration with other institutions. It also draws data from a wide range of external sources which are indicated in the relevant sections of this document. The development of the GEC Model benefited from expert review within the IEA and beyond, and the IEA continues to work closely with colleagues in the international modelling community.

- Economic growth assumptions for the short to medium term are based on IMF World Economic Outlook and Oxford Economics. Over the long term, growth in each GEC Model region is based on a well-established macroeconomic model integrating demographic and productivity trends, macroeconomic conditions and the pace of technological change.
- Rates of population growth for each GEC Model region are based on the medium-fertility variant projections from the United Nations Population Division World Population Prospects.
- Fuel end-use prices are derived from international prices (modelled endogenously as the prices levels needed to stimulate sufficient investment in supply to meet demand) and subsidy/tax levels – including CO_2 prices where applicable – and vary by country. For electricity end-use prices, the model calculates prices as a sum of the wholesale electricity price, system operation costs, transmission & distribution costs, other supply costs, and taxes and subsidies.

Incorporation of a diverse range of technologies is a key feature of the GEC Model. Extensive research is undertaken to update the range of technologies in the model, as well as their techno-economic assumptions.

The GEC Model includes the breadth of technologies that are available on the market today. Additionally, the model integrates innovative technologies and individual technology designs that are not yet available on the market at scale by characterising their maturity and expected time of market introduction. For each sector and technology area, new project announcements and important technological developments are tracked in databases that are regularly published.

The modelled scenarios are informed by such detailed technology tracking process, including the status of project-level planning and financing. For technology development progress and the time to bring new technologies to markets, the scenarios assume different pace of progress as the support and degree of international cooperation on clean energy innovation increases with the ambition in decarbonisation.

The following databases are particularly relevant for the definition of the different scenarios:

- Clean Technology Guide: interactive database that tracks the technology readiness level (TRL) of over 500 individual technology designs and components across the whole energy system that contribute to achieving the goal of net zero emissions. The Guide is updated every year.

- Clean Energy Demonstration Projects Database: newly launched in 2022, that provides more detailed tracking of the location, status, capacity, timing and funding, of over 400 demonstration projects across the energy sector.
- Tracking Clean Energy Progress: annual tracking of developments for 55 components of the energy system that are critical for clean energy transitions and their progress towards short-term 2030 milestone along the trajectory of the Net Zero by 2050 Scenario.
- Hydrogen Projects Database: covers all projects commissioned worldwide since 2000 to produce hydrogen for energy or climate-change-mitigation purposes.
- Global EV Outlook: annual publication that identifies and discusses recent policy and market developments in electric mobility across the globe. It is developed with the support of the members of the Clean Energy Ministerial Electric Vehicles Initiative (EVI).

Technology costs are an important input to the model. All costs represent fully installed/delivered technologies, not solely the equipment cost, unless otherwise noted as for fuel cells. Installed/delivered costs include engineering, procurement and construction costs to install the equipment. Some illustrative examples include the following:

- **Industry** costs reflect average iron and steel production costs for a given technology and differentiate between conventional and innovative production routes.
- **Power generation technology** costs are provided for major markets for renewable energy technologies including solar PV, wind, hydropower and bioenergy, coal-fired power plants, gas-fired power plants, carbon capture technologies and nuclear power, with detail on all major contributors to the levelized cost of electricity, including overnight capital costs, capacity factor, cost of fuel inputs, plus operation and maintenance. Additional technology and regional detail are also available.
- **Electric Vehicle** costs reflect production costs, not retail prices, to better reflect the cost declines in total cost of manufacturing, which move independently of final market prices for electric vehicles to customers. For the global average battery pack size, historical values in 2021 have been used. In hybrid cars, the future cost increase is driven by regional fuel economy and emissions standards.
- **Electrolyser** costs reflect a projected globally weighted average of installed electrolyser technologies (excluding the People's Republic of China, where lower costs are assumed), including inverters. Please view the various assumptions that underpin the IEA's analysis on hydrogen for additional details.
- **Fuel cell** costs are based on stack manufacturing costs only, not installed/delivered costs. The costs provided are for automotive fuel cell stacks for light-duty vehicles.
- **Utility-scale stationary battery costs** reflect the average installed costs of all battery systems rated to provide maximum power output for a four-hour period.

A summary of selected key data inputs – including macro drivers such as population, economic developments and prices as well as techno-economic inputs such as fossil fuel resources or technology costs – are available in the Global Energy and Climate Model key input dataset.

Introduction to IEEJ decarbonisation pathways

The IEEJ, together with the Economic Research Institute for ASEAN and East Asia (ERIA), conducted a joint project, called Decarbonisation of ASEAN Energy Systems: Optimum Technology Selection Model Analysis up to 2060 in 2021 and 2022. The study:

- aims to quantitatively describe the energy transition pathway necessary to realise carbon neutrality in ASEAN countries through model analysis;
- provides information to formulate energy policies in each country and seek support from developed countries; and
- suggests how to minimise the additional costs of transforming the energy supply-demand structure by using a cost-optimal technology selection model, which evaluates combinations of energy technologies.

The study uses a single model covering the ten ASEAN countries. In analysing the model, the ERIA/IEEJ discussed energy policies and actual situations with the ASEAN governments and, on that basis, considered assumptions for the analysis and priorities of technologies to be introduced.

Scenario description

In this comparative analysis report, the following case of net zero CO_2 emissions in 2050 or 2060 (CN2050/2060) will be presented.

CN2050/2060 reflects nationally declared carbon-neutral target years and considers natural carbon sinks in Indonesia, Malaysia, Myanmar, Thailand and Viet Nam based on discussions with each country.

In addition to this case, the Decarbonisation of ASEAN Energy Systems: Optimum Technology Selection Model Analysis up to 2060 study analysed a baseline without any CO_2 emissions target, an innovation case, a 2030 stringent target case and a CN2050/2060 without natural carbon sinks, details of which can be found in the original report if interested. The model has been continuously updated from the original report in terms of, for example, assumptions on fossil fuel prices reflecting recent high energy prices.

Energy policies and climate pledges considered

CN2050/2060 reflects nationally declared carbon-neutral target years and considers natural carbon sinks in Indonesia, Malaysia, Myanmar, Thailand, and Viet Nam based on discussions with each country. When an energy-related CO_2 emission reduction target with natural carbon sink becomes less than 50%, its target has been capped at 50%.

Target year and assumptions of natural carbon sink in CN2050/2060

Country	CN Target year	Energy-related CO_2 emission reduction target from 2017	Assumed natural carbon sink[2] in the target year
Brunei Darussalam	2050	100%	
Cambodia	2050	100%	
Indonesia	2060	50%	2050 target of the LCCP scenario in the LTS (-300 Mt)
Lao PDR	2050	100%	
Malaysia	2050	50%	2016 value of the inventory (-241 Mt)
Myanmar	2060	60%	2040 target of the unconditional NDC (-13 Mt)
Philippines	2060	100%	
Singapore	2050	100%	
Thailand	2050	50%	2050 target of the Carbon Neutrality Pathway in the LTS (-120 Mt)
Viet Nam	2050	70%	2030 target of the unconditional NDC (-59 Mt)

Notes: LTS = long-term strategy, LCCP = low-carbon scenario compatible with Paris Agreement target, NDC = nationally determined contribution.

International cooperation and finance

In May 2021, the Ministry of Economy, Trade and Industry (METI), Japan announced the Asia Energy Transition Initiative (AETI), which includes a variety of support for the realisation of various and pragmatic energy transitions in Asia. The AETI intends to, first and foremost, support for formulating energy transition

[2] Absorption of emissions from the land use, land-use change and forestry (LULUCF) sink.

roadmaps, and in a manner consistent with these roadmaps, to provide USD 10 billion financial support for renewable energy, energy efficiency, LNG, CCUS and other projects. This support for formulating energy transition roadmaps for each of ten ASEAN countries has been provided through the study of ERIA/IEEJ. Japan's initiative for carbon neutrality in Asia has recently culminated to the "Asia Zero Emission Community" (AZEC) as announced by Prime Minister Kishida in January 2022. Even under the AZEC, the ERIA/IEEJ's support for roadmaps remains one of the main pillars of Japan's cooperation.

Consultation process

Since 2021, the ERIA/IEEJ have had intensive discussions with each of almost ten ASEAN countries. Unlike the IEA's analysis, the ERIA/IEEJ's study can analyse and show the roadmap of each ASEAN country. Through these discussions, the ERIA/IEEJ modified the carbon-neutral target years as well as assumptions in order to more accurately reflect each ASEAN country's national circumstances. Most notably, while the ERIA/IEEJ's initial analysis did not take into account natural carbon sinks, the analysis was modified so that they could be part of net zero pathways.

However, while the results of analysis well reflected ASEAN countries' views, the roadmaps do not necessarily mean agreement with them. The study is a credible but second opinion to support ASEAN countries as they develop their own roadmaps for energy transition towards carbon neutrality.

Energy sector representation

The analysis was conducted using the IEEJ-NE model, an optimum technology selection model (the Institute of Energy Economics, Japan [IEEJ]–<New Earth> [NE] model) developed by Otsuki et al.[3] and encompassing the entire energy system. The analysis covers the ten ASEAN countries from 2017 to 2060, with representative years 2017, 2030, 2040, 2050, and 2060, and with discount rate of 8%. The analysis considers energy-related CO_2.

The IEEJ-NE model is formulated as a dynamic linear programming model. Like the market allocation (MARKAL) model developed by the Energy Technology Systems Analysis Program (ESTAP) of the IEA, the IEEJ-NE model takes the cost and performance of each energy technology as input values and yields a single

[3] Otsuki, T, H. Obane, Y. Kawakami, K. Shimogori, Y. Mizuno, S. Morimoto, Y. Matsuo (2022), Energy mix for net zero CO_2 emissions by 2050 in Japan, An analysis considering siting constraints on variable renewable energy, IEEJ Transactions on Power and Energy (Denki Gakkai Ronbunshi B), 142 (7), pp.334-346.
Otsuki, T, R. Komiyama, and Y. Fujii (2019), Techno-economic Assessment of Hydrogen Energy in the Electricity and Transport Sectors Using a Spatially-disaggregated Global Energy System Model, Journal of the Japan Institute of Energy, 98 (4), pp.62–72.

combination of the scale and operational patterns of individual energy technologies to be introduced. Doing so minimises the total cost of the energy system when various constraints such as CO_2 emissions and power supply-demand balance are given. The model covers the energy conversion and end-use sectors (industry, transport, households, and commercial), and incorporates more than 350 technologies into them. The model evaluates combinations of the technologies by giving factors such as capital costs, fuel costs, and CO_2 emissions to each technology. The model includes low-carbon technologies such as solar PV power generation, onshore and offshore wind power generation, hydrogen (H_2)-fired power generation, ammonia (NH_3)-fired power generation, and negative-emission technologies such as direct air capture with carbon storage (DACS) and bioenergy with carbon capture and storage (BECCS).

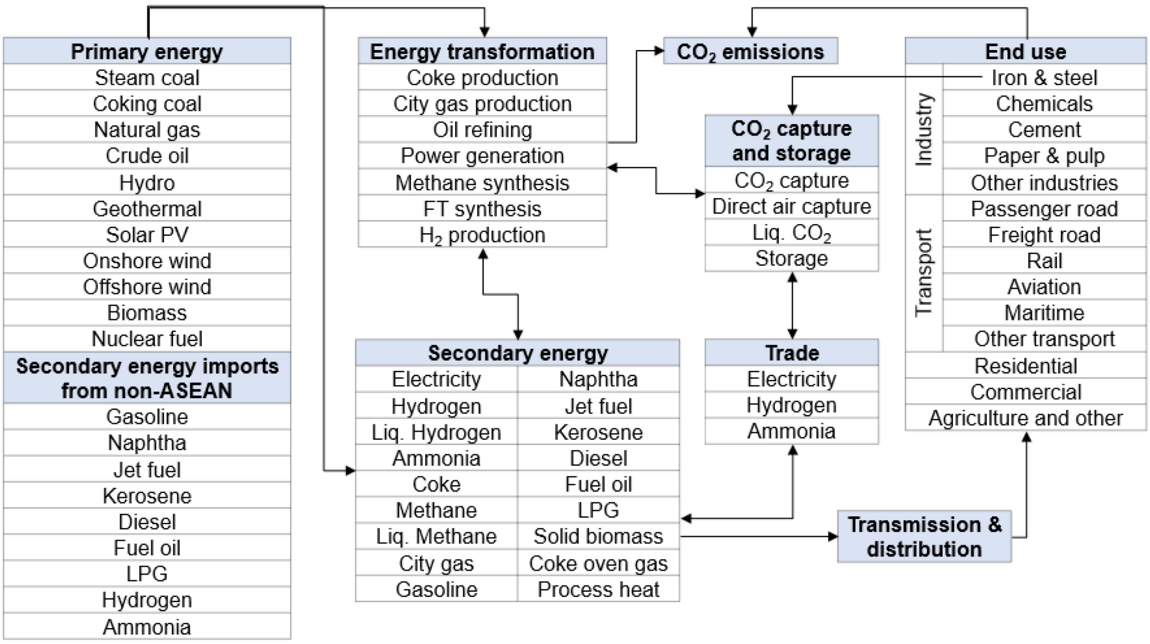
Selected low-carbon technologies in the model

Renewables	Solar photovoltaic, onshore wind, offshore wind, hydro, geothermal, biomass
Nuclear	Light water reactor
CO_2 capture, utilisation, and storage	CO_2 capture: Chemical absorption, physical absorption, direct air capture
	CO_2 utilisation: Methane synthesis, FT liquid fuel synthesis
	CO_2 storage: Geological storage
H_2	Supply: Electrolysis, coal gasification, methane reforming, H_2 separation from NH_3, H_2 trade amongst ASEAN countries, H_2 imports from non-ASEAN countries
	Consumption: H_2 turbine, natural gas-H_2 co-firing, fuel cell electric vehicle, H_2-based direct reduced iron-electric arc furnace, fuel cell ship, H_2 aviation, H_2 heat for industries, fuel synthesis (methane, FT liquid fuel, NH_3)
NH_3	Supply: NH_3 synthesis, NH_3 trade amongst ASEAN countries, NH_3 imports from non-ASEAN countries
	Consumption: NH_3 turbine, coal-NH_3 co-firing, H_2 separation
Negative-emission technologies	Direct air capture with CCS (direct air CCS), biomass-fired power generation with CCS (bioenergy with carbon capture and storage)

Notes: CCS = CO_2 capture and storage, CO_2 = carbon dioxide, FT = Fischer-Tropsch, H_2 = hydrogen, NH_3 = ammonia.

The IEEJ-NE model shows the entire energy system, starting from energy imports, secondary energy conversion, intraregional energy trade, CO_2 capture and storage (CCS), and final consumption. The model assumes various types of energy to be consumed.

Modelled energy system



Notes: CO_2 = carbon dioxide, H_2 = hydrogen, FT = Fischer-Tropsch, liq. = liquid, LPG = liquefied petroleum gas, PV = photovoltaic.
Source: ERIA/IEEJ.

Modelling of the end-use sectors is based on data from the ERIA Energy Outlook and Energy Saving Potential in East Asia 2020, the IEA energy balance table, and the IEEJ outlook 2021. However, some sectors are not simulated due to lack of data availability.

In the model, the power supply-demand is divided by time to express the power variations of solar or wind energy and the system integration cost. One year for power supply-demand is divided into 2 190 time slices (4-hour resolution). In addition, international trades of energy and CO_2 are explicitly modelled. This is important in order to incorporate the measures for strengthening natural resource sharing within ASEAN countries.

Modelled end-use sectors

	BRN	KHM	IDN	LAO	MYS	MMR	PHL	SGP	THA	VNM
Industry										
Iron & Steel			✓				✓		✓	✓
Cement			✓				✓		✓	✓
Chemicals	✓		✓		✓	✓	✓	✓	✓	✓
Paper & Pulp			✓			✓	✓		✓	✓
Other industries	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Transport										
Passenger LDV	✓		✓		✓	✓	✓	✓	✓	✓
Bus & Truck	✓		✓		✓	✓	✓	✓	✓	✓
Rail					✓	✓	✓	✓	✓	
Aviation			✓		✓	✓	✓		✓	✓
Navigation			✓		✓	✓	✓	✓	✓	✓
Other transport	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Residential & commercial										
Light and appliances	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Space cooling	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Water heating	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Kitchen	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Agriculture and other	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes: BRN = Brunei Darussalam, KHM = Cambodia, IDN = Indonesia, LAO = Lao People's Democratic Republic, LDV = light-duty vehicle, MYS = Malaysia, MMR = Myanmar, PHL = Philippines, SGP = Singapore, THA = Thailand, VNM = Viet Nam. The manufacturing processes of iron and steel for each country are based on World Steel Association Steel Statistical Yearbook. The assumptions on cement, such as efficiency for each country, are based on Global Cement and Concrete Association.

Key assumptions

The analysis is based on key assumptions below.

- Economic indicators, such as population and GDP, are based on ERIA Energy Outlook and Energy Saving Potential in East Asia 2020.
- Fossil fuel prices are estimated based on Stated Policies Scenario of IEA World Energy Outlook 2022, which reflects the current energy policy settings. While oil refers to international price, gas and coal refer to domestic price in ASEAN countries.
- Capacity of grid connections amongst ASEAN countries is constrained based on the planned capacity and comments from each country.
- Prices of imported hydrogen and ammonia from non-ASEAN countries are assumed based on the government of Japan's long-term H_2 supply chain target. An upper limit on imports is also imposed. Domestic blue or green hydrogen production is available as well.
- Annual CO_2 storage capacity is set based on the cumulative potential in each country from IEA's Carbon capture, utilisation and storage: the opportunity in Southeast Asia study. Imports and exports of captured CO_2 among ASEAN countries are also considered.

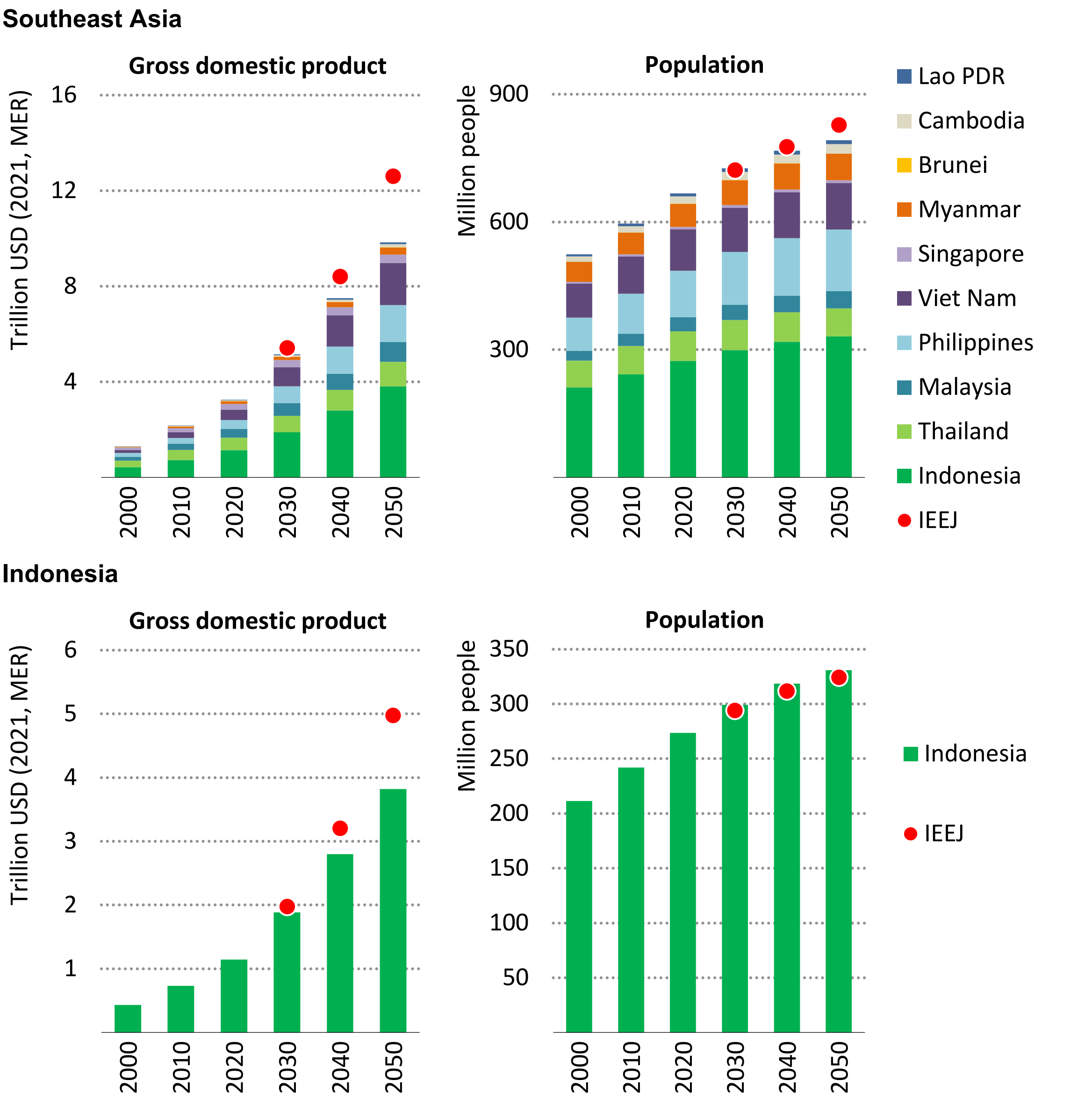
- An upper limit on biofuel supply for vehicles is assumed to increase in proportion to demand for road transport.
- Capital costs of power generation technologies are based on publicly available reports – such as the Technology Data for the Indonesian Power Sector Catalogue for Generation and Storage of Electricity and information published by the Danish Energy Agency – obtained by ASEAN countries.
- As energy storage technologies, the model considers pumped hydro storage, lithium-ion batteries and compressed H_2 tanks. Future cost reduction is based on Cost Projections for Utility-scale Battery Storage: 2020 Update by the National Renewable Energy Laboratory of the United States.
- Upper limits on solar PV and wind power capacity are estimated by IEEJ with GIS data to consider geographic conditions and land use. Upper limits on hydro, geothermal and biomass-fired power capacity are assumed based on various literatures and information provided by ASEAN countries.

Comparison of energy and emissions pathways

The energy and emissions pathways for the IEA APS and IEEJ CN2050/2060 are compared through to 2050, also comparing additional key drivers that strongly influence the projections. The quantitative comparisons include total energy supply, CO_2 emissions, related indicators and use by fuel, total final consumption by sector and fuel, and electricity generation by source. The key pillars of decarbonisation are identified and compared between the two scenarios, highlighting key points of agreement and distinction.

Key drivers

Gross domestic product and population by country in Southeast Asia and Indonesia

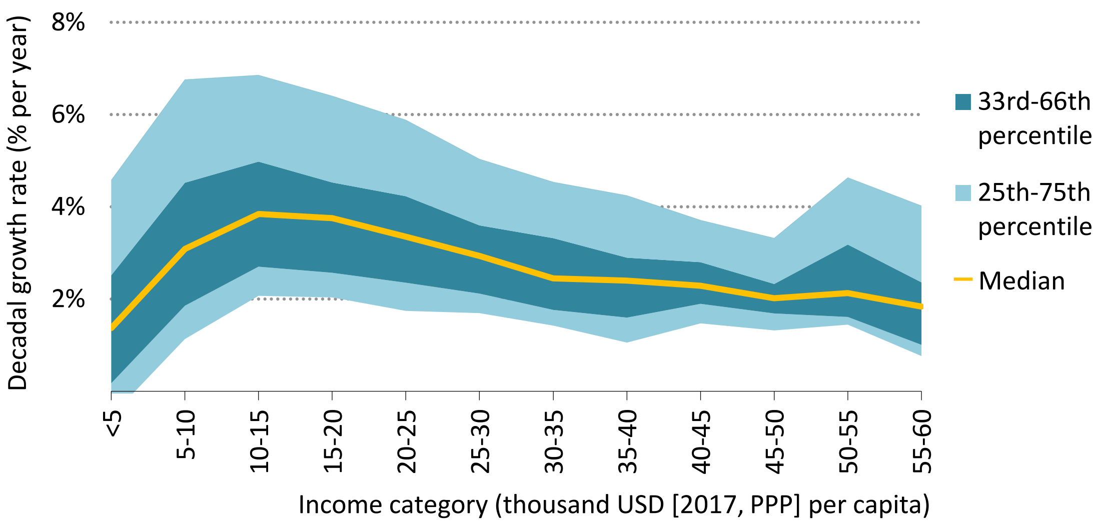


By 2050, the population in Southeast Asia exceeds 800 million people and the economic output grows rapidly over the period – an average rate of 3.8% for IEA and 4.6% for IEEJ.

There are a host of key drivers for long-term energy outlooks and decarbonisation pathways. In addition to the policy settings and assumptions about low emission technology costs and development, the two most important are projected growth of the economy and population. GDP is an indicator of the overall activity and production of an economy, and strongly linked to both energy supply and demand. Population is closely linked to the demand for energy services, which combined with other indicators including GDP, underpin energy demand trends in buildings and transport.

To add perspective to long-run GDP projections, the IEA considers 70 years of global macroeconomic experience. The annualised real GDP growth rate by decade achieved by all medium- and large-size economies[4] since 1950 are analysed, grouping countries into income categories (levels of GDP per capita). The median growth rate over a decade was less than 2% per year at low development levels of less than USD 5 000 per capita, around 3% in the income category of USD 5 000-10 000 per capita and 4% in the USD 10 000-20 000 per capita income category. Higher income levels were characterised by a narrower range between the best and worst performers and slower growth – a median rate of around 2.5% per year above USD 30 000 per capita and closer to 2% above USD 40 000. At these levels, many options are exhausted and growth is driven by rates of technology-driven productivity improvements and very high levels of human capital, notably education and health.

GDP growth rate per capita by decade versus starting GDP per capita in each decade, 1950-2019



Notes: IEA analysis based on data from the 2021 version of the Penn World Tables. PPP= purchasing power parity.

As countries get richer, GDP growth rates tend to slow as easy opportunities to achieve fast growth are exhausted.

This historical experience informs IEA macroeconomic assumptions. The IEA APS assumes annual GDP growth for Southeast Asia of 4.7% from 2020 to 2030 (as seen from 2000 to 2020) and 5.1% for Indonesia. In the long term, however, the

[4] For the purposes of this analysis, a large- or medium-size economy is one with more than 0.05% of world GDP in 2019, 100 countries have a share of GDP above this threshold.

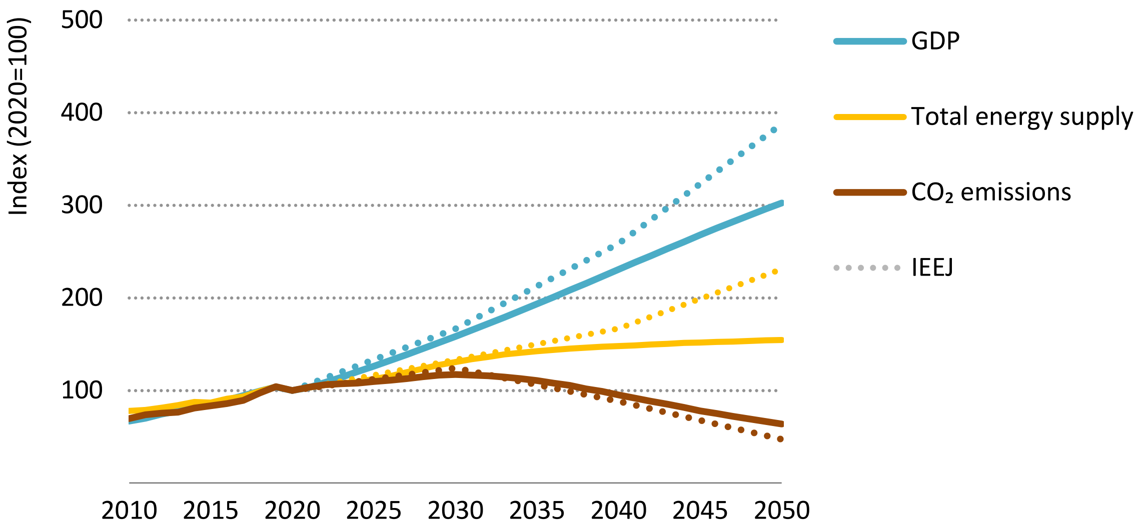
projected GDP growth rate slows to 3.3% from 2030 to 2050 for Southeast Asia and 3.6% for Indonesia, as ASEAN countries progress to the level of an advanced economy, growth options are progressively exhausted, and the drivers of growth come to depend on global, long-run rates of technology-driven productivity improvements. Indonesia is the largest economy today in the region and the IEA APS assumes it remains so through to 2050, as GDP growth averages 4.1% from 2020 to 2050. Economies in other countries in Southeast Asia are assumed to grow at an average rate of 3.6% from 2020 to 2050. In terms of population in Southeast Asia, the IEA APS has continued growth over the next decade before slowing over the 2030s and 2040s. Indonesia represents the largest population in the region and maintains its share of the regional total at just over 40% through to 2050.

The IEA and IEEJ scenarios share several points of agreement, including a well-aligned GDP growth rate in aggregate until 2030 and population growth trend that is very similar to 2030, with slight variations after 2040.

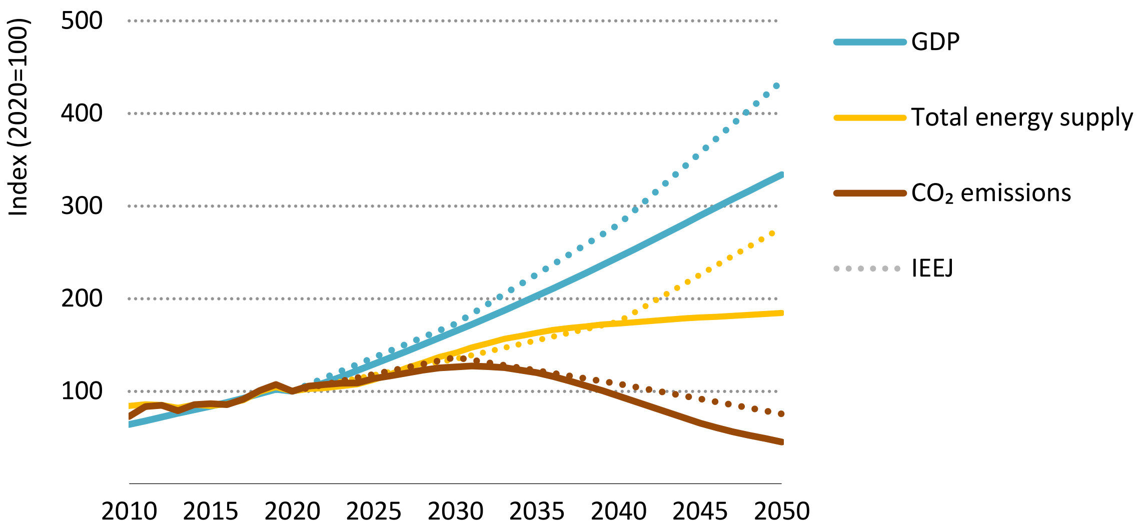
However, the IEEJ scenario assumes stronger economic growth beyond 2030 in Southeast Asia (4.6% from 2020 to 2050), particularly for Indonesia (5.0% from 2020 to 2050). The IEEJ scenario is more closely aligned with the economic growth set forth in Indonesia's Long-Term Strategy submitted to UNFCCC in 2021, while GDP growth in the IEA APS is sufficient for Indonesia to achieve its goal of becoming the fourth-largest economy globally by 2045. Also, the IEEJ's assumption on economic growth in Southeast Asia uses that of ERIA's Energy Outlook, reflecting country-level visions. The differences for macroeconomic growth and population set the stage for divergences in energy supply and demand between the IEA and IEEJ decarbonisation pathways, particularly beyond 2030.

Change in economic output, energy consumption and energy-related CO_2 emissions in Southeast Asia and Indonesia

Southeast Asia



Indonesia



Note: energy-related CO_2 emissions refers to carbon dioxide emissions from the combustion of fossil fuel and non-renewable wastes; and energy-related CO_2 removal. Note that this does not include emissions from agriculture, forestry and other land use emissions (AFOLU), from industrial and fuel transformation processes (process emissions), fugitive emissions from fuels, flaring or CO_2 from transport and storage.

Both analyses include significant decarbonisation of energy in Southeast Asia to 2050, while total energy supply is well aligned to 2030 before a distinct separation to 2050.

In the IEA APS, GDP, total energy supply and CO_2 emissions decouple to 2050, breaking from recent trends. Total energy supply decouples from GDP growth – total energy supply growing at 1.5% per year compared with GDP growth of 3.8%. This reflects gains in energy efficiency in end-uses through electrification and more efficient appliances, and the transition towards non-combustion renewable technologies. At the same time, CO_2 emissions peak around 2030 and then decline to 2050, with an average change of -1.7% per year from 2020 to 2050 in Southeast Asia. Indonesia demonstrates similar trends with continuous growth for GDP, a plateauing of total energy supply after 2040 and peak CO_2 emissions in the early 2030s.

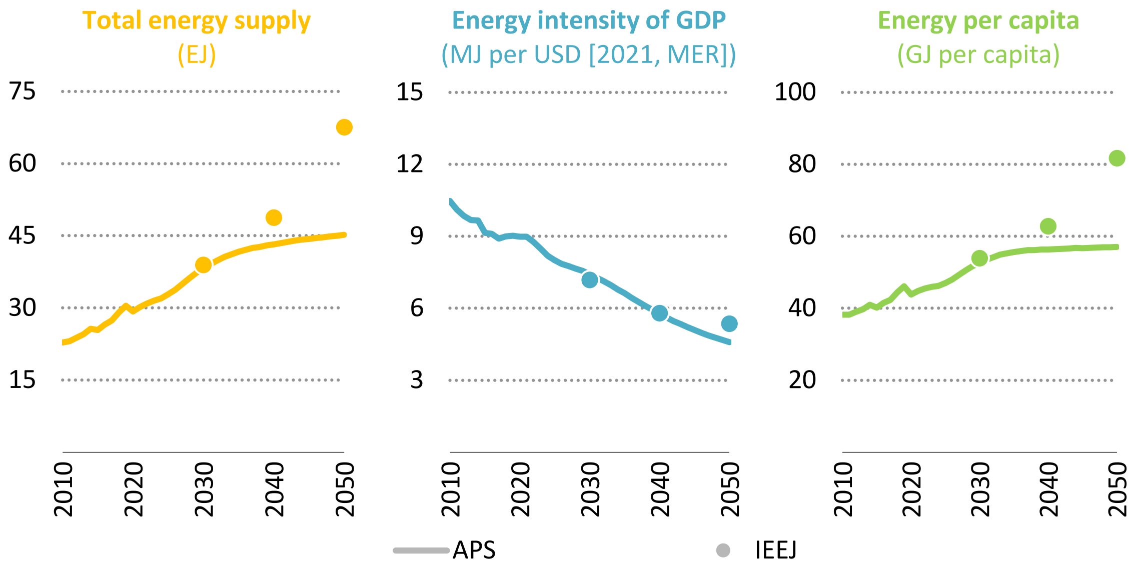
For Southeast Asia in total, the IEA and IEEJ projections for economic growth, energy consumption and CO_2 emissions are similar to 2030. After that year, economic growth and total energy supply growth are notably higher in the IEEJ scenario, while CO_2 emissions are slightly lower to 2040 and 2050.

In Indonesia, both IEA and IEEJ scenarios show closely aligned energy and CO_2 indicators up to 2040. However, there are notable differences, with IEEJ projecting much stronger GDP growth and total energy supply growth after 2040, which is similar to the trend in Indonesia's Long-Term Strategy. Additionally, the IEA APS shows faster CO_2 emissions reductions after 2040, while IEEJ relies less on energy-sector emissions reductions to meet climate ambitions and relies more heavily on energy-related carbon dioxide removal (CDR) and land use change.

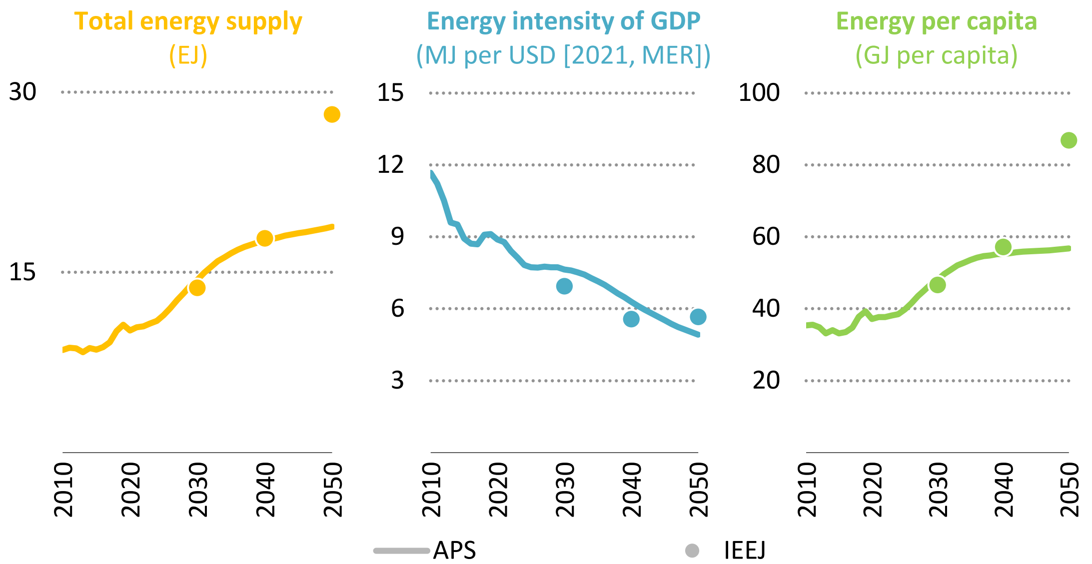
Total energy supply

Total energy supply and key indicators in Southeast Asia and Indonesia

Southeast Asia



Indonesia



Both analyses see notable gains for the energy intensity of economies in Southeast Asia, but differences in total energy supply growth drive distinct energy per capita trends to 2050.

Total energy supply is a critical metric for measuring energy demand, as it encompasses the use of all primary energy sources. This overall energy metric combined with economic activity and population, provide useful indicators for understanding the efficiency of energy use in an economy and the pace of energy transitions.

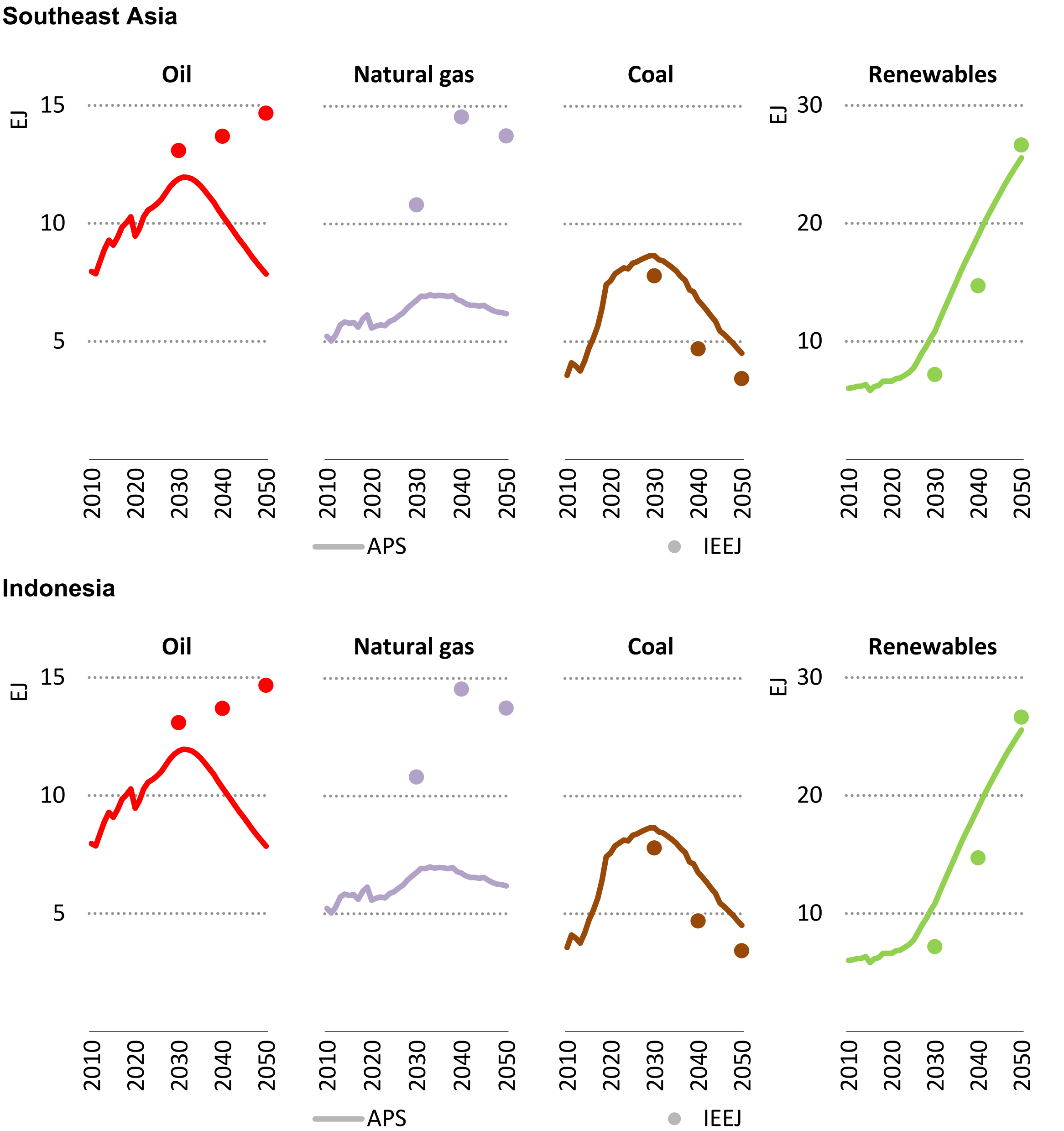
In the IEA APS, the energy intensity of GDP continues to steadily decline in Southeast Asia, as it has over the past two decades. By 2050, the energy intensity of the Southeast Asia economy is about half of the level in 2020, with a similar reduction in Indonesia. Over the same period, energy per capita rises by just 30% in Southeast Asia and 53% in Indonesia, reaching a plateau for both around 2035.

For Southeast Asia, both the IEA and IEEJ scenarios show close alignment in total energy supply in absolute terms and per capita to 2030. Furthermore, the energy intensity of GDP is similar through to 2050. However, in the IEA APS, total energy supply growth slows down significantly after 2035 compared to IEEJ, which may indicate differences in economic growth assumptions.

Similarly, for Indonesia, both scenarios show closely aligned total energy supply in absolute terms and per capita up to 2040, with the energy intensity of GDP reaching similar levels in 2050. However, in the IEA APS, total energy supply growth and per capita slows down significantly after 2040 compared to IEEJ.

Scaling up total energy supply and transitioning towards low-emissions sources calls for scaling up investment in Southeast Asia. In the IEA APS, average annual capital spending in energy over the 2011-2020 period was USD 75 billion. Of this total, for every dollar invested in unabated fossil fuels, about 50 cents were invested in clean energy. Looking forward, both analyses would see a significant scale-up of total investment in the energy sector to meet growing energy service demand combined with a shift of spending from fossil fuels towards clean energy technologies. Reducing costs of clean energy technology, including through R&D for technologies not yet in the market, as well as mobilising capital from both public and private sources of financing will be key to Southeast Asian countries transitions.

Total energy supply of selected fuels in Southeast Asia and Indonesia



Note: Due to data availability, renewables include traditional use of biomass.

Fossil fuels all peak in the 2030s in the IEA APS, while oil and natural gas continue growing to 2050 and 2040 respectively for IEEJ. Renewables grow rapidly in both analyses.

The composition of total energy supply by source provides an overview of the nature of the decarbonisation pathway and the balance of solutions taken to achieve overall emissions reductions targets. In the IEA APS, the composition of total energy supply is transformed over the period from 2020 to 2050. Fossil fuels represent the majority of total energy supply in 2020, and the use of oil, natural gas and coal continue to increase to 2030 before each reaches a peak and declines. From 2030 to 2050, oil declines by 41%, coal by 54%, and natural gas by a more modest 12%. At the same time, the use of renewable energy takes off, rising from 23% of total energy supply in 2020 to 25% in 2030 and 57% in 2050. Along the way, renewables overtake fossil fuels in total energy supply around 2045 in the IEA APS.

For Southeast Asia, both the IEA and IEEJ scenarios show a peak in coal consumption and similar renewable trends up to 2050. However, there are significant differences between the two scenarios. The IEA APS suggests a peak in oil consumption, while the IEEJ scenario shows strong continuous growth, with consumption in 2050 being twice that of IEA. Additionally, natural gas growth is significantly lower in IEA up to 2030, with a subsequent decline, whereas IEEJ shows strong growth up to 2040 and slower decline, with consumption in 2050 being over twice that of IEA. The IEEJ scenario also indicates a faster and immediate decline of coal, with consumption in 2050 being a quarter below that of IEA.

A significant difference in oil consumption seems to partly derive from different energy service demands for heavy-duty vehicles that is difficult to electrify, while over half of passenger cars shift to battery electric vehicles by 2050 in both scenarios. Natural gas is expanding by 2040 in the power and industry as major source of energy in the IEEJ scenario. A large part of emissions from gas-fired power is captured after 2040.

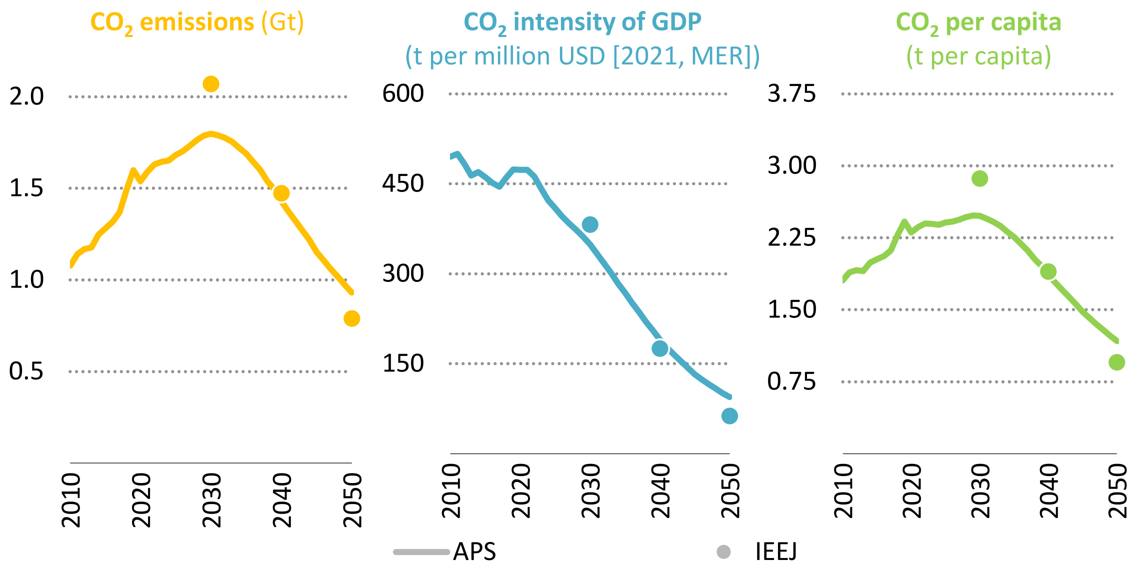
For Indonesia, both scenarios show a peak in coal consumption and similar renewable trends up to 2050. However, there are notable differences between the two scenarios. The IEA APS suggests a peak in oil consumption, while the IEEJ scenario shows strong continuous growth, with consumption in 2050 being 3.4 times that of IEA. Moreover, natural gas growth is significantly lower in IEA up to 2050, with IEEJ showing strong growth up to 2040 and then a decline, with consumption in 2040 being twice that of IEA. The gap is reduced, but consumption in 2050 is still 45% higher in IEEJ than in IEA.

The differences in economic growth assumptions contribute to some of these noted differences. While both the IEA and IEEJ pathways include very similar levels of renewable energy, additional energy demand in the IEEJ CN2050/2060 is an important factor in greater contributions of fossil fuels, whose emissions are reduced through carbon capture or offset by other technologies or nature-based carbon removal towards 2050/2060.

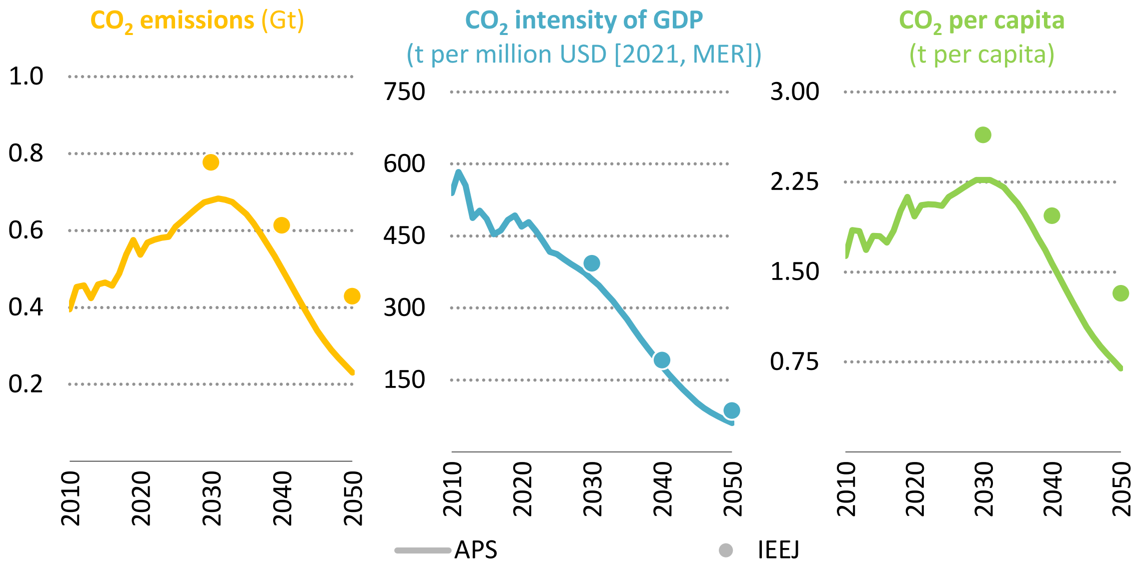
CO_2 emissions

Energy-related CO_2 emissions in Southeast Asia and Indonesia

Southeast Asia



Indonesia



While the carbon intensity of Southeast Asia economies declines in both, CO_2 emissions growth to 2030 is twice as large for the IEEJ, while by 2050 declines are 40% in the IEA APS relative to 2020 compared with 50% in the IEEJ analysis.

In the IEA APS, energy-related CO_2 emissions steadily rise to 2030 in Southeast Asia, reaching a peak in that year that is 17% above the level in 2020. After 2030, CO_2 emissions turn and steeply decline, ultimately falling to a level in 2050 that was last seen in 2006. Combined with a growing economy, this means that the CO_2 intensity of the Southeast Asia economy steadily decreases over the next 30 years, after holding roughly steady over the past decade. CO_2 emissions per capita also peak around 2030 in the IEA APS before declining steadily, returning to a level not seen in the region since 1995. Indonesia follows a similar pathway to the overall region, though the CO_2 intensity of the economy continues declines that have occurred over the past decade.

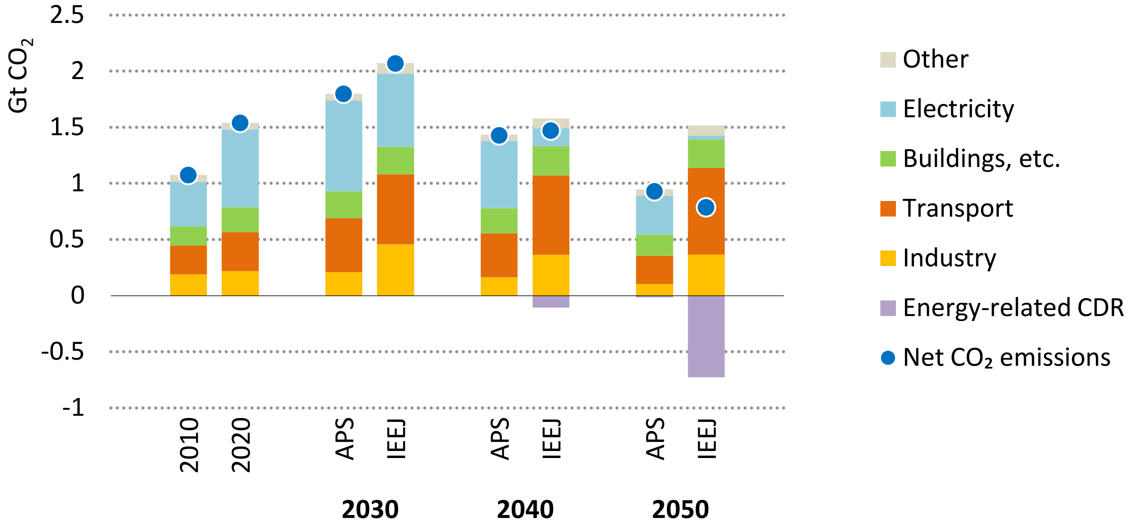
Comparing the scenarios for Southeast Asia and Indonesia, both IEA and IEEJ indicate a peak in total CO_2 emissions and CO_2 per capita in the medium term. The trends for CO_2 per unit of GDP and CO_2 per capita are also closely aligned to 2040 and 2050. However, there are key differences in the pathways for CO_2 emissions, related to differences in policy settings and technology development. The IEA APS shows significantly lower growth in CO_2 emissions to 2030, achieving targets set in nationally determined contributions, followed by a decline, while the IEEJ scenario has strong growth until 2030, followed by a faster decline thereafter.

In Indonesia, the points of agreement are similar to Southeast Asia, with a peak in total CO_2 emissions and CO_2 per capita, and CO_2 per unit of GDP well aligned to 2050. However, the key difference is that the decarbonisation is deeper in the IEA APS, with significantly lower growth in CO_2 emissions to 2030 and a sharper decline afterwards.

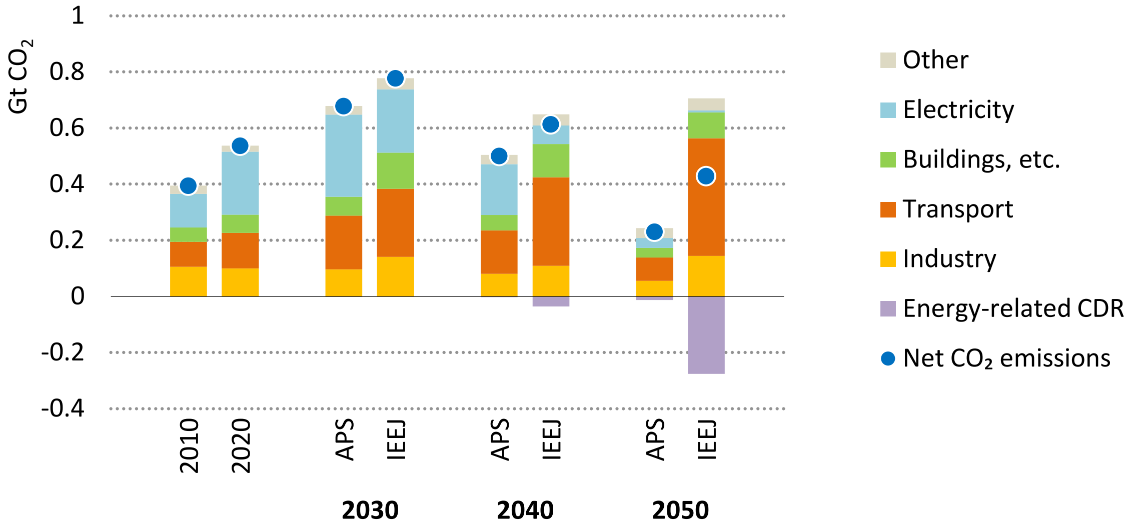
These differences can be explained by different assumptions on energy-related CDR and natural carbon sink. The IEEJ projects larger contribution of both technological and nature-based carbon removal than the IEA. Also costs of energy-related CDR can significantly be reduced only after 2030, affecting the speed of emissions reduction under the IEEJ scenario.

Gross energy-related CO_2 emissions by sector, carbon dioxide removals and net emissions in Southeast Asia and Indonesia

Southeast Asia



Indonesia



Note: Energy-related CDR = carbon dioxide removal from the atmosphere through bioenergy with carbon capture and storage (BECCS) and through direct air capture and storage (DACS).

Both analyses include deep emissions reductions in the electricity sector, while emissions in transport and industry remain notably higher in the IEEJ CN2050/2060, offset by more CDR than in the IEA APS.

Out of total energy-related CO_2 emissions in the IEA APS, the electricity sector is the largest emitting sector and emissions continue to increase until 2030, before being cut by more than half by 2050. To 2050, the electricity sector remains the largest emitter. The transport and industry sectors also see a rise in emissions until 2030 before reducing by 28% and halving by 2050, respectively.

The building sector sees relatively stable emissions over the long term, while meeting higher energy service demand.

There are several key points of agreement between the IEA and IEEJ scenarios, starting with the largest reductions in emissions coming from the electricity sector. This is due to the availability of a number of low-emissions technologies, including renewables, nuclear power, and hydrogen and ammonia. A second point of agreement is that industry and transport are harder to abate, calling for residual emissions to be partially counterbalanced by CDR.

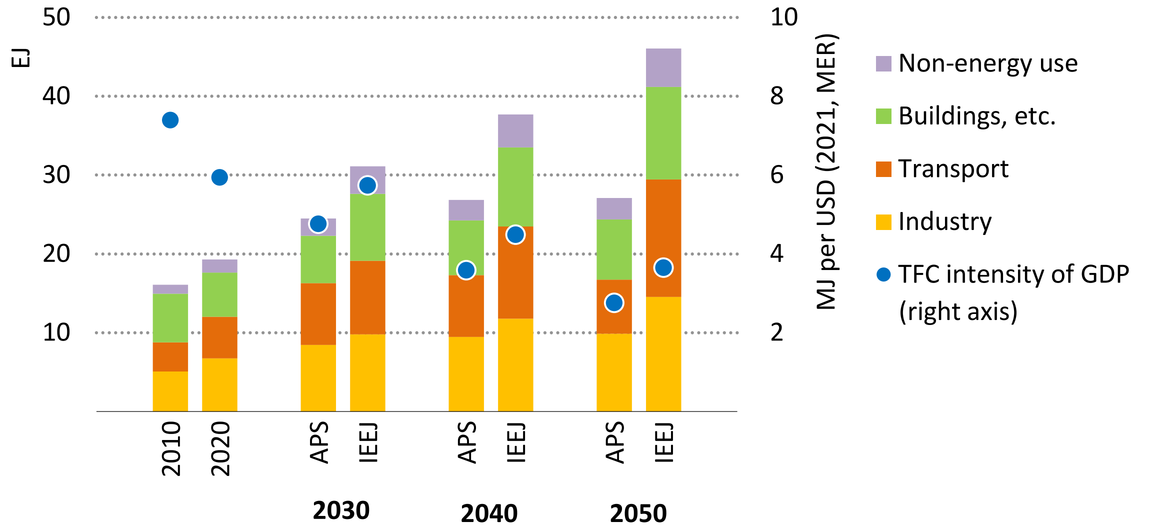
Both IEA and IEEJ analysis take into account action to halt and reverse deforestation. The IEA APS considers all announced initiatives in the region, such as the Reducing Emissions from Deforestation and Forest Degradation (REDD+) programme in Cambodia and the Enhanced Natural Regeneration (ENR) Programme in Indonesia. IEEJ analysis takes into account land use, land use change and forestry (LULUCF) for Indonesia, Malaysia, Myanmar, Thailand and Viet Nam based upon consultations with these countries. CO_2 emissions from AFOLU decline substantially in the next decade to become a net CO_2 sink in the latter half of the twenty-first century in the APS and before 2030 in IEEJ. Where national net zero targets make use of AFOLU sinks to offset remaining energy-related emissions, this is reflected in both IEA and IEEJ modelling.

However, there are key differences between the IEA and IEEJ scenarios. In the IEEJ scenario, the electricity sector eliminates emissions by 2050, rather than remaining the largest emitter. A second key difference is that all end-use sectors see a decline in emissions in the IEA, while emissions from the transport and industry sectors have continuous growth to 2050 in the IEEJ scenario. In the IEEJ scenario, CDR provides a significant counterbalance to residual emissions in the transport and industry sectors as it becomes cost-effective toward 2050/2060, while remaining limited in the IEA APS.

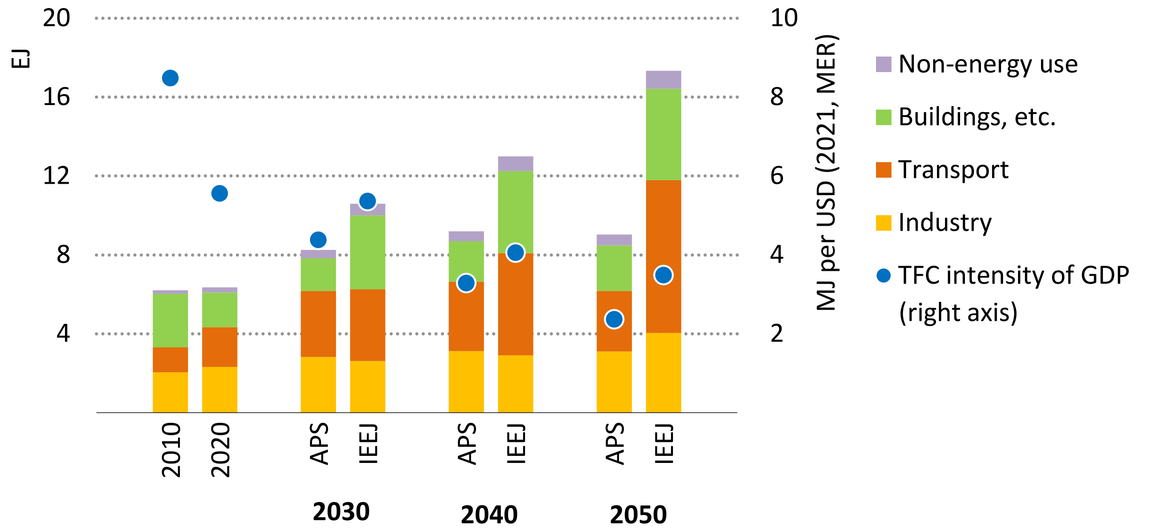
Total final consumption by sector

Total final consumption by sector and intensity of GDP in Southeast Asia and Indonesia

Southeast Asia



Indonesia



Note: TFC = Total final consumption.

Higher economic growth assumptions partly drive stronger energy consumption growth in the IEEJ analysis for Southeast Asia and Indonesia, with larger differences in transport and buildings.

Total final consumption (TFC) of energy in Southeast Asia is projected to continue recent growth in 2030 in the IEA APS, before slowing as energy efficiency is deployed in all sectors. From 2030 to 2050, TFC in Southeast Asia increases by just 11%, with modest growth in industry and more significant growth in buildings offset by reductions in transport, mainly through electrification reflecting specific policies in Indonesia, Malaysia, Thailand and Singapore. Non-energy use remains a minor contributor to TFC through to 2050 in Southeast Asia. Indonesia TFC reaches a plateau around 2040 in the IEA APS, with energy consumption in each sector remaining broadly stable to 2050.

Both the IEA and IEEJ scenarios have continued TFC growth in Southeast Asia and Indonesia to 2050, driven by multiple sectors as the economies continue to develop. However, the pace of growth is notably different between the two scenarios. The IEEJ projects that TFC in Southeast Asia will more than double from 2020 to 2050, compared to a 40% increase projected by the IEA. In Indonesia, TFC growth in the IEA APS is just over 40%, compared with a nearly tripling in the IEEJ scenario. This pace of growth is more closely aligned with Indonesia's Long-Term Strategy submitted to the UNFCCC in 2021.

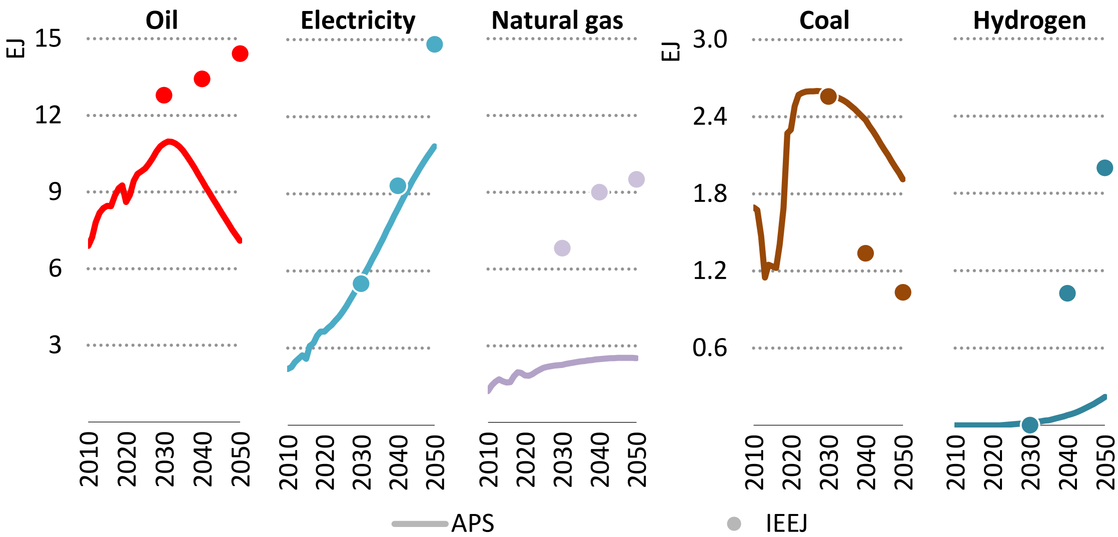
These differences in TFC growth from 2020 to 2050 should be compared with differences in GDP growth. While the IEEJ projects 3.9 times and 4.4 times GDP increase for Southeast Asia and Indonesia respectively from 2020 to 2050, the IEA APS is 3.0 times and 3.3 times. The gap between the IEA APS and IEEJ is larger in TFC growth than in GDP growth, reflecting greater roles for end-use energy efficiency and higher shares of electricity in the IEA APS.

The IEEJ also projects much stronger growth rates in the transport and buildings sectors in Southeast Asia and Indonesia than the IEA. The IEEJ path for TFC in the Southeast Asia transport sector to almost triple by 2050, compared to a 31% increase projected by the IEA. In Indonesia, the IEEJ projects almost a quadruple increase, while the IEA projects a 53% increase. In the buildings sector, the IEEJ projects a doubling of TFC in Southeast Asia, compared to a 36% increase projected by the IEA. In Indonesia, the IEEJ projects a more than doubling, while the IEA projects a 33% increase.

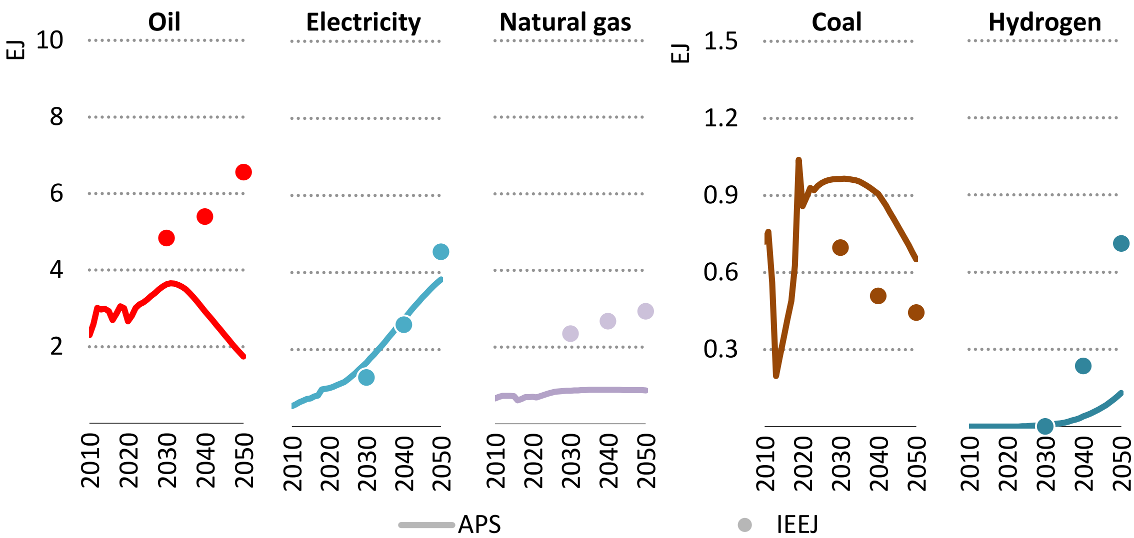
Total final consumption by fuel

Total final consumption for selected fuels in Southeast Asia and Indonesia

Southeast Asia



Indonesia



Both analyses see rising electricity use and a peak for coal, while there are notable differences in the paths for oil, natural gas and hydrogen.

The composition of TFC by fuel shifts markedly in Southeast Asia in the IEA APS. Fossil fuels in total decline from 66% in 2020 to 54% in 2050, though oil has a clear peak in 2030 while coal shows a long plateau in the 2020s and early 2030s before declining sharply, and natural gas consumption stabilises over the long term. Oil and coal are substituted mainly by increasing the use of electricity and eventually hydrogen in transport and industry in particular in the IEA APS. In Indonesia, oil and coal peak around 2030, natural gas use remains broadly flat, while electricity use quadruples to 2050 and low-emissions hydrogen makes inroads after 2030.

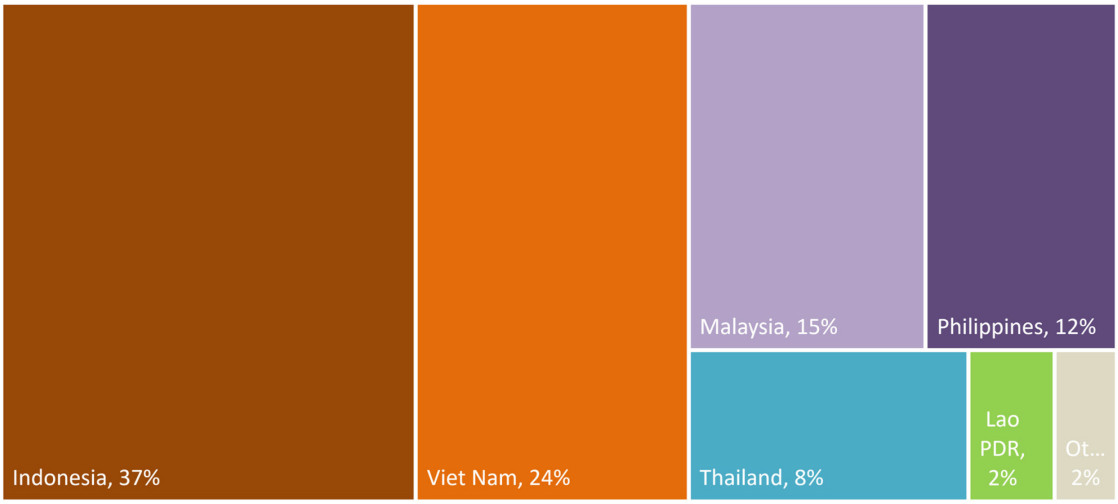
Comparing TFC by fuel in Southeast Asia reveals important differences in the modelled decarbonisation pathways by the IEA and IEEJ. Both the IEA and IEEJ agree that coal consumption will peak, and electricity trends until 2040 are aligned. However, key differences exist. The IEA projects a peak in oil consumption, while the IEEJ projects strong continuous growth. Consequently, oil consumption in 2050 is double in the IEEJ compared to the IEA. Natural gas growth is also significantly lower in the IEA, with consumption in 2050 being 3.8 times lower than in the IEEJ. Additionally, the IEEJ projects a faster and immediate decline of coal, with consumption in 2050 being half that of the IEA. The IEEJ also projects faster growth in electricity demand after 2040, with a 40% higher consumption than the IEA in 2050. Finally, the IEEJ scenario includes faster uptake of hydrogen use, with consumption being nine times higher than in the IEA by 2050.

In Indonesia, both the IEA and IEEJ project a peak in coal consumption, with aligned electricity trends until 2050. However, key differences exist. The IEA projects a peak in oil consumption, while the IEEJ projects strong continuous growth, resulting in oil consumption in 2050 being 3.8 times higher in the IEEJ than the IEA. The IEEJ also projects natural gas consumption to be 3.4 times higher in 2050 than the IEA. The IEEJ projects a faster and immediate decline in coal, with consumption in 2050 being 32% lower than in the IEA. Finally, the IEEJ scenario again includes faster uptake of hydrogen use, with consumption being 5.5 times higher than in the IEA in 2050.

Again, these points of distinction for TFC are linked to the assumed economic growth in the region. Higher growth in the IEEJ analysis contribute to continued or even larger use of fossil fuels.

Electricity generation by source

Southeast Asia coal-fired electricity generation in 2020, share by country



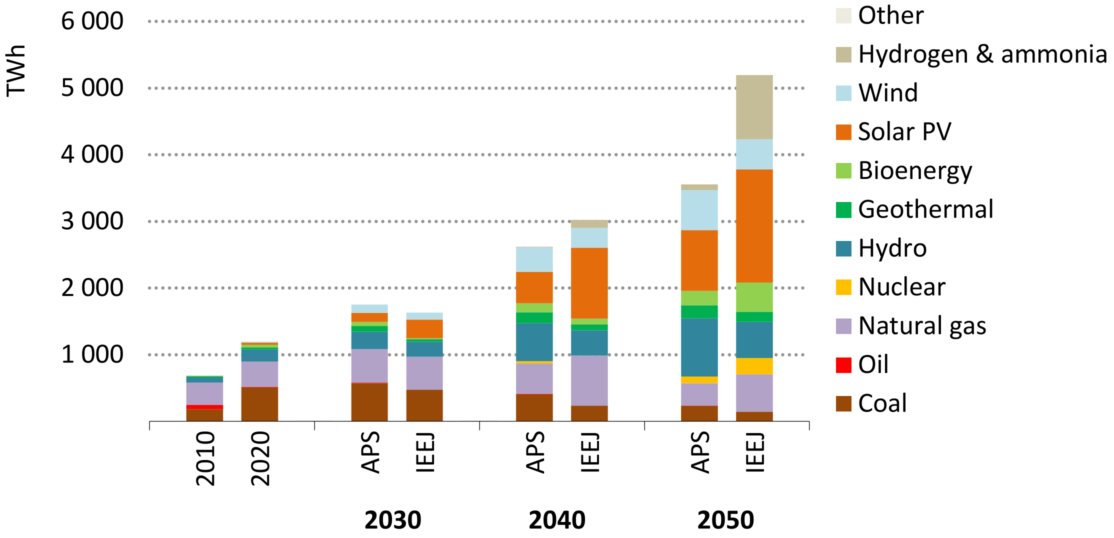
Coal is a major source of electricity across Southeast Asia, with Indonesia and Viet Nam accounting for over 60% of coal-fired generation in the region as of 2020.

Southeast Asia coal-fired power plant capacity today stands at 90 GW, with an average age of 12 years. Coal meets close to 45% of electricity supply in Southeast Asia. Coal-fired units in Thailand are older, with 19 years on average while units in Viet Nam's fleet are only 8 years on average. Malaysia, Indonesia and Philippines coal fleets have an average age of 13 years. Those five countries concentrate over 95% of Southeast Asia installed coal-fired capacity and generation.

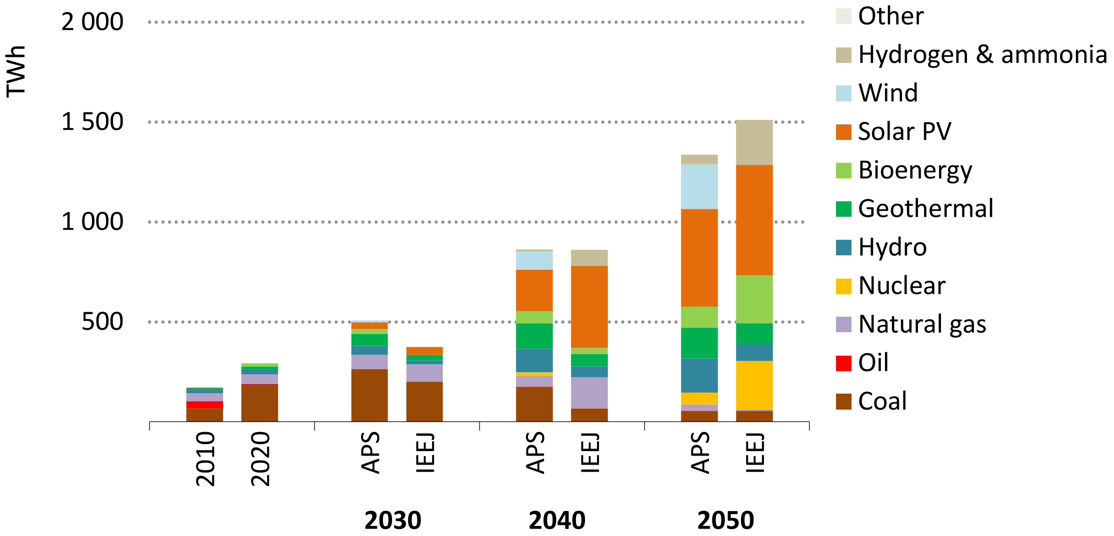
In the APS additions of unabated coal slow from an average of 5.5 GW/year over the 2011-20 period to less than 2 GW/year over the period to 2030 before coming to an end, while alternative sources of low emission electricity are scaled up. The share of unabated coal in electricity generation drops to 33% in 2030 and only 6% in 2050. In the CN2050/2060, the IEEJ projects that the existing coal-fired power plants will start co-firing with biomass/ammonia and CCS installation in the 2040's and that unabated coal-fired power plants will no longer operate in 2050.

Electricity generation by source in Southeast Asia and Indonesia

Southeast Asia



Indonesia



Electricity generation is set to increase rapidly in both scenarios in Southeast Asia and Indonesia, while the role of hydrogen and ammonia, and nuclear differ in the long run.

The electricity sector is critical in any decarbonisation pathway, and achieving a decarbonised electricity mix while meeting increasing electricity demand is challenging yet crucial. The IEA APS scenario outlines key elements for decarbonisation in Southeast Asia and Indonesia, including scaling up renewable energy technologies – led by solar PV and hydropower, complemented by wind, geothermal and bioenergy – complemented by nuclear power, low-emissions hydrogen and ammonia. In addition, the scenario envisions a peak in unabated coal-fired generation around 2030, followed by a long-term decline, and moderate growth for the unabated use of natural gas until 2030, followed by reduced use.

The IEA and IEEJ scenarios share points of agreement, including strong growth in total generation until 2050, declining share of fossil fuels, nuclear power gaining a foothold in Southeast Asia, and renewables being the central pillar of electricity decarbonisation. However, there are key differences between the scenarios. The IEEJ scenario envisions a stronger growth in total electricity supply, partly linked to the assumed economic growth in the region, with a 46% higher increase by 2050 compared to the IEA APS. This also implies that while total generation from renewable sources is 17% higher in IEEJ scenario than in the IEA APS, their share is lower, reaching 63% in 2050, compared to 79% in the IEA APS. The IEEJ also includes a faster and immediate decline in coal-fired generation, which would be 36% lower than in the IEA APS by 2050 for Southeast Asia. This is partly due to faster introduction of co-firing in coal-fired generation under the IEEJ scenario. Furthermore, higher electricity supply means that natural gas-fired generation peaks later in the IEEJ scenario, in 2040, and at a higher point for both Southeast Asia and Indonesia. Nuclear power is also less central to the IEA decarbonisation pathway in Southeast Asia, with 2.5 times higher growth from zero in IEEJ for Southeast Asia and four times for Indonesia.

Hydro power is more central to the IEA decarbonisation pathway in Southeast Asia, with hydro representing 25% of the mix in Southeast Asia and 13% in Indonesia by 2050, compared to 11% and 5% respectively in IEEJ. Wind power also plays a more central role in the IEA APS, with wind reaching 17% of Southeast Asia electricity supply by 2050 compared to 9% in IEEJ. In Indonesia, the IEA APS projects a contribution of 17% of the mix from wind power, while the IEEJ scenario sees no deployment as a result of cost-minimisation.

Finally, with stronger growth in total electricity supply, hydrogen and ammonia are more central to the IEEJ decarbonisation pathway, with levels reaching 19% of the mix in Southeast Asia and 15% in Indonesia by 2050, compared to 2% and 3% respectively in the IEA APS. Solar PV is central to both scenarios, with a quarter of electricity supply in the IEA APS and a third in IEEJ. However, the higher electricity supply in the IEEJ scenario means that solar PV is two times higher in IEEJ than in IEA by 2050.

Implications

The IEA APS and IEEJ CN2050/2060 describe two possible decarbonisation pathways for Southeast Asia and Indonesia. Each represents a path, but not necessarily the pathway, as there are many uncertainties to consider and achieving net zero goals will involve countless decisions by people in the region and around the world. Both analyses aim to provide information to policy makers in the region and beyond on potential ways to tackle the overall challenge to reduce CO_2 emissions and fulfilling country-level ambitions to reach net zero emissions in the long term.

While the IEA and IEEJ present two distinct pathways, there are a number of shared pillars of decarbonisation, including:

- Scaling up renewable energy is central to both scenarios, leading the decarbonisation of the electricity sector and for direct use in transport.
- The importance of electrification to improve the energy efficiency of many applications, including transport, and take advantage of decarbonised electricity supply.
- The strong shift away from the use of unabated coal-fired power plants, which represents the single largest source of CO_2 emissions in Southeast Asia today.

There are also several distinctions in the decarbonisation pathways described, which is to be expected as the scenarios were developed in separate exercises that are based on two different modelling frameworks, take different approaches and reflect different policy settings for countries in Southeast Asia. These differences are important considerations for the comparisons.

One of the most significant distinctions is the assumption of economic growth, leading to differences of projected total energy supply as well as TFC. Although the IEA APS and IEEJ CN2050/2060 include a very similar contribution of renewable energy, the IEEJ CN2050/2060 includes greater roles for fossil fuels equipped with carbon capture, and hydrogen and ammonia in the long term.

A second important difference in the approach is the extent of emissions reductions in the energy sector in order to reach net zero targets, linked to different assumptions for emissions reductions outside the energy sector, including agriculture, forestry and other land use. A critical uncertainty reflected in the two scenarios is also the role of CDR in achieving overall climate ambitions, where the IEA APS includes a more limited role than IEEJ, and therefore calls for deeper decarbonisation in all sectors. The two decarbonisation pathways compared in this paper also reflect uncertainties around the pace of technology development, commercialisation and cost, as well as the prevailing fossil fuel prices.

Clean energy transitions must be secure, sustainable and affordable. Energy transitions offer the opportunity to build safer and more sustainable energy systems, while maintaining energy security will require attention to both traditional and new vulnerabilities. In addition, there are many uncertainties that will influence the pathway towards net zero targets, both within and outside the energy sector. Policy makers have the most important role to play to navigate these factors and move the world closer to its climate goals. International cooperation will be critical to promote technology innovation and knowledge-sharing, including on the challenges faced, solutions developed, and policy and regulatory approaches applied. As transitions call for scaling up investment, the affordability of clean energy transitions will also depend on reducing the cost and improving the availability of capital.

IEA Publications
International Energy Agency
Website: www.iea.org
Contact information: www.iea.org/contact

Typeset in France by IEA, April, 2023
Cover design: IEA
Photo credits: © shutterstock