IRENA
International Renewable Energy Agency

ENERGY TRANSITION INVESTMENT OPPORTUNITIES IN SOUTHEAST ASIA

A PREVIEW OF ASEAN AND INDONESIA FINDINGS

Note: This is a preview of findings from the forthcoming IRENA reports, *Renewables outlook for ASEAN: Towards a regional energy transition* and the *Indonesia energy transition outlook*. This document is intended to inform discussions at the IRENA G20 Investment Forum in Indonesia on 31 August – 1 September 2022. The findings presented here may change ahead of the launch of these reports.

ISBN: 978-92-9260-462-2

Citation: IRENA (2022), *Energy transition investment opportunities in Southeast Asia: A preview of ASEAN and Indonesia findings*, International Renewable Energy Agency, Abu Dhabi.

About IRENA

The **International Renewable Energy Agency (IRENA)** serves as the principal platform for international co-operation, a centre of excellence, a repository of policy, technology, resource and financial knowledge, and a driver of action on the ground to advance the transformation of the global energy system. A global intergovernmental organisation established in 2011, IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security, and low-carbon economic growth and prosperity. **www.irena.org** www

For further information or to provide feedback: **publications@irena.org**

This preview report was authored by Nicholas Wagner (IRENA) and Dolf Gielen (Director, IRENA Innovation and Technology Centre), and includes contributions by Adam Adiwinata, Badariah Yosiyana, Emanuele Taibi, Francisco Boshell, Maisarah Abdul Kadir, Michael Taylor, Ricardo Gorini, Sean Collins, Raul Miranda, Walter Sanchez and Zainab Omolade Ajibade. Additional valuable comments and suggestions were provided by Ahmed Badr, Bishal Parajuli, Diala Hawila, Elizabeth Press, Gurbuz Gonul, Gondia Sokhna Seck, Michael Renner, Nazik Elhassan, Rabia Ferroukhi, Ute Collier and Xavier Casals. Editing and layout support were provided by Francis Field and Myrto Petrou.

IRENA would like to thank the Government of Denmark for supporting IRENA with the work that formed the basis of this preview report.

CONTENTS

ENERGY CONTEXT

The Southeast Asia region will see rapid economic growth over the coming decades and, in turn, energy use will grow significantly. Energy supply within the states of the Association of Southeast Asian Nations (ASEAN) [1]is dominated by fossil fuels, which make up over 85% of primary energy (ACE, 2020). Today, Southeast Asia stands at a crossroads. On the one hand, it can pursue a path of continued reliance on fossil fuels, most of which come from non-indigenous sources, thereby increasing the region's exposure to volatile and increasingly expensive global commodity markets. On the other, the region could utilise its ample, affordable and indigenous renewable energy resources.

As the region is also increasingly committing itself to ever more ambitious climate targets, including net-zero commitments, a transition towards net-zero will take decades and planning must begin now in earnest. This preview of forthcoming IRENA reports for ASEAN and Indonesia shows that it is timely to consider an energy transition based largely on renewable energy and efficiency. The transition outlined in this document is also in line with a climate-proof future that is economically prosperous, secure and socially inclusive.

Coal retirement, coupled with the continued expansion of renewables, is an important step in aligning with net-zero targets. ASEAN is home to 12% of global coal-fired power plant capacity - an indicator for its global relevance (ACE, 2022). Several ASEAN member states are considering different options to reduce or end coal utilisation in the power sector. For instance, Indonesia, the Philippines and Viet Nam are participating in an early coal retirement initiative under the leadership of the Asian Development Bank, targeting a total reduction of around 30 GW in coal power plant capacity by between 2030 and 2035 (Asian Development Bank, 2021). Following Indonesia's appointment to the presidency of the G20, the country has officially announced the energy transition as one of the main pillars of its agenda.

There has been a growing deployment of renewable energy (RE) in the region. Between 2015 and 2021, the total installed capacity from renewables jumped from 55 GW to 93 GW, respectively, according to International Renewable Energy Agency (IRENA) statistics. By the end of 2021, Viet Nam, Thailand and Indonesia were leading the region with a total of 42.5 GW, 12 GW, and 10.6 GW of installed renewable energy capacity, respectively (IRENA, 2022a).

ASEAN has ambitious renewable energy goals in the near-term. The region has aspirational targets to achieve a 23% share of renewable energy in primary energy supply and a 35% share of renewable energy in installed capacity by 2025. However, investments in recent years have fallen short in delivering on the 2025 objectives. Renewables in ASEAN accounted for only 13.9% of primary energy and 28.7% of power capacity in 2019 (ACE, 2020), with estimates for 2021 showing these shares have increased to 14.2% in primary energy and 33.5% in power capacity. While the installed capacity target looks within reach, the primary energy target will be a challenge.

At the 39th ASEAN Ministers on Energy Meeting (AMEM) in 2021, the ministers of the region agreed to: "Endeavour in the future to explore an aspirational long term regional target towards lower-emission energy systems, in accordance with our common but differentiated responsibilities and respective capabilities, that can contribute to lowering GHG emissions" and to "Intensify [their] efforts on long-term energy and climate policy and planning to increase the rate of energy efficiency and conservation, expand renewable energy sources and deploy advanced, cleaner and low-carbon energy technologies towards low greenhouse gas (GHG) emissions and climate resilient development" (ASEAN, 2021). This document and the forthcoming reports can serve as a foundation to provide a perspective on what a an energy pathway that prioritises the deployment of renewable energy could look like.

1 The Association of Southeast Asian Nations comprises ten Member States: Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam.

AN ENERGY TRANSITION ROADMAP

IRENA's roadmaps consider multiple possible future energy pathways. The two main scenarios are the Planned Energy Scenario (PES), which considers current and planned policies; and the 1.5°C Scenario (1.5-S), which follows IRENA's World energy transition outlook (WETO) 1.5-S scenario aiming to reach net-zero emissions globally by 2050. For the 1.5-S, multiple power sector supply scenarios are considered for ASEAN, one with 90% renewable power generation (1.5-S RE90), and one with 100% renewable power generation (1.5-S RE100); additionally for Indonesia a scenario with 85% (1.5-S RE85) is also considered.

The ASEAN region will be a key driver of global energy demand growth over the next three decades. In the PES, final energy consumption almost triples, electricity demand increases more than four times and energy-related GHG emissions double, all while indigenous domestic fossil fuel supply shrinks and import dependency rises.

In the 1.5-S, renewable energy can meet over two-thirds of final energy demand, cutting energy-related CO_2 emissions by 75% compared to the PES in 2050, or less than half compared to today's energy- and process-related CO_2 emissions. This reduction is all the more impressive considering energy demand doubles. However, as is the case in the 1-5-S in WETO, other mitigation technologies will be required to achieve net-zero emissions by 2050.

The combination of renewable power and electrification of end uses - such as from electric vehicles - constitutes the core of the energy transition in ASEAN. However, it is not the only solution; this trend towards electrification is also supplemented by a growing use of bioenergy (to meet around 20% of final demand, more than doubling its share) and efficiency measures (around 2.5%/year additional energy intensity improvement compared to the PES when viewed in primary energy terms). Bioenergy will play a crucial role for certain sectors; however, it must be scaled-up in line with strong sustainability criteria (IRENA, 2022b). In the power sector, where the scale-up will need to utilise agricultural residues, wastes and biomethane, bioenergy based thermal generators can provide dispatchable electricity. Existing coal and natural gas fired generators can, with some retrofits, switch to combusting bio-based fuels and gases.

BOX 1 IRENA engagement with ASEAN

Guided by the ASEAN IRENA MoU and Action Plan, signed during the 36th AMEM in 2018 in Singapore, IRENA has advanced the implementation of the regional action plan through various activities. These include policy workshops, innovation days, power system and energy demand analyses, participation in the energy events of ASEAN Member States, and many others. In the context of its ASEAN cooperation, IRENA works closely with the ASEAN Centre for Energy, housed in the Directorate General of Electricity of Indonesia.

As part of these joint activities, the Renewable energy outlook for ASEAN was released in 2016 (IRENA & ACE, 2016). This was followed by the Renewable energy prospects: Indonesia report in 2017 (IRENA, 2017). This framework has been further developed in 2020-22. With the support of the government of Denmark, and in close cooperation with ASEAN, IRENA has in the last three years developed a 1.5°C scenario for ASEAN that is consistent with the World energy transitions outlook (IRENA, 2022c), IRENA's flagship global publication on what the world needs to do to decarbonise energy in line with the Paris Agreement. The latest work for ASEAN previewed in this report will include a regional roadmap, but also deep-dives for Indonesia and Malaysia. The results for ASEAN will be launched on the occasion of the 40th AMEM later this year, while the deep-dives for Indonesia and Malaysia will follow shortly thereafter.

BOX 2 Analysis approach and overview

As one of the fastest growing regions in the world, Southeast Asia is crucial to a global energy transformation that is powered by sustainable and affordable energy and achieves global energy and climate commitments - particularly those of the Paris Agreement.

The analysis is based on a technology-rich partial equilibrium modelling framework called REmap. This includes a detailed, bottom-up demand analysis for end-use sectors (industry, buildings and transport) for all ten ASEAN member states, and power system capacity expansion planning using PLEXOS in combination with power systems flexibility analysis using IRENA's FlexTool (IRENA, 2020). One power system model has been developed for ASEAN that represents all countries individually, while two more detailed power systems models have been developed for Indonesia and Malaysia, respectively.

The models draw on the unique IRENA datasets for resource endowment (IRENA, n.d.) and technology cost data (IRENA, 2022d).

- The **Planned Energy Scenario (PES)**, the primary reference case, reflects current energy polices, and contains energy and climate policies in place (those that have been translated into law, not aspirational targets that aren't yet implemented in national law or planning structures).
- The **Transforming Energy Scenario (TES),** which is consistent with limiting global temperature rise to two degrees and largely focuses on 'low-hanging' and readily affordable and deployable technologies. This scenario is not outlined in this document but will feature in the forthcoming reports.
- The **1.5°C Scenario (1.5-S)** aims for net-zero by 2050. It follows the vision of IRENA's flagship global publication, the World energy transitions outlook. In the case of Indonesia, three variants for the power sector have been assessed for 85%, 90% and 100% renewable power shares by 2050. In the case of ASEAN, two have been assessed, with 90% and 100% renewable power by 2050. However, the power sector results for 2030 are largely consistent across the three variants, as the differences between the high renewable scenarios for 1.5-S are only seen as shares surpass 80% renewable power, which occurs after 2030.

This long-term energy planning will have global as well as regional socio-economic impacts. IRENA explores the impacts of the energy transition with a macro-econometric model that links the energy system and the world's economies within a single quantitative framework. This socio-economic footprint of energy transition roadmaps results from the many interactions and feedbacks between the energy system, and the wider economy and social systems. Understanding the socio-economic footprint of energy transition roadmaps in the ASEAN region and Indonesia informs policy making for a successful transition. The results are presented in the form of indicators, including for GDP, jobs (economy-wide and energy sector) and human welfare, to inform energy system planning and policy making to ensure a just and inclusive energy transition.

IRENA has assessed the socio-economic benefits of the energy transition roadmap (1.5˚C Scenario) for ASEAN and Indonesia, with different climate policy baskets that vary in the level of carbon pricing and international collaboration, and include policy instruments to address improvements in intra-income distribution. The analysis showcases the important role of international collaboration in providing vital improvements in the transition's socio-economic footprint in developing countries such as those in the ASEAN region. The socioeconomic impacts will be discussed in a separate paper.

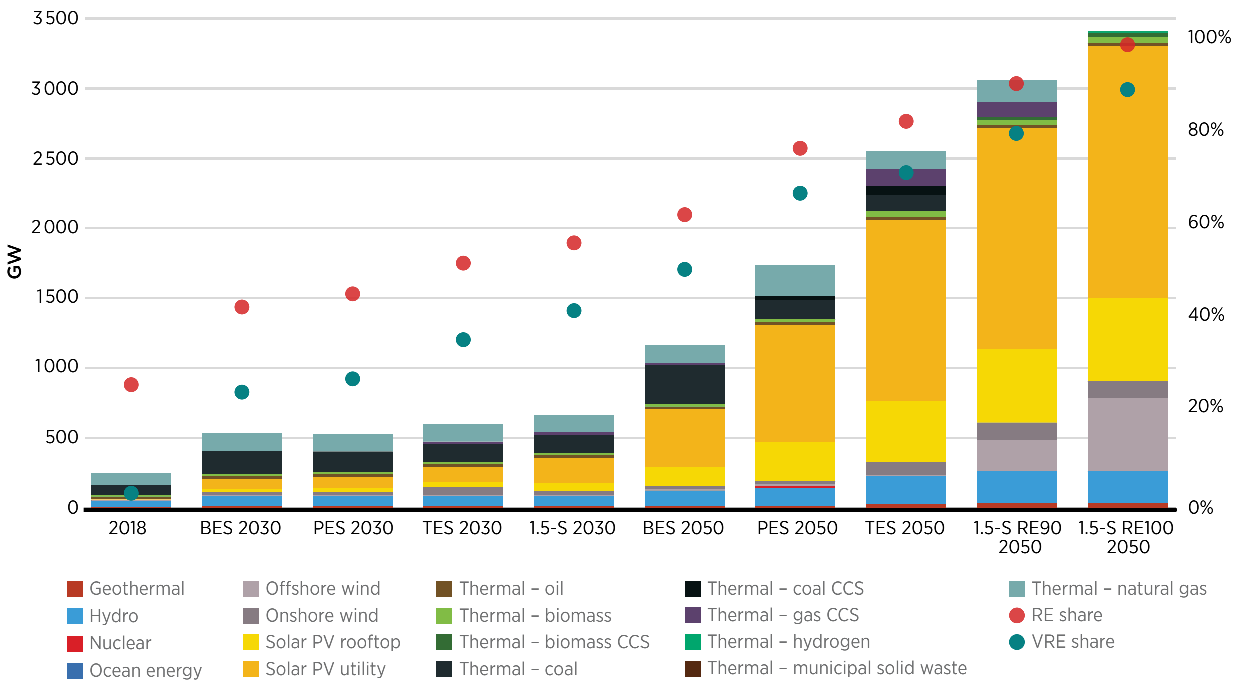
POWER SECTOR TRANSFORMATION

The power sector holds particular importance in the energy transition and especially in the ASEAN region. Electricity demand will continue to grow rapidly; in the PES, demand is projected to increase from 1 000 TWh today to 4 080 TWh in 2050. In the 1.5-S, electricity demand increases over five-fold to 5 300 TWh in 2050 due to increased electrification, whilst the electricity share in final consumption increases from less than 20% today to 46% in 2050. This reflects a much-accelerated electrification compared to the 27% electricity share in the PES in 2050.

In 2021, renewables accounted for 33.5% of power capacity in ASEAN. In the 1.5-S, the share of renewables increases to 55% in 2030 and to 90-100% in 2050. Solar PV and wind account for the majority of the growth in the share of renewables. For such a pathway, in absolute terms, 240 GW solar PV is needed by 2030 (utility scale and rooftop) and 30 GW wind (onshore and notably offshore). Capacities then need to increase up to ten-fold over 2030 values in the following two decades towards 2050. Furthermore, geothermal (+30 GW), hydropower (+50 GW) and biomass power (+15 GW) will grow substantially up to 2030, complemented by the emerging deployment of marine energy technologies.

RENEWABLE POWER WILL DOMINATE THE ELECTRICITY SYSTEM

FIGURE 1 ASEAN power capacity (left y-axis) by scenario, RE and VRE share (right y-axis), 2018, 2030, 2050

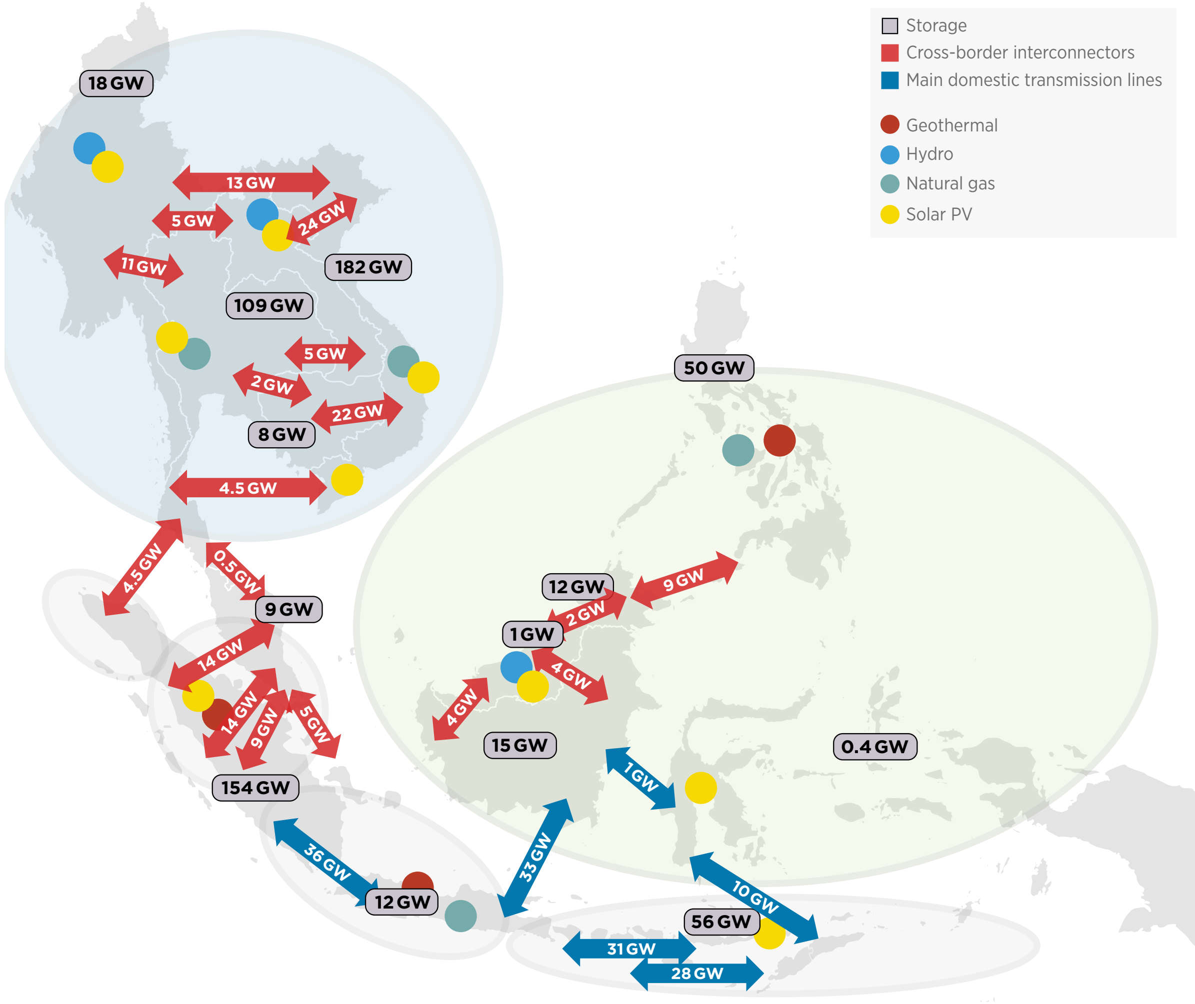


Notes: (RE) renewable energy; (VRE) variable renewable energy.

Coinciding with the rapid scale up of renewable power technologies, significant investment in energy flexibility is required. Power system flexibility needs to be ensured, and transmission grid capacity should be expanded and strengthened for renewables integration. Both cross border interconnectors and domestic transmission lines will need to be scaled up significantly. Regional interconnection will need to expand to almost 160 GW by 2050 and storage will need exceed 600 GW by 2050 in the 1.5-S RE90.

REGIONAL INTERCONNECTION AND DOMESTIC TRANSMISSION WILL NEED TO EXPAND SIGNIFICANTLY

FIGURE 2 Regional interconnection expansion in ASEAN and battery storage, 1.5-S RE90, 2050



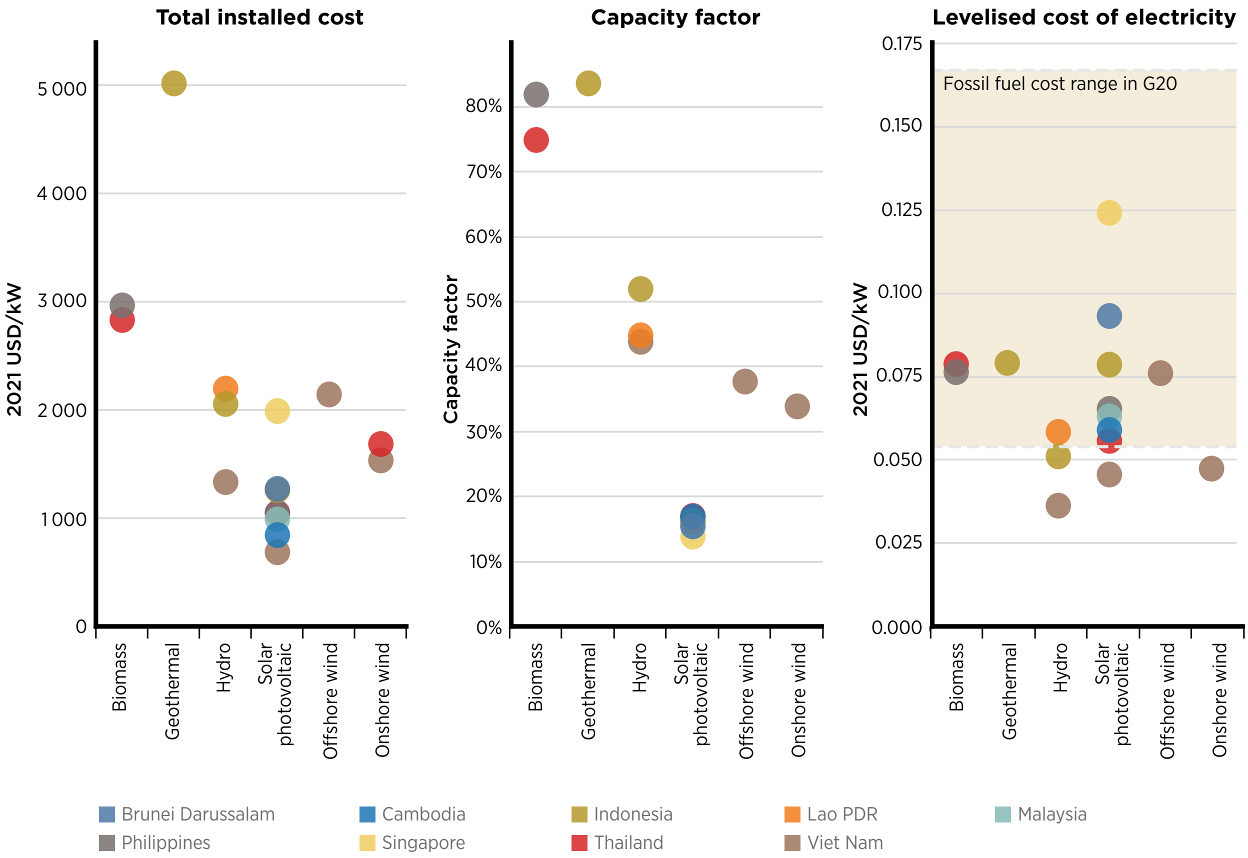
Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

The shift to renewable power and electrification is a trend that has been seen in recent years. The competitiveness of renewables continued to improve in 2021. Data from the IRENA Renewable Cost Database and analysis of recent power sector trends affirm their essential role in the journey towards an affordable and technically feasible net-zero future. The period 2010-2021 has witnessed a seismic shift in the balance of competitiveness between renewables, and incumbent fossil fuel and nuclear options. The global weighted average levelised cost of electricity (LCOE) of newly commissioned utility-scale solar PV projects declined by 88% between 2010 and 2021, that of onshore wind and CSP by 68%, and offshore wind by 60% (IRENA, 2022c).

Renewable energy technology costs in ASEAN countries span a wide range. Figure 1 shows the total installed costs, capacity factors and LCOE for projects commissioned in ASEAN countries in 2021. Viet Nam has achieved some of the most competitive cost structures in the region, with production costs for hydropower, utility-scale solar PV and onshore wind below USD 0.05/kWh.

RENEWABLE POWER TECHNOLOGY COSTS CONTINUE THEIR RAPID DECLINE

FIGURE 3 **Total installed costs, capacity factors and cost of electricity by country, 2021**



Source: IRENA Renewable Cost Database.

Note: Data is the weighted-average (by capacity) for projects in the database, which are a subset of total projects commissioned in 2021.

IRENA surveyed finance, utility, developer and bank professionals on the cost of finance for renewable power generation projects in 2021. The survey concluded that financing costs (the weighted-average cost of capital [WACC]) for solar PV, onshore wind and offshore wind were higher elsewhere in ASEAN than in more established renewable energy markets in Malaysia and Viet Nam. This survey data was used to calibrate a benchmark model of WACC, with results for ASEAN countries for utility-scale solar in the range of 4.5% (for Thailand and Singapore) to 6% (for Indonesia and Viet Nam) and a high of 7.5% (for Cambodia and Lao PDR). Wind WACC has similar ranges, with the largest market in Viet Nam, averaging 5.1% for onshore wind and 7.4% for offshore wind. In some of these markets, as these technologies become more mainstream and supporting policies are implemented, the financing cost will come down. Reducing the WACC will also, in turn, increase the competitiveness of these technologies and lower the cost for procuring electricity from solar PV and wind.

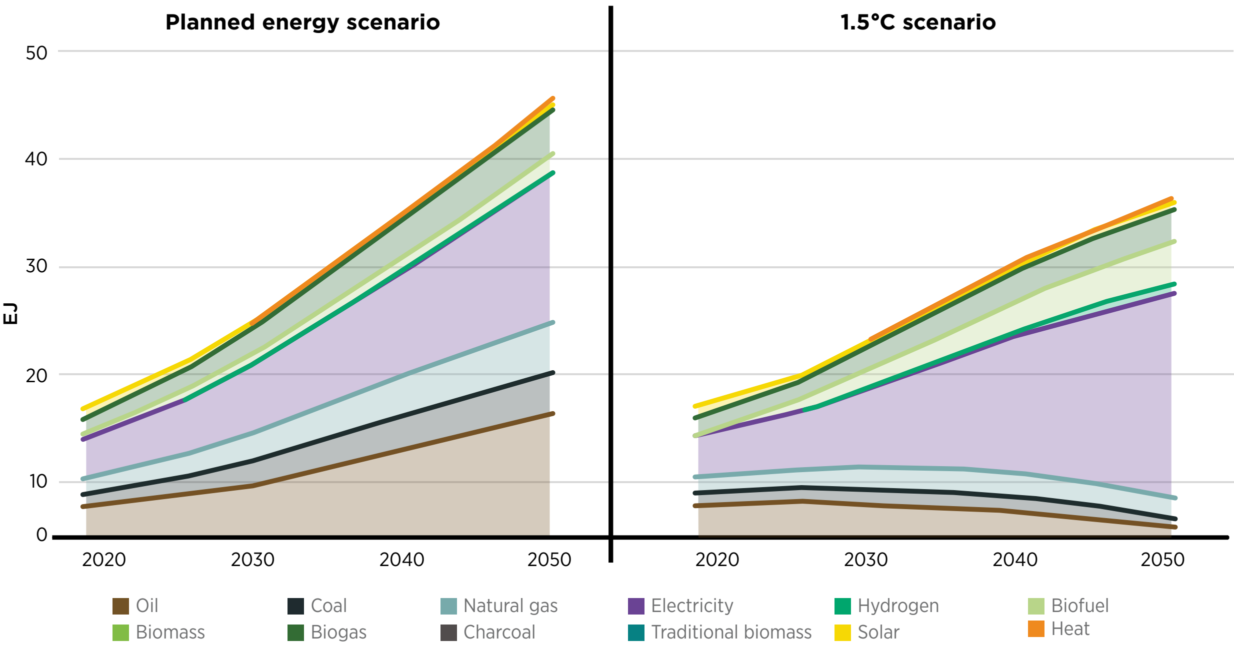
ENERGY DEMAND AND END-USE SECTORS

The region will see energy demand grow at around 3% annually. Total final energy consumption will increase from 17 EJ/yr in 2018 to over 45 EJ/yr by 2050 in the PES. To put this in perspective, in 2019 the EU-27 consumed 42 EJ of final energy.

Industry will continue to be the largest end-use consuming sector, followed by transport and buildings. In the 1.5-S, demand is reduced by around 20% due to electrification and efficiency increases, while the fuel mix changes significantly - with the share of electricity growing to 46%, biofuels increasing by 50% and with the emergence of hydrogen and its derivates.

ENERGY DEMAND WILL INCREASE 2.5-FOLD WITH THE 1.5-S REDUCING DEMAND BY 22%, LARGELY DUE TO EFFICIENCY IMPROVEMENTS AND END-USE ELECTRIFICATION

FIGURE 4 **Total final energy consumption in ASEAN; PES and 1.5-S, 2018-2050**



In industry, energy demand will increase 3.6% per year. In the 1.5-S, the sector will become considerably less reliant on fossil fuels, which currently dominate the sector's energy supply. Increasing energy efficiency is also important to restrain energy demand growth. Circular economy practices that promote the reuse of materials can also slow energy demand growth.

In terms of energy supply, the electrification of process heat in the 1.5-S will see electricity account for over half of the sector's energy consumption by mid-century. Biofuels can be scaled up to allow ASEAN's industry sector to benefit from the utilisation of modern biomass and reduced dependence on fossil fuel. The region will also see an increased role for hydrogen in the decarbonisation of hard-to-electrify, high temperature process heating applications beginning in around the 2030s. Also, the utilisation of solar thermal and geothermal technologies will offer additional options in decarbonising some industries with low to medium temperature process heating applications, such as the food industry. The share of fossil fuels will be reduced to less than one-fifth of total energy demand, with more than half of this coming from natural gas.

In transport, annual EV sales increase to 13 million in 2030 and 38 million units in 2050 in the 1.5-S to account for an 80% stock share in 2050. This is supplemented by electric two- and three-wheelers that will number in the hundreds of millions by 2050. Meanwhile, heavy-duty vehicles will deploy a mix of clean energy - both electric and bio-based. Biofuel will be needed also for shipping and aviation. Overall liquid biofuel use grows strongly from 15 billion litres today to 50 billion litres in 2030 and c. 115 billion litres in 2050. Scaling biofuel sustainably and affordably is crucial to gather the required investment and wider acceptance (see bioenergy section below).

Energy demand in the buildings sector will grow by nearly 3% annually, reaching 10 EJ by 2050 in the PES. Space cooling will dominate the buildings sector's energy demand, growing from a 17% share in 2018 to almost half in 2050. In absolute terms this implies growth in energy demand from space cooling of six-times compared to 2018. More stringent energy efficiency standards will reduce electricity demand from space cooling by about one-quarter in the 1.5-S over the PES. The share of cooking energy demand will fall to below 20% due to the phasing out of traditional biomass and transition towards clean cooking technologies - mainly LPG in the PES and electrification in the 1.5-S. The utilisation of electric stoves, mainly in the residential sector and small commercial businesses, will primarily substitute LPG and become the main energy source for cooking. Overall electrification and more stringent energy efficiency implementation will reduce the buildings sector energy consumption by an additional 27% in the 1.5-S compared to the PES. Electricity will be the dominant carrier in the future. Oil products (namely LPG) will account for about 15% by 2050 in the PES but will decrease below 10% in the 1.5-S. Utilisation of biomass will decrease from about one-third of total energy demand in the buildings sector to only about 5% in all scenarios, largely as a result of the phasing out of traditional forms of biomass.

In terms of total energy, currently around 14% of primary energy is supplied by renewables. In the 1.5-S, the share will reach 26% by 2030, and over the longer term will increase to 60%. It is important to note that due to the convention used to calculate primary energy equivalents for energy sources such as solar, wind and hydro - which assume 100% efficiencies - this diminishes their respective share in primary energy terms compared to fuels that are combusted. Therefore, an alternative metric to consider the importance of renewables is final energy, which sees the renewable share reach 27% by 2030 and 65% by 2050 in the 1.5-S.

"THE ENERGY SYSTEM WILL SEE A SWITCH TO RENEWABLES IN BOTH POWER AND END-USES IN THE 1.5°C SCENARIO"

TABLE 1 Summary table of key indicators by scenario for ASEAN, 2018, 2030, 2050

		2018	2030			2050			
		HISTORICAL	PES	TES	1.5-S	PES	TES	1.5-S RE90	1.5-S RE100
Power	RE installed capacity (%)	30	46	53	57	77	86	88	99
	RE installed generation (%)	23	34	41	39	60	76	90	100
	Total primary supply (PJ)	5	107	142	241	1 121	1 730	2 108	2 402
Supply	Total primary supply (PJ)	22 633	34 610	32 721	31 724	61 936	54 265	45 585	
	RE share (%), PECM	18	19	24	26	25	42	60	
Demand	Final consumption, including non-energy use	19 100	28 571	27 369	26 339	50 592	44 777	40 783	
	RE share, fuels & electricity (%)	19	21	26	27	29	45	60	65
	Electricity consumption share (%)	20	22	26	28	27	38	45	
Other indicators	TPES energy per capita (GJ/capita)	36	48	45	44	79	71	61	
	Energy intensity (GJ/million USD)	8 142	7 475	7 695	7 568	5 251	4 268	4 202	
	Energy intensity improvement rate (%/yr)		1.1	1.4	2	1.5	1.9	2.5	
	Electricity consumption per capita (kW/capita)	1 631	2 473	2 720	2 824	4 734	5 856	6 394	
Emissions	$MtCo_2$ – energy related	1 434	2 114	1 826	1 777	2 763	1 252	709	

INDONESIA MUST BECOME A KEY DRIVER FOR THE ENERGY TRANSITION

The developments in Indonesia reflect the findings for ASEAN. The geography of the country poses specific challenges due to its size, load centres, and the many islands. The island of Java is densely populated and represents nearly 70% of Indonesia's electric load, which limits land area. Significant new transmission capacity will be needed, for example, to strengthen the connections with Sumatra (+80 GW, half of all transmission capacity expansion).

The findings suggest a need for 65 GW of additional PV by 2030, together with a rapid expansion of hydropower (+9 GW) and geothermal (+4 GW). Additional growth is needed in associated infrastructure, such as transmission, distribution and storage. Also, biofuel supply and EV chargers will need to grow rapidly. The table below shows the level of investment needed in these important energy transition technologies up to 2030 in the 1.5-S; in total, around USD 337 billion will need to be invested in Indonesia in energy transition related technologies and infrastructure.

SHORT-TERM TECHNOLOGY AND INVESTMENTS IN INDONESIA SHOULD FOCUS ON RENEWABLES AND ENABLING INFRASTRUCTURE

TABLE 2 Selection technology deployment needs and investments, Indonesia, 1.5-S, 2030

INDONESIA 1.5-S SHORT TERM INVESTMENT REQUIREMENT (2018-2030)		PARAMETER		TOTAL INVESTMENT (BILLION USD)
Power	**Solar PV**	Installed capacity (GW)	66	44
	Other RE (non-hydro)	Installed capacity (GW)	11	17
	Hydro	Installed capacity (GW)	16	22
Grid and flexibility	**Transmission (national)**	Km (thousand)	113	43
	Distribution	Km (thousand)	1 296	32
	Storage	GW	12	5.5
	Biofuels supply	billion litres	35	19
Electrification	**EV chargers**	million units	1.3	22
	EV sales	million units	6.4	129

The share of renewables in power generation will increase from 20% today to 34% in 2030, with further growth to 85-100% by 2050. The solar PV share in generation will grow from near zero today to 16% in 2030 and 50-60% in 2050. The coming eight years are critical to establishing a solar industry in Indonesia, as installed capacity will need to expand to 600-800 GW in 2050. This growth, combined with rapid innovations and the emergence of new high efficiency PV technologies such as tandem cells and multijunction cells, will create new business opportunities for Indonesia.

To put this in perspective, global installed PV capacity is around 800 GW (AC) today. In the longer term, such high PV shares will require substantial new flexibility, including in the form of battery storage. Smart charging and EVs can also play a role and Indonesia is already pursuing industrialisation opportunities in this area based on indigenous nickel resources and the emerging EV market.

ASEAN has seen recent success stories in larger scale deployment of variable renewables. In the case of solar PV, significant expansion has been seen in Viet Nam, which has also increased its manufacturing base. Also, Malaysia and Thailand have scaled up solar PV installation considerably in recent years. Indonesia can learn from these countries and international best practices to rapidly scale energy transition technology deployment while also fostering a local manufacturing base.

INVESTMENT OPPORTUNITIES

Significant investment is needed across the energy system in ASEAN Member States. In the short-term to 2030 in the 1.5-S, a rapid scale up of key renewable technologies will be required. Investment must focus on key energy transition technologies and enabling infrastructure, including:

- 241 GW of solar PV by 2030, requiring USD 156 billion in investment;
- hydropower requiring USD 56 billion and geothermal requiring USD 24 billion;
- significant expansion of the grid, requiring investment of USD 174 billion; and
- EV sales of 13 million cars, and USD 47 billion invested in 3.7 million charging stations.

INVESTMENT IN ASEAN TO 2030 SHOULD FOCUS ON RENEWABLES AND ENABLING INFRASTRUCTURE

TABLE 3 ASEAN Investment needs, 2018-2030, 1.5-S

1.5-S SHORT TERM INVESTMENT REQUIREMENT (2018-2030)		PARAMETER		TOTAL INVESTMENT (BILLION USD)
Power	**Solar PV**	Installed capacity (GW)	241	156
	Other RE (non-hydro)	Installed capacity (GW)	56	90
	Hydro	Installed capacity (GW)	73	56
Grid and flexibility	**Transmission (international)**	Km (thousand)	17	13
	Transmission (national)	Km (thousand)	247	92
	Distribution	Km (thousand)	2 739	69
	Storage	GW	29	8
	Biofuels supply	billion litres	57	66
Electrification	**EV chargers**	million units	3.7	47
	EV (car) sales	million units	13	349

In the short-term to 2030, under the 1.5-S, USD 987 billion will need to be invested in energy transition related technologies and infrastructure across ASEAN. Over the longer-term, cumulative energy investment over the period to 2050 in the 1.5-S will need to increase just under three-fold compared to the PES, to as high as USD 7.3 trillion (for 1-5-S RE100). This requires investments of around USD 230 billion per year. For the period to 2030, nearly USD 100 billion per year is needed. Power generation accounts for nearly 40% of the investment needs to 2030 with significant additional sums needed in end-use renewables (such as biofuels), energy efficiency and complementary infrastructure.

INVESTMENTS OVER THE LONG-TERM IN ASEAN WILL NEED TO TRIPLE

TABLE 4 ASEAN investment needs, 2018-2050, by scenario

INVESTMENT REQUIREMENT (BILLION USD)			2018-2030			2018-2050			
			PES	TES	1.5-S	PES	TES	1.5-S RE90	1.5-S RE100
Power	Renewable energy	Solar PV	71	96	156	555	836	1 104	1 245
		Wind	56	100	56	56	143	739	1 474
		Hydro	56	56	56	163	313	367	368
		Geothermal	15	24	24	32	73	96	99
		Biomass	10	10	10	18	50	44	67
	Nuclear					90	0	0	0
	CCS	Natural gas CCS	0	20	22	0	109	104	0
		Coal CCS				132	307	0	0
		Biomass CCS				0	0	231	341
	Fossil fuel	Natural gas	39	39	39	103	39	59	39
		Coal	118	90	90	118	90	90	90
Grid and flexibility	Transmission (national)		66	83	92	367	367	461	461
	Transmission (international)		6	27	29	6	228	246	285
	Distribution		50	62	69	200	275	346	346
	Storage		3	5	8	43	71	189	351
Renewable end uses	Biofuels supply		38.3	66.3	66.3	112	197	235	235
Energy efficiency	Buildings		58.3	67.7	77.4	343	523	688	688
	Industry		20.6	46.7	115.7	208	248	509	509
	Transport		12.9	18.9	31.1	116	298	419	419
Electrification	EV chargers		6	31	47.2	48	278	419	419
Total investment requirement (billion USD)			**636**	**843**	**989**	**4 445**	**2 609**	**6 346**	**7 346**

Note: Investment totals for 2050 in TES, and 1.5-S RE90 and RE100, for coal and natural gas are already committed in national plans and do not represent additions within those scenarios. These comprise projects that have been built since 2018, or are in the pipeline to occur by 2030 in the PES, and the values are thus carried over as cumulative investment in 2018-2050.

INDUSTRIALISATION OPPORTUNITIES

A just energy transition is essentially a negotiated process that is centred on a social dialogue between governments, industry/employers and workers, as well as wider stakeholders including, for example, energy consumers and communities. A just transition should contribute to decent jobs (including for those people directly affected by the energy transition) and poverty eradication as well as to the mitigation of negative social and economic impacts. The following discussion will focus on the Indonesian case.

According to the International Institute for Sustainable Development (IISD), the oil and gas sector in Indonesia has been declining for years and is projected to continue to decline by 11% per year due to aging oil fields and lack of exploration (IISD, 2022). The coal sector is predominant, employing at least 100 000 workers in 2018. In 2020, Indonesia was the largest exporter of coal in the world, with the bulk of its total production of 679 million tonnes being exported to countries in southeast Asia. The economic relevance is distributed unevenly: in East Kalimantan, coal mining accounted for 45% of the region's GDP in 2019. Also, in parts of Sumatra coal mining is a key economic activity. New plants are planned to be built by 2030 that will provide 13.8 GW of power. Also, coal power is subsidised through a cap on the PNL coal price that is well below today's global market value and the subsidies for oil and gas consumption exceed production royalties.

At the same time, changes to facilitate the energy transition are being introduced. In early October 2021, Indonesia became the fourth country in Asia to pass a carbon tax. It is set at a minimum of USD 2.1 per ton of carbon dioxide - a low number but a start, as many countries do not even price carbon. A carbon market is expected to operate by 2025.

There are plans to create a Green Industrial Area to produce green aluminium, solar panels, and industrial silicone in North Kalimantan (Bulungan regency). It is centred around the planned 11 GW Kayan hydropower project. The project is a collaboration between the governments of Indonesia, China and the UAE (ASEAN Briefing, 2021). The park aims to attract producers of high-tech and precision products such as lithium-ion batteries, semiconductors, solar panels, green aluminium and industrial silicon, among many others. This project will help diversify the economy in the region over the coming decades and replace some of the jobs that may be lost when coal is phased out globally. The government estimates that construction will absorb 100 000 workers and between 50 000 and 60 000 for its operation, but this could rise to 200 000 workers if tenants bring their subsidiaries. Hydropower plants and solar power plants will power the park, setting the model for the development of future green industrial parks in the country. An estimated USD 12 billion is required to construct the plants and USD 1 billion to develop ports near the park.

At a national scale, BAPPENAS estimates that by pursuing a net-zero by 2050 plan, Indonesia would create 1.8-2.2 million green jobs in the energy, EVs, land restoration and waste sectors by 2030 (LCDI, 2021). This would vastly exceed the number of existing jobs in fossil fuels. The transition, however, would need to be carefully managed to ensure sufficient support for engagement of affected workers and communities.

According to IRENA analysis, the energy transition is positive for job creation in Indonesia's energy sector. The number of people working in the Indonesian energy sector by 2030 could reach around 5.2 million and 5.1 million under PES and 1.5-S, respectively. The numbers are slightly lower under the 1.5-S than under the PES, given job losses in conventional energy (i.e. fossil fuels and nuclear), even though these are almost offset by gains in renewables and other energy transition-related technologies (i.e. energy efficiency, power grids and flexibility, hydrogen). Dedicated policies would be required to address the structural dependency on fossil fuel labour and to galvanise a more ambitious approach to the energy transition. Renewable energy jobs in Indonesia are expected to reach 2.5 million by 2050 under 1.5-S. Strengthening of energy transition related supply chains, as discussed below, offers the prospect of additional jobs.

SOLAR PV INDUSTRIALIZATION OPPORTUNITIES

In 2021, around 257 GW of new renewable power generation capacity was added worldwide. More than half was solar PV; about 133-140 GW of newly installed systems was commissioned during 2021 alone (AC), with more than 180 GW of modules at DC level. IRENA's WETO shows the need to have 10 TW of renewable power in place by 2030 worldwide according to the 1.5-S pathway, compared to 3 TW installed capacity at end of 2021. To meet that goal, annual capacity additions need to increase to over 800 GW per year - a threefold increase.

Solar PV has a key role to play worldwide, including in ASEAN states and Indonesia. In ASEAN in IRENA's 1.5-S, USD 156 billion would need to be invested in solar PV capacity alone by 2030. Longer-term to 2050, between USD 1 080 and USD 1 245 billion would need to be invested in plants in the 1.5-S to the year 2050.

Solar is significantly cheaper than fossil or nuclear based power generation. In 2021 alone, the global weighted-average LCOE of utility-scale solar PV fell by 13% to USD 0.046/kWh. The global weighted-average total installed cost of utility-scale solar PV was USD 857/kW in 2021.

Over 843 GW PV was in operation in AC terms by the end of 2021, and 1 000 GW in DC terms. According to IRENA's 1.5-S pathway we need around 16 TW PV by 2050. Some other scenarios suggest even more PV in the coming decades. Utility-scale dominates but rooftop accounts for around a third of global installations, with smaller roles for floating and building integrated PV.

The typical cost of a solar PV project can be split into modules and other costs. While much attention is focused on module manufacturing opportunities, other costs do in fact dominate. These include racks, inverters, grid connection and other components, project preparation, as well as financing costs (US DOE, 2022). These other costs also represent a significant economic opportunity.

China dominates today's global PV production: polysilicon (66%), wafers (>95%), cells (78%) and modules (72%) and by the end of 2022 China is expected to have 500 GW annual module production capacity and 550 GW wafer production capacity of the industry standard crystalline silicon-based technology.

Manufacturers are also investing in new, high-efficiency cells, such as TOPCon, heterojunction and multi-junction cells. Higher efficiency modules are a key goal in limiting costs, as they reduce the area required for the module and some other cost components (e.g. racking/mounting, cabling, etc.). Innovation in cell architecture is a permanent feature of the solar PV industry; but change is rapid, the industry rarely knows what its tech pathway looks like beyond a decade or even half-decade into the future. A commitment to scaling up manufacturing capacity therefore requires an ongoing commitment from policy makers and industry, in addition to minimum levels of scale if the goal is a fully vertically integrated supply chain.

Although they employ different approaches to achieve it, both TOPCon and heterojunction rely on passivated contacts to address recombination losses due to metallic contacts (a primary shortcoming of most conventional cell technologies). The near-term technology direction is likely to be determined by the market evolution of these two technologies, while multi-junction cells are expected to have a greater impact in the long-term. TOPCon manufacturing builds upon PERC production equipment and the manufacturing process changes are limited. In TOPCon cells, the semiconductor materials is stacked with a very thin silicon oxide layer, which takes on both passivation and contact functions.

Heterojunction solar cells combine two different technologies into one cell, consisting of a crystalline wafer-based silicon cell between two layers of amorphous thin-film silicon. The combination of the two materials allows for simultaneous benefits from both the absorption properties of standard silicon wafer-based cells and the passivation characteristics of thin-film amorphous silicon. This combination unlocks higher efficiency levels compared to conventional (homojunction) silicon solar panels. However, heterojunction technology requires a very distinct manufacturing process, which may lead to higher investment. It remains to be seen which of these technologies will gain market dominance.

About 60 GW of TOPCon manufacturing capacity is expected to be reached by the end of 2022, while announcements for reaching a heterojunction capacity of up to 80 GW by 2023 have also been made. Estimates suggest that about 10-15 GW of heterojunction technology manufacturing will be operational by the end of 2022, most of which will be in China.

The production capacity of cells and modules in ASEAN Member States is modest, although Malaysia produces 3% of global modules and 4% of cells, while Viet Nam produces 4% and 2%, respectively. To be competitive, a full supply chain must be developed at scale. Today's operations must sustain an industry in the 10-20 GW per year scale if ASEAN seeks to produce a sufficient quantity of solar modules to meet the majority of its domestic demand. China was responsible for about 70% of module production in 2021, up from 50% in 2010. Important manufacturers in South East Asia include Viet Nam (5%), Malaysia (4%) and Thailand (2%), but most manufacturing capacity in these countries was developed by Chinese companies focusing on exports.

Deploying the latest technology is one way to achieve market entry. The average efficiency of crystalline modules - the dominant technology making up 95% of the market - increased from 14.7% in 2010 to 20.9% in 2021. Further efficiency gain increases are expected with TOPCon, heterojunction and multijunction further down the road. Environmental, social and corporate governance (ESG) is also on the radar of the PV industry's development. Eco-design is critical, while reducing critical material use is also a very important aspect, not only for sustainability but to scale up production with limited resources. Capital requirements increase as you go up the value chain from module assembly to polysilicon production and advanced cell manufacturing.

Critical materials mining and processing is another area that creates new economic opportunities. Much of the value added is related to materials supply. Module production requires significant amounts of glass and aluminium, which account for 80% or more of the weight of modules. Silver and polysilicon together make up less than 5% of a module's weight, but at current prices account for nearly two-thirds of material costs. Metallisation pastes that contain silver have been an important cost component in the wafer-to-cell process. Given the relatively high cost of silver recently, the industry has placed significant focus on different ways to reduce metal consumption in cells.

Power systems need flexibility to deal with the variability of solar and wind. This requires new technology but also new market designs and regulations, new operational practices and new business models. Innovations across these four pillars need to be combined to create new solutions. A good example is smart charging of electric vehicles, which can be timed to better align when production of solar and wind is at its peak.

We need to ensure there is sufficient flexibility in power systems to deal with solar variability. That includes batteries for day/night storage but also new solutions for seasonal storage or long range hydrogen trade. These flexibility measures also constitute an important economic opportunity.

INDONESIA BATTERY AND EV MANUFACTURING

Global EV sales are on the rise. In 2022, with four million sold through June (CleanTechnica, 2022) and potentially 8-10 million forecasted to sell for the entire year, and with a projected growth to 40 million units by 2030 (MI Tech News, 2022). The battery represents the single most important cost component in an EV.

The rapidly growing popularity of electric vehicles is causing the demand for lithium-ion batteries to soar. An optimised supply chain with a focus on vertical integration and strategic partnerships is vital to mitigate risks and guarantee a secure supply of essential raw and refined materials.

Indonesia wants to develop an integrated electric vehicle (EV) supply chain and become an EV battery producer and exporter. Southeast Asia's largest economy has the ambitious goal to make batteries with a capacity of 140 gigawatt hours (GWh) in 2030 (including 50 GWh for export) (Gaikindo, 2022) - more than 16 times its current global EV battery production capacity of about 8.7 GWh (1% of global capacity) (IEA, 2022).

The country's ambitions are motivated by both upstream and downstream aspects of the supply chain: the world's biggest nickel producer wants to capitalise on its mineral resources but also aims to reduce emissions by creating a domestic EV market. It is therefore important to consider the sustainability and impacts of nickel mining and processing.

Upstream in the supply chain, Indonesia leverages its nickel reserves and uses measures to attract foreign investment in nickel processing. Midstream and downstream, Southeast Asia's largest car market offers incentives for EV battery (component) producers, EV manufacturers and consumers.

South Korean investments are currently building the country's first EV battery plant, scheduled to start production in 2024, as well as its first EV plant. Nickel processing for use in batteries started in 2021, with more projects in the pipeline, mainly due to Chinese investments.

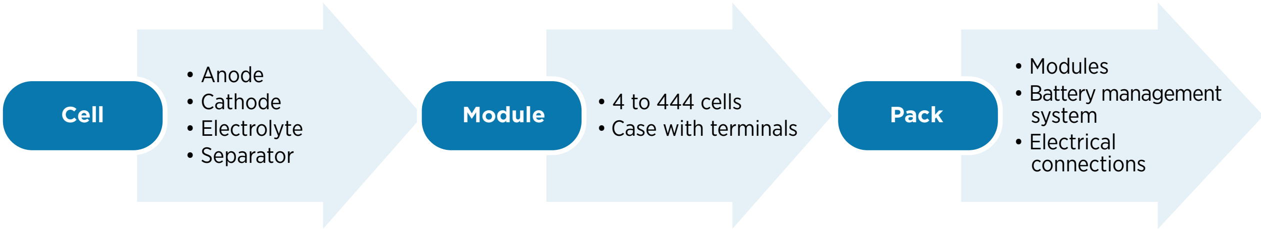
Whether or not Indonesia can reach its goal to produce 140 GWh in 2030 will depend on attracting substantial foreign investment over the next few years. The government will also need to address challenges to conducting business in Indonesia as well as ESG concerns related to nickel mining and processing, and how to better engage local communities and workers.

In recent years, a combination of rapid technological progress and scaled-up production rates have led to improved performance and a general fall in production costs for BEV batteries, while growing raw material costs and the recent semiconductor shortage have caused prices to temporarily rise again over the last two years.

Battery costs are heavily influenced by the cell technology used, the production location and the price of raw materials. Cell costs comprise approximately 75% of the total cost of the battery pack. Materials, such as cathode and anode active materials (CAM and AAM), account for 70% of the cost of each cell, with raw and refined materials like cobalt- and nickel-sulphates and lithium salts accounting for more than 30% of cell costs.

BATTERY PRODUCTION WILL BE CRUCIAL FOR THE REGION TO ELECTRIFY

FIGURE 5 The three stages of electric vehicle battery production



Source: Coffin and Horowitz, 2018.

ITS TRANSPORT SECTOR AND REAP THE BENEFITS OF THE TRANSITION

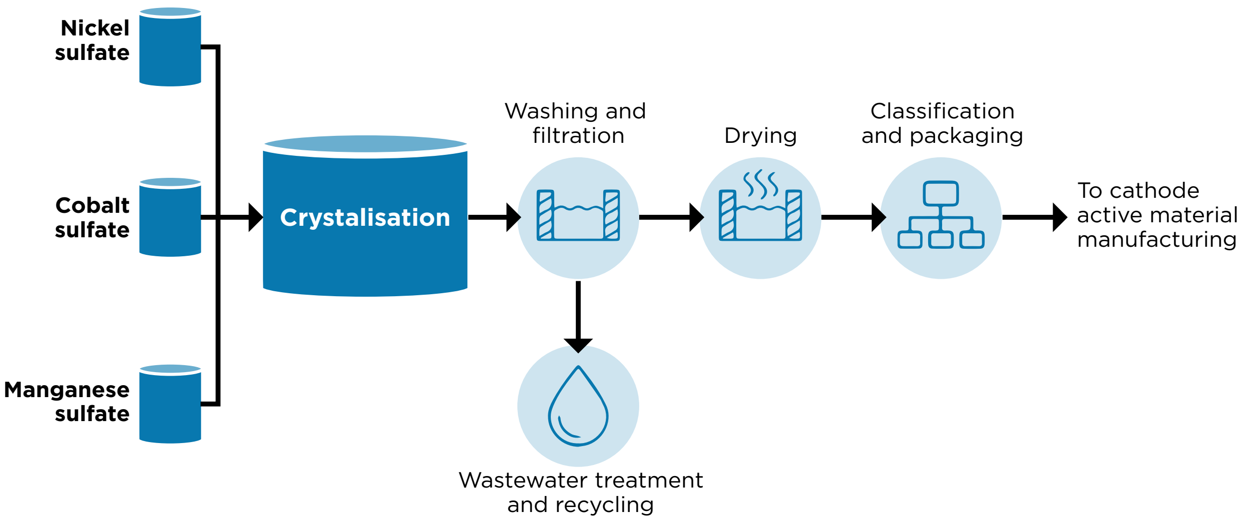
Battery chemistry is somewhat flexible, notably cathode chemistry. The trend is towards high nickel or nickel-free cathodes. The preparation of cathode materials requires specific knowledge and processing to ensure a quality product.

The precursor market is currently concentrated in China, but countries such as Indonesia are looking to move downstream to produce precursor materials to complement their raw materials.

Producing precursors for NMC cathode chemistries requires three main raw materials - nickel sulfate, cobalt sulfate and manganese sulfate. The cathode active material is produced from NMC hydroxide through lithiation and calcination to form the lithium nickel manganese cobalt oxide.

MUCH OF THE MATERIALS NEEDED FOR CATHODE PRODUCTION CAN COME FROM INDIGENOUS SOURCES IN ASEAN

FIGURE 6 Cathode active material production process



ALUMINIUM MANUFACTURING

Indonesia produced 245 kt of aluminium in 2020 (around 0.4% of world production). Production of alumina feedstock amounted to 1.5 Mt in 2021 (1%) while bauxite mineral mining amounted to 18 Mt (5%) the same year (USGS, 2022). The Indonesian President has declared the importance of mineral down-streaming for Indonesia.

In the past, Indonesia supplied about 60 percent of China's bauxite imports, but new legislation has halted bauxite exports in a drive to increase national value added.

Production of aluminium is a very energy intensive process. Modern smelters use around 13 500 kWh/t aluminium (International Aluminium, 2022). Historically many smelters have been placed next to hydropower plants to benefit from reliable low-cost renewable electricity. Around 1.5 GW of baseload power generation capacity is needed per Mt of annual aluminium production capacity.

Whereas today's aluminium production is not very significant in Indonesia, ambitious plans exist to develop new smelters, notably in North Kalimantan and Irian Jaya as well as an expansion of the Guaradanjung North Sumatra smelter from 250 to 300 kt per year. Together with Emirates Global Aluminium a feasibility study will explore a further expansion to 400 kt per year (The National, 2022). Inalum is planning a new 500 kt smelter in North Kalimantan. Also, PT Adaro Aluminium Indonesia signed a letter of intent to invest USD 728 million in a smelter project to be built in the Green Industrial Park Indonesia in North Kalimantan province (which translates into 300 kt aluminium per year) (Adaro, 2021). The goal is to supply new solar panel industry and electric car manufacturing. Adaro's aluminium smelter will utilise renewable energy from a hydroelectric power plant - which the company says includes modern, environmentally-friendly construction standards - and a solar power plant.

Tsingshan Holding Group is planning to enter the field by building the new aluminium smelter in conjunction with Huafon Group. The firm operates an industrial park in Sulawesi, which is the planned location of the smelter. Tsingshan would initially produce at a rate of 500 thousand metric tons per annum by 2023 (Aluminium Insider, 2021).

Also, the preparation of feedstock is slated for expansion; Antam intends to open a new alumina refinery in West Kalimantan with a 1 Mt/yr capacity in 2023 (Antam, 2021). This will double the national alumina production capacity.

As aluminium production is expanded from 250 kt to around 1.5 Mt in the coming years, this will require around 2.5 GW of baseload power. More growth can be expected in the following years and decades. The ongoing investments for alumina production and smelting are in the order of USD 10 billion.

NICKEL PRODUCTION

Nickel is a metal that has significant resources globally, with land-based resources estimated to be at least 300 million tonnes, with about 60% in laterites and 40% in sulfide deposits. Indonesia is the world's largest nickel producer. It is set to produce over 1.2 million tonnes of Nickel Pig Iron (NPI) this year, and by 2025 will be producing well over 1.5 million t/year.

Indonesian production is based on the laterite resource type. The laterite resource vastly exceeds the sulfide resource, a reason why Indonesia is currently expanding its production significantly, with USD 42 billion of planned investments by Fortescue and Tsingshan, while other parties are also investing in the Indonesian nickel mining and processing sector.

To extract nickel, laterite ores require extensive and complex treatment, which has been historically more expensive than sulphide ores. So far, markets for NPI and battery grade nickel have functioned independently, with battery grade nickel being much more expensive.

Mined nickel can be split into two broad categories: low- and high-grade primary nickel. High-grade nickel (Class I) accounts for 55% of all nickel mined while low-grade primary nickel (Class II) accounts for the remaining 45%. Class I nickel contains at least 99.8% nickel. Class II nickel, such as NPI or iron-nickel actually contains a relatively small amount of nickel - 8-16% and 15-55%, respectively.

Battery technology exclusively uses Class I nickel for cathode production. Only Class I nickel is traded on the LME due to the high purity standard of the mined metal. Such LME exchange-traded Class I nickel satisfies specific delivery standards (this accounts for less than 25% of total finished nickel supply).

Companies take NPI and process it further to high-matte nickel products that contain 75% nickel. Saprolite ore (from laterite soils) is refined and turned into NPI, which is in turn refined into nickel matte and then further processed to make Class I nickel.

Growing EV battery demand could mean NPI supply being diverted away from stainless steelmaking in battery production. Through new processes the supply bottleneck for nickel sulphate has been broken and the expectation is that Class I and Class II nickel prices will converge, considering that conversion of NPI to nickel sulphate adds around USD 5 500-6 500/t nickel.

The process to convert NPI to matte and then further into $NiSO_4$ would increase the carbon footprint substantially, contributing 50-70 tonnes of emissions per tonne of nickel mined. An alternative process uses high-pressure acid leach (HPAL) technology to recover nickel and cobalt separately from each other from low-grade nickel-oxide laterite ores. The nickel that is recovered is Class I, battery grade nickel sulphate. The technology has been deployed in New Caledonia. However, high capital expenditure and environmental waste management costs have caused it to lag behind current methods.

Also, 39% of global nickel reserves are found in locations that are exposed to high or extreme biodiversity risks and because nickel typically comes in thin ore deposits these areas are often destroyed. Proactive ESG is therefore critical for widespread acceptance of the product.

SCALING BIOENERGY SUSTAINABLY AND AFFORDABLY

According to the WETO, bioenergy today makes up around 50% of renewable energy use. Achieving the net zero goal will not be possible with renewable electricity and energy efficiency alone. Bioenergy will represent 25% of total primary energy supply globally by 2050 in IRENA's 1.5-S. That would require just over 150 EJ of biomass primary supply, or around a three-fold increase over 2019 levels – entailing a challenging scale-up effort.

In ASEAN Member States, the scale-up is similar. In absolute terms, the increase will be from around 3.2 EJ (primary) to 10.1 EJ by 2050 in the 1.5-S. In 2018, around 14% of final energy came from bioenergy sources in the region, with a little under half from traditional sources of bioenergy. By 2050 in the 1.5-S, the share will increase to 19%, with all traditional uses of bioenergy replaced with modern bioenergy. Scaling up bioenergy use will therefore be crucial for the region to meet its energy and climate goals, and must coincide with bioenergy use that is sustainable and affordable.

In IRENA's analysis for ASEAN, bioenergy scale-up will require substantial investment in bioenergy supply. Already in the PES, the region will require USD 112 billion of investment in biofuel supply; however, for the transition cases (TES and 1.5-S), investment will need to range from USD 197 to 235 billion – more or less a doubling of investment representing an average annual investment over the period of around USD 7 billion per year.

IRENA analysis (IRENA, 2022b) demonstrates an abundance of untapped bioenergy in Southeast Asia, with at least 7.1 EJ of bioenergy residues alone available per year by 2050 just in the five countries studied (Indonesia, Malaysia, Myanmar, Thailand and Viet Nam). All bioenergy potential from agricultural residues, closing yield gap, reduced wastes and productive forests would achieve approximately 14 EJ by 2050 in Indonesia, Malaysia, Viet Nam, Myanmar and Thailand (IRENA, 2017). The potential is even higher when considering the remaining five ASEAN Member States. Therefore, the region has the potential to meet the 10.1 EJ required in the 1.5-S.

IRENA has identified sustainable bioenergy pathways for residues that will enable bioenergy to compete economically with fossil fuels in the region's energy markets and concluded that, in medium-term horizons, these selected sustainable biomass residues could economically meet 2.8 EJ of the energy demand in the region. This would create potential benefits of USD 144 billion of net present value, creating over 452 000 new resilient jobs and saving around 442 million tCO_2e of greenhouse gas (GHG) emissions per year. Additional residue potential is available in these countries that is less economically affordable and would require financial support or supporting policies. Also, there is significant economically affordable additional potential in the remaining five ASEAN countries: Brunei, Cambodia, the Philippines, Lao PDR, and Singapore, however the analysis did not cover those countries.

BIOENERGY SCALE-UP IN INDONESIA

Indonesia has approximately 55 million hectares of agricultural land and approximately 98 million hectares of forest. Indonesia's large land mass, coupled with its abundant rain and sunshine throughout the year, facilitates a thriving agricultural sector. This translates into significant potential for biomass feedstock supply, accessibility and sustainability.

Bioenergy is the largest energy source among renewables in Indonesia, with primary supply amounting to around 1 400 PJ in 2018. A majority of the country's renewable energy use comprises traditional uses of bioenergy (mainly for cooking in the residential sector) in the country's rural areas and remote islands.

Indonesia has a thriving agricultural sector that contributed approximately 13% of its total GDP (OECD, 2020b) from 26.3 million ha of arable land in 2018 (FAOSTAT, 2021). The country is a major global producer of palm oil and coconut, mangoes, natural rubber, rice, bananas, coffee, pepper, maize, cassava, pineapple, sweet potatoes, oranges and sugarcane (FAOSTAT, 2021). Among these, the three agricultural crops with the greatest potential for scaling residue-derived bioenergy are oil palm, rice and sugarcane. These include palm kernel shells, empty fruit bunch, old trunks, rick husks, rice straw, sugarcane bagasse, sugarcane tops and sugarcane leaves (IRENA, 2022c)

In Indonesia, solid residues derived from palm oil, rice and sugarcane production have the greatest potential; these include palm kernel shell, empty fruit bunch, old palm trunk, rice straw, rice husks, sugarcane bagasse, tops and leaves.

Looking at Indonesia in more detail, there is potential to scale up bioenergy when considering estimated total availability of all residues. The estimated volumes for sustainable bioenergy residue feedstock in 2050 in Indonesia is estimated at nearly 300 Mt of annual feedstock potential, or around 6 EJ.

RESIDUES PLAY AN IMPORTANT ROLE IN SCALING-UP SUSTAINABLE BIOENERGY USE

TABLE 5: Estimated availability of selected biomass residue energy resource

COUNTRY	FEEDSTOCK	QUANTITY AVAILABLE BY 2050 (MILLION TONNES)
Indonesia	Agricultural residues (palm oil, rice and sugarcane)	197.4
	Rubber	13.7
	Acacia	5
	Palm oil mill effluent (POME)	78.8
	Cassava pulp	10

PALM OIL

Global palm oil production has increased 30-fold in the past 50 years to more than 70 million tonnes, according to the UN Food and Agriculture Organization. Indonesia and Malaysia account for about 85% of the world's supply of palm oil. Indonesia was by far the world's leading producer (43.8 Mt) and exporter (28 Mt) of palm oil (Statistia, 2022). Unlike Malaysia, however, which exported the majority of the palm oil it produced, Indonesia was also one of the world's biggest consumers of palm oil, using it as both an edible oil and in biofuels (15 Mt in total).

About 14% of global vegetable oil supplies go to biodiesel production. Under its 'B30' mandate, Indonesia - the world's largest palm oil producer and exporter - blends 30% palm-oil based fuel into its biodiesel to lower its fuel imports and boost domestic production of palm oil, and intends to raise this to 40%. According to FAO and OECD, the use of vegetable oil to produce biodiesel is projected to grow 23.2% to 7.9 million Mt between 2021 and 2030.

Currently, nearly 8% of Indonesia's sprawling landmass is covered by oil palm plantations (14.6 million ha out of 190 million ha). Growth of palm oil production has slowed down in recent years due to deforestation concerns and policies. The slowdown in Indonesia, which produces around 60% of the world's palm oil, also has been seen in Malaysia and other palm-oil producing countries. Palm-oil production in these countries grew by 18% from 2015 to 2018, but by 4% from 2018 to 2021, according to the Council of Palm Oil Producing Countries. By 2020, 83% of Indonesian and Malaysian palm oil refining capacity wouldn't buy palm oil linked to deforestation.

Deforestation and peatland loss produces about 4.8 billion tCO_2e per year globally, according to the World Resources Institute. This is more than the total emissions of the EU. Clear cutting for palm oil plantations is a major contributor which releases about 174 tonnes of carbon per hectare (Ecole Polytechnique Federale de Lausanne, 2018).

Indonesia ranked second in terms of net loss of forest cover, losing 26 million ha during the last three decades (FAO, 2020e). In Indonesia, oil palm plantations have expanded by around 14.7 million ha, accounting for 23% of the country's forest loss between 2000 and 2016 (2020 NYDF Goal 2 Progress Assessment). Although the establishment of oil palm plantations is primarily driven by the global edible oil market, the production of biofuels has, to some extent, contributed to the conversion of forests (OECD and FAO, 2016).

Most palm oil mills already have sufficient energy supply to run their facilities by utilising on-site residues such as mesocarp fibre and palm kernel shell as fuels for boilers. Also, palm oil mills are typically fitted with their own turbines and generators to fulfil energy demand. Most POME (an oily wastewater generated by palm oil processing mills and consists of various suspended components) biogas facilities in Indonesia were built for meeting internal energy demand, including for boiler burners. An additional benefit of increasing investment in biogas plants is that more palm kernel shells are available for export or the domestic market (this will increase the benefits for mill owners when palm kernel shell prices are high). Given the huge energy potential of POME, it is important to tap this resource instead of just treating it as waste. This will, in turn, enhance the sustainability of the oil palm sector.

According to the 2020 Goal 2 progress assessment report, companies in the palm oil, and pulp and paper sectors in Southeast Asia "are consistently more advanced than their counterparts in cattle and soy supply chains in Latin America". The report also concludes that, in 2018, 81% of Indonesian palm oil exports were derived from a small number of companies that had adopted "no deforestation, no peat and no exploitation (NDPE)" practices (Forest Declaration Platform, 2020).

However, several challenges remain in order to effect real change toward halting deforestation. These include, amongst others, making companies' commitments workable by strengthening vertical integration with their subsidiaries and suppliers as well as promoting landscape or jurisdictional approaches whereby biofuel market stakeholders are also horizontally integrated in the sustainability governance framework.

ENABLING FRAMEWORKS FOR BIOENERGY

In the ASEAN region it is important to identify accessible biomass feedstocks in the short-term to demonstrate the viability of this source for energy markets, while also moving to address political, legal, social and environmental concerns. Infrastructure construction to increase biomass accessibility in the medium and long terms will directly impact the scalability of feedstock and deliver socio-economic benefits.

Volumes of accessible bioenergy resources will grow over time with increased market awareness, improved logistics chains, technology enhancements and mounting private financing appetite. There is an urgent need to build awareness amongst decision makers of commercially proven technical solutions.

Based on lessons learned from successful projects in established markets, decision makers in Southeast Asia should seek to:

- explore how agricultural and industrial sectors can collaborate to establish supply and logistics networks for creating secure and sustainable biomass supplies;
- determine which fuel processing technologies would be appropriate for the sustainable bioenergy resources available and would meet the specifications of local energy markets;
- identify knowledge and technology gaps that require further R&D and pilot projects to test the "first-of-a-kind" risks of deploying such technologies in Southeast Asia's markets; and
- form ministerial level collaboration to unlock further opportunities and ensure the smooth execution of bioenergy strategies in each country.
- Decision-makers can also accelerate the adoption of sustainable biomass by demonstrating the commercial successes achieved in markets that have advanced the deployment of sustainable bioenergy. At the same time, decision-makers can regulate sustainable bioenergy use while creating fiscal incentives by:
- influencing energy market dynamics by increasing taxation on fossil fuels, whilst reducing the tax burdens on sustainable biomass;
- giving tax incentives for R&D and investments in new facilities, plants and equipment that are fuelled by sustainable bioenergy; and
- providing feed-in-tariffs to incentivise private sector participation in the market (which is proven in Southeast Asia and elsewhere).

Indonesia can seek to create more incentives for private companies to retrofit their facilities with commercially viable technology that will allow existing plants to use biomass feedstock for the heat generation process. Agricultural residue from major crops is identified as a potential feedstock. Mobilising palm oil residues and waste such as EFB, PKS, old trunks and POME for bioenergy feedstock will not only reduce GHG emissions but also boost the overall sustainability of the oil palm industry.

Private financiers of renewable energy projects often cite security of bioenergy supply as one of the biggest obstacles to investing in bioenergy projects. There are various factors that determine the total available volumes of bioenergy, including biomass scalability and seasonality. One way that governments can mitigate the seasonality of biomass outputs is by forming a central collection agency to map the collection of residuals from various agricultural practices and crops throughout the year and distribute them systematically according to demand.

Fossil fuel subsidies in Indonesia, which lower fossil fuel costs, make solid biofuel feedstock less attractive. To increase commercial viability and reduce the cost of producing solid biofuels, the Indonesia government can introduce a favourable regulatory framework; remove subsidies for fossil fuels; and increase spending on R&D to further reduce the cost of conversion from biomass to energy.

CONCLUSIONS

The ASEAN region will be a key driver of global energy demand growth over the next three decades. The region will therefore need to be a driver of the energy transition and lead in the deployment of affordable, clean, sustainable energy. Embracing renewable energy is pivotal when considering that energy consumption will almost triple, and an increasing share of fossil fuel will come from imported sources, threating security of supply, affordability, the climate and the local environment.

This preview has briefly outlined some of the key findings from IRENA's forthcoming reports for ASEAN and Indonesia. Total energy transition investment needs amount to USD 1 trillion for ASEAN up to 2030. For the period to 2050, USD 6-8 trillion in investments are needed to boost the share of renewables in national energy mixes as well as to electrify demand sectors and expand energy transition related infrastructure.

It also shows that, along with this transition, significant industrialisation opportunities exist. In the 1.5-S, renewable energy can meet over two-thirds of final energy demand across ASEAN, while cutting energy-related CO_2 emissions by 75% compared to PES, strengthening indigenous supply and lowering costs. ASEAN has good renewable resources and renewables can become the dominant form of energy supply in the coming three decades. While these opportunities have been described in qualitative terms, they have not yet been quantified.

Electricity demand will continue to grow rapidly. In the 1.5-S, electricity demand increases over five-fold. With planning cycles for the power sector that typically take decades, preparations must be made now for the rapid and sustained expansion of renewable power technologies. In most cases, this shift has not yet been fully understood or embraced by national authorities, utilities and operators. Notably, the role of solar PV can be further strengthened in national capacity expansion plans.

Solar PV expansion will need to be supplemented with other renewables. This decade, hydropower and geothermal deserve special attention, while beyond 2030 the role of solar PV is critical, with a massive expansion potential in the region that equals more than twice today's global PV installed capacity. Significant expansion of regional interconnection and storage will also need to go hand in hand with this transition.

The cost of finance for renewable power generation projects - particularly solar PV and wind - remains high in some markets. IRENA's surveys concluded that financing costs for solar PV, onshore wind and offshore wind were higher than in more established renewable energy markets outside ASEAN. Therefore, as these technologies become more mainstream and supporting policies are implemented, financing cost will come down.

Reducing the WACC will also, in turn, increase the competitiveness of these technologies and lower the cost of procuring electricity from solar PV and wind. There is a need to mobilise and align all sources of public and private climate finance to boost clean energy investment for the region.

Policies must support expanding local industries to take advantage of the significant value chain that will need to be created. The market required signals that allow investments into competitive GW-scale manufacturing capacity from technologies ranging from solar PV modules to larger balance-of-system components, batteries and EVs.

While variable renewable energy shares are comparatively low today, power system flexibility will require more attention beyond 2030. IRENA flexibility analysis suggests that the power systems in the region can operate with high shares of VRE (+50%), provided the right flexibility measures are put in place. All flexibility measures will be important, from flexible generation, demand response and smart-charging to expansion of grids and storage. Scaling up smart and clean energy technologies in the region is key for a successful energy transition.

Overall energy system investments need to ramp up substantially - on average to just below USD 100 billion per year for the region from now until 2030 in the 1.5-S - around 50% higher than in the PES. This represents more than a doubling compared to recent years. In the longer term, around USD 230 billion per year is needed. This includes power generation but also grids and flexibility, as well as EV and energy efficiency measures and direct-use renewables such as biofuels.

The example of Viet Nam has shown that it is possible to ramp up renewable energy investment in the region in only a few years if the right enabling frameworks are created. Viet Nam is a good example of how solar PV and wind energy can be supported to achieve significant expansion of capacity. However, lessons from this rapid growth can also be learned. For instance, regarding the need for accompanying measures to expand and upgrade grid and transmission infrastructure in the power sector. Also, policymaking needs to avoid creating boom-bust cycles.

The energy transition will create a substantial number of additional jobs. Efforts to develop national and regional supply chains should be pursued further. This includes solar PV, batteries and VE, as well as minerals and materials for the energy transition. The availability of critical minerals provides an important opportunity to develop sustainable supply chains that can create new economic activity.

The scenarios outlined in the forthcoming IRENA reports, Renewables outlook for ASEAN: Towards regional energy transition, and the Indonesia energy transition outlook, highlight the pivotal role that renewables will need to play in the ASEAN region. These studies show that renewable potentials are vastly underutilised and can be expanded for less cost to end-consumers than conventional energy sources. They also present significant opportunities to create local value chains and industries. As the world moves towards a net-zero future, ASEAN can play a key role, but planning for this transition must begin today.

REFERENCES

ACE (2020), "The 6th ASEAN Energy Outlook", ASEAN Centre of Energy, aseanenergy.org/the-6th-asean-energy-outlook

ACE (2022), *Challenges and Implications of Coal Phase-down to the ASEAN Energy Landscape*, ASEAN Centre for Energy

Adaro (2021), "Adaro to Commence Building Aluminum Smelter at Indonesia's Green Industrial Park", www.adaro.com/files/news/berkas_eng/2090/ADRO%2020211223%20ADRO%20Green%20Aluminium%20English.pdf

Aluminium Insider (2021), "Tsingshan Planning 1 MMTPA Aluminium Smelter In Indonesia", https://aluminiuminsider.com/tsingshan-planning-1-mmtpa-aluminium-smelter-in-indonesia

Antam (2021), "Proyek-proyek pengembangan antam", www.antam.com/uploads/proyek-pengembangan-antam.pdf

ASEAN (2021), "Joint Declaration of 39th ASEAN AMEM", https://asean.org/wp-content/uploads/2021/09/Bandar-Seri-Begawan-Joint-Declaration-Final.pdf

ASEAN Briefing (2021), "Indonesia to Construct World's Largest Green Industrial Park", www.aseanbriefing.com/news/indonesia-to-construct-worlds-largest-green-industrial-park

Asian Development Bank (2021), "ADB, Indonesia, the Philippines Launch Partnership to Set Up Energy Transition Mechanism", www.adb.org/news/adb-indonesia-philippines-launch-partnership-set-energy-transition-mechanism

CleanTechnica (2022), "Record EV Sales Month Globally! 12% Share For BEVs!", https://cleantechnica.com/2022/08/01/record-ev-sales-month-globally-12-share-for-bevs

Ecole Polytechnique Federale de Lausanne (2018), "Palm oil: The carbon cost of deforestation", www.sciencedaily.com/releases/2018/06/180619123018.htm

Forest Declaration Platform (2020), "2020 Goal 2 Assessment", https://forestdeclaration.org/resources/2020-goal-2-assessment

Gaikindo (2022), "Menteri BUMN Resmikan Perusahaan Holding Pengembang Baterai Kendaraan Listrik", www.gaikindo.or.id/menteri-bumn-resmikan-perusahaan-holding-pengembang-baterai-kendaraan-listrik/

IEA (2022), *Global EV Outlook 2022*, Paris, www.iea.org/reports/global-ev-outlook-2022

IISD (2022), Achieving a just energy transition in Indonesia, International Institute for Sustainable Development, www.iisd.org/system/files/2022-07/achieving-just-transition-indonesia.pdf

International Aluminium (2022), "Primary Aluminium Smelting Energy Intensity", https://international-aluminium.org/statistics/primary-aluminium-smelting-energy-intensity

IRENA (2017), "Renewable Energy Prospects: Indonesia, a REmap analysis", International Renewable Energy Agency, Abu Dhabi.

IRENA (2020), "IRENA FlexTool", /energytransition/Energy-System-Models-and-Data/IRENA-FlexTool, www.irena.org/energytransition/Energy-System-Models-and-Data/IRENA-FlexTool (accessed 24 June 2020).

IRENA (2022a), *Renewable Energy Statistics 2022*, Abu Dhabi: International Renewable Energy Agency

IRENA (2022b), "Scaling up biomass for the energy transition: untapped opportunities in Southeast Asia", International Renewable Energy Agency, www.irena.org/publications/2022/Feb/Scaling-up-biomass-for-the-energy-transition-Untapped-opportunities-in-Southeast-Asia

IRENA (2022c), *World Energy Transitions Outlook: 1.5°C Pathway*, Abu Dhabi: International Renewable Energy Agency, https://irena.org/publications/2022/Mar/World-Energy-Transitions-Outlook-2022

IRENA (2022d), *Renewable power generation costs in 2021*, Abu Dhabi: International Renewable Energy Agency, https://irena.org/publications/2022/Jul/Renewable-Power-Generation-Costs-in-2021

IRENA (n.d.), "Global Atlas for Renewable Energy", International Renewable Energy Agency (IRNEA), http://irena.masdar.ac.ae/ (accessed 7 April 2016).

IRENA & ACE (2016), "Renewable Energy Outlook for ASEAN: A REmap Analysis", International Renewable Energy Agency (IRENA); ASEAN Centre for Energy, www.irena.org/DocumentDownloads/Publications/IRENA_REmap_ASEAN_2016_report.pdf

LCDI (2021), "A GREEN ECONOMY FOR A NET-ZERO FUTURE: How Indonesia can build back better after COVID-19 with the Low Carbon Development Initiative (LCDI)", https://lcdi-indonesia.id/wp-content/uploads/2021/10/GE-Report-English-8-Oct-lowres.pdf

MI Tech News (2022), "Record electric car sales as world governments double down on support", https://mitechnews.com/auto-tech/report-record-electric-car-sales-as-world-governments-double-down-on-support/

Statistia (2022), "Palm oil industry in Indonesia - statistics and facts", Statistia, www.statista.com/topics/5921/palm-oil-industry-in-indonesia/#dossierContents__outerWrapper

The National (2022), "EGA deepens technology co-operation with Indonesia and Bahrain", www.thenationalnews.com/business/2022/03/31/ega-deepens-technology-co-operation-with-indonesia-and-bahrain

US DOE (2022), "Solar photovoltaics - supply chain deep dive assessment", www.osti.gov/biblio/1871588

USGS (2022), "Aluminum Statistics and Information", United States Geological Survey, www.usgs.gov/centers/national-minerals-information-center/aluminum-statistics-and-information

IRENA
International Renewable Energy Agency

www.irena.org