Renewable Energy Manufacturing

OPPORTUNITIES FOR SOUTHEAST ASIA

Sustainable Energy for All, Andromeda Tower 15th floor, Donau City Strasse 6, 1220, Vienna, Austria
ISBN 978-92-9270-224-3 (print); 978-92-9270-225-0 (electronic)

Published in August 2023.

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Abbreviations

ASEAN	Association of Southeast Asian Nations
BESS	battery energy storage systems
CAPEX	capital expenditure
E2W	electric two-wheeler
ESG	environmental, social, and governance
EU	European Union
EV	electric vehicle
FYP	five-year plan
GDP	gross domestic product
GW	gigawatt
GWh	gigawatt-hour
ICE	internal combustion engine
IEA	International Energy Agency
Lao PDR	Lao People's Democratic Republic
LCOE	levelized cost of electricity
LCOS	levelized cost of storage
LFP	lithium iron phosphate
MW	megawatt
NMC	nickel manganese cobalt
OEM	original equipment manufacturer
PRC	People's Republic of China
PV	photovoltaic (solar)
R&D	research and development
RE	renewable energy
RISE	Regulatory Indicators for Sustainable Energy
TW	terawatt
US	United States

Statements from Partners

"As we often say in ADB, the battle against climate change will be won or lost in Asia and the Pacific. A decisive front in that battle is Southeast Asia. This research shows the promise of renewable energy manufacturing – with policy, technical, and financing support – in helping the region's developing countries to transition away from coal-based energy, while lowering carbon emissions, expanding local industrial capabilities, spurring job creation, and driving long-term economic growth.

Ramesh Subramaniam
Director General and Group Chief, Sectors Group, Asian Development Bank

ADB

"Southeast Asia has the potential to become a leader in renewable energy manufacturing to contribute to the global renewable energy deployment, while simultaneously achieving economic growth and mitigating the impacts of climate change. This report proves how increasing private sector investments into local renewable energy manufacturing sectors, strengthening regional value chain collaboration, and bringing together key stakeholders will create jobs, increase GDP, and help Southeast Asian nations meet their climate goals.

Antha Williams
Environment Program Lead, Bloomberg Philanthropies

Bloomberg Philanthropies

"The clean energy industry is already a massive growth opportunity, and will need to scale even more rapidly for us to achieve carbon neutrality globally by 2050. Southeast Asia, which is home to one-fourth of the world's population, is well positioned to become a global leader in renewable energy manufacturing with its vibrant business environment and large talent pool. In doing so, the region can boost the supply of affordable and reliable renewable energy solutions to people and communities in Southeast Asia and around the world, and create new job opportunities locally.

Helen Mountford
President and CEO, ClimateWorks Foundation

climateworks FOUNDATION

"By growing their renewable energy manufacturing capabilities, Southeast Asian countries can increase GDP, create jobs and decarbonize energy systems, contributing to both economic growth and climate progress. This report highlights how countries within the region can establish strong, local industries that will contribute to a prosperous and sustainable future.

Damilola Ogunbiyi
CEO and Special Representative of the UN Secretary-General for Sustainable Energy for All, and Co-Chair of UN-Energy

SUSTAINABLE ENERGY FOR ALL

Introduction

Southeast Asia will be impacted disproportionately by climate change. Five out of its 10 economies rank among the world's top 20 countries most vulnerable to climate change,[1] and the region could lose up to 30% of its gross domestic product by 2050 due to increases in global temperature and extreme weather events.[2]

Greenhouse gas emissions in Southeast Asia must be reduced by 10% to 25%[3] by 2030 (relative to its current trajectory) to limit global warming to a 1.5°C pathway. Substantial and collective action by governments and businesses is required. As of today, about half of all governments within the region have committed to net-zero targets.[4]

Against this backdrop, the region's energy consumption is also expected to grow significantly. The International Energy Agency (IEA) projects that between 2020 and 2050, Southeast Asia's electricity demand will grow by 2.5x, and its energy consumption for transport will more than double.[5] A major push to electrify transportation and deploy renewable energy will be essential for the region to meet its decarbonization commitments. This is reflected in the energy strategies across the member states of the Association of Southeast Asian Nations (ASEAN).[6]

This has the potential to achieve dual objectives in Southeast Asia. Firstly, it would enable the region to meet rising energy demand while lowering carbon emissions. Secondly, the development of local manufacturing capabilities could support job creation and economic growth. In Southeast Asia, low-carbon mobility and clean power have the potential to contribute $90 billion to $100 billion in revenues by 2030, while 6 million renewable energy jobs are expected to be created by 2050.[7,8]

This report, by the Asian Development Bank, Bloomberg Philanthropies, ClimateWorks Foundation and Sustainable Energy for All, presents an assessment of the potential of renewable energy manufacturing in Southeast Asia across three sectors: solar photovoltaic (PV), batteries, and electric two-wheelers. It also proposes potential ambition and outcomes for each sector and identifies key opportunities for intraregional collaboration. The report draws on multiple sources, including analysis from McKinsey & Company.

[1] *GermanWatch. Global Climate Risk Index (2021). Based on Germanwatch's Long Term Climate Risk Index in its Global Climate Risk Index 2021 report; countries are scored based on impact from number of fatalities, gross domestic product loss and number of events arising from climate change across 2000–2019*

[2] Swiss Re Institute. *2021. The Economics of Climate Change: Impacts for Asia. May.* https://www.swissre.com/risk-knowledge/mitigating-climate-risk/economics-of-climate-change-impacts-for-asia.html. *GDP loss estimates based on a 2-2.6C increase in global temperatures, considered as the "likely range of global temperature increase from pre-industrial times to mid-century"*

[3] *S. Paltsev, M. Mehling, N. Winchester, J. Morris and K. Ledvina. 2018. Pathways to Paris: ASEAN.* MIT Joint Program Special Report. *According to the report, ASEAN needs to reduce its emissions by 11% under the unconditional pledges, and by 24% under the conditional pledges, by 2030 to meet Paris commitments.*

[4] *McKinsey Global Energy Perspectives as of November 2022.*

[5] *IEA. 2022. Southeast Asia Energy Outlook 2022. p. 54 (transport) and p. 68 (electricity). The report projects regional electricity supply to grow by 260% in the Stated Policies Scenario and 280% in the Sustainable Development Scenario by 2050.*

[6] *ASEAN Renewable Regional Energy Regional Approach. 2023.*

[7] *IRENA Global Renewables Outlook. 2020. The 30 million and 6 million refer to the difference in the number of additional jobs (including in manufacturing renewable energy systems) in renewables in 2050 vs. 2017 in IRENA's Transforming Energy Scenario (TES)*

[8] *All mention of dollars ($) in this report refers to US Dollars.*

Executive Summary

There is an estimated $90 billion to $100 billion revenue opportunity in Southeast Asia's low-carbon mobility and clean power segments by 2030. Southeast Asia already is well-positioned to meet the demand for manufactured inputs into these sectors, as it already produces 9%–10% of the world's solar photovoltaic (PV) cells and modules, ~50% of global nickel output, and 6%–10% of all electric two-wheelers today. It also possesses natural advantages to support the scale-up of production: 16 terawatt (TW) of technical solar potential, 25% and 10% of global nickel and cobalt reserves respectively, and 25% of the global two-wheeler market.

Solar PV Manufacturing

Solar PV manufacturing capacity in Southeast Asia is largely concentrated in cells (55 gigawatts [GW]) and modules (70 GW), with the potential to achieve an aspirational capacity of 125–150 GW module capacity by 2030. The market is led by manufacturers from the People's Republic of China (PRC) (e.g., Jinko, JA Solar, Longi, Trina) and is largely focused on exports. Total Southeast Asian demand stands at only ~3 GW per annum, far below regional production capacity.

At the same time, domestic demand has the potential for sustained growth, and can provide certainty of revenues for local manufacturers. To develop a robust demand market, stakeholders will need to ensure the following five drivers are in place: parity of greenfield levelized cost of energy; a supportive regulatory environment; mitigation of developer risk; availability of grid infrastructure; and sufficient grid flexibility and storage. The region's middle-ranked performance on the World Bank's Regulatory Indicators for Sustainable Energy (RISE) index for renewable energy policy suggests there is further room to encourage renewables deployment through supportive regulations.

Manufacturers interviewed for this study[9] cited challenges around business environment, labor productivity, underdeveloped local supply chains, and inefficient logistic systems as key barriers to scaling solar PV in less established Southeast Asian markets. Addressing these challenges through improvements in ease of doing business and cost competitiveness will likely be key to unlocking the sector. To focus policy interventions and enable supporting mechanisms, strategic alignment will be needed at a national level – for example, to designate the sector as a national priority, increase national policy ambition on solar PV capacity, and facilitate strategic partnerships (e.g., via government-to-government collaboration on trade and knowledge transfer, business-to-business partnerships, and engagements with multilateral organizations for financing support and technical assistance).

Battery Manufacturing

There is potential for Southeast Asia to develop a regional battery manufacturing value chain, increase national and regional demand, and establish itself as a regional and global export hub, producing 140-180 gigawatt-hours (GWh) of battery cells by 2030. Although there is a very limited battery manufacturing footprint in the region today, Southeast Asia's natural resource endowment, including rich reserves of critical minerals like nickel and cobalt, has piqued the interest of downstream manufacturers to expand production within the region.

Given limited regional demand (representing less than 2% of the global market), prospective manufacturers would likely need to focus on exports as the main market driver, with growing domestic demand as a secondary driver. The emphasis on export sales will require competing with established global players primarily on cost, even while collaborating through value chain integration and knowledge transfers to expand technical capabilities. Key success factors to ensure cost competitiveness will include vertical integration, production at scale, and operational excellence. With significant efforts to ensure these factors are in place, some countries are expected to be able to be competitive with leading global manufacturing hubs such as Japan, the PRC, and the Republic of Korea.

To ramp up the domestic battery manufacturing industry, Southeast Asian countries would need to address several manufacturers' key concerns to expanding their investment in the region. Enabling factors cited by manufacturers interviewed for this study include the scale of domestic demand, competitiveness of manufacturing, export potential, effectiveness of infrastructure and logistic network, and transparency in policy development and government

[9] *Interviews of regional and global manufacturers and industry experts were conducted for this research.*

effectiveness. To unlock these critical success factors, several supportive mechanisms can be put in place by country stakeholders, such as facilitating partnerships to create an end-to-end battery ecosystem, introducing policies to encourage demand and manufacturing investments, implementing operational excellence programs, and developing targeted educational plans to close labor productivity gaps.

Electric Two-Wheeler (E2W) Manufacturing

Assembly capacity for E2Ws in Southeast Asia is 1.4–1.5 million units per annum, with the potential to reach 4 million units by 2030. The manufacture of key components (such as motors, controllers, and converters) is nascent, with only a few original equipment manufacturers (OEMs) producing these parts in-house. Startups and regional players are currently the predominant players, while incumbent internal combustion engine (ICE) OEMs have not made significant inroads. Players largely cater to domestic demand, which amounted to approximately 240,000 units across the region in 2021. The penetration rate of E2W in total sales is currently less than 1% in most Southeast Asian countries, representing significant growth potential if the right demand, supply, and infrastructure factors are in place.

Seven key demand factors will need to be in place to unlock demand in Southeast Asian countries. Parity in total cost of ownership between E2W and ICE 2W products, adequate charging infrastructure, adequate capacity to meet domestic demand, supportive demand and supply-side policies, the availability of products that meet customer preferences, the ability for E2W brands to compete against strong incumbent ICE brands, and the availability of vehicle financing and distribution networks.

Challenges cited by interviewed manufacturers considering to invest in the region included low domestic demand, poor potential for return on manufacturing investments, a lack of supplier ecosystem, and inconsistencies and lack of depth in government policies, with the degree and type of challenges varying by Southeast Asian country. These challenges will need to be addressed through public and private sector collaboration on mechanisms such as (but not limited to) continuing to offer financial incentives to boost demand, introducing manufacturer incentives such as exemptions on corporate tax and import duties, and production-linked incentives. Strategic alignment would also be needed at a national level to accelerate the phase-out of ICE 2Ws and to build out charging and swapping infrastructure.

Intra-regional Collaboration

Southeast Asia can build on its strong history of regional collaboration to enhance competitiveness and meet its net-zero targets. For example, production factors could benefit from trade across the value chain and regional efforts to improve workforce quality and distribution. Demand markets could be supported by the build-out of the ASEAN Power Grid to enable higher renewables deployment through multilateral power trade and expanded grid balancing areas. Harmonization of technical standards for E2W vehicles and charging stations could enable OEMs to develop products that suit needs across markets.

In partnership, we at the Asian Development Bank, Bloomberg Philanthropies, ClimateWorks Foundation, and Sustainable Energy for All are developing an implementation roadmap that details initiatives to be launched over the next 5 years to support the region to scale its renewables manufacturing ecosystem. We would like to invite all interested policymakers, industry and other ecosystem players to join our dialogue to jointly scale up this effort.

CHAPTER 1

A Strong Manufacturing Foundation

Exhibit 1

$90 billion-$100 billion opportunity in low-carbon mobility and clean power by 2030

Estimated sustainability revenue pools in Southeast Asia, 2030

$55-60B Low-carbon mobility	**$35-40B** Clean power	**$20-25B** High efficiency buildings	**$15-$20B** Circular products & packaging	**$10-$20B** Low-carbon agriculture and food supply chain	**$5-10B** Bioenergy	**$5-$10B** Industrial decarboni-zetion	**$3-5B** Hydrogen	**$2-$8B** Carbon markets and CCUS
Electrification of vehicle power trains - 2W and 4W Charging infra and energy services EV financing and maintenance Fleet electrification	Renewable power generation (solar PV, wind, geothermal, hydro) Microgrids and resiliency Flexibility and energy storage	Energy efficiency and building controls Building electrification On-site clean energy	Sorting and processing tech Sustainable packaging Sustainable fashion Circular products and upcycling Reverse logistics supply chain svcs	Low-carbon proteins Sustainable timber Tech enhancements for crop yields Crop preserva-tion / waste reduction Methane inhibitors	Bio-refineries Biofuel innovation Waste to energy/value	Green cement and CO2 negative aggregates High efficiency iron & steel production Decarboniza-tion of industrial process heat	H2 electrolyzers H2 blending materials Hydrogen mobility Project development	Sorbents for carbon capture CO2 to fuel Direct air capture Novel point - source capture CO2 capture infra Marketplaces and exchanges Carbon credit brokers / retailers

Sources: McKinsey Center for Future Mobility, IRENA, country power development plans, McKinsey analysis

Within Southeast Asia's $160 billion to $200 billion sustainability revenue pools in 2030, 55%–60% is driven by low-carbon mobility and clean power, representing significant opportunities for manufacturers of inputs into these sectors (Exhibit 1).

The region has made headway with capturing this opportunity. In low-carbon mobility, it has seen success in attracting international and local players to set up facilities for electric two-wheeler vehicles (E2W) assembly. In clean power, the region is already a global exporter of solar photovoltaic (PV) cells and modules. Planned capacity investments along the batteries value chain will serve both sectors.

Leveraging its natural advantages (Exhibit 2), Southeast Asia could aspire to further scale its renewables manufacturing capacity and to be a key contributor to global decarbonization.

Exhibit 2

Southeast Asian countries are well-positioned to meet ambitious goals by 2030

Solar PV	**Batteries**	**Electric 2-Wheelers**
• 16 TW of solar PV technical potential regionally • Malaysia, Thailand, and Viet Nam already produce 9%-10% of the world's solar PV cells and modules	• The region holds 25% and 10% of global nickel and cobalt reserves respectively • Indonesia and the Philippines produce ~50% of the world's nickel output	• Indonesia and Viet Nam account for ~16% of global 2W sales and 6%-10% of the world's E2W assembly capacity • The region collectively makes up about 25% of the world's 2W market
70 GW Current footprint → **125-150 GW** Potential 2030 aspiration	**0 GWh** Current footprint → **180 GWh** Potential 2030 aspiration	**1.4-1.6 million units** Current footprint → **4 million units** Potential 2030 aspiration

2W = two-wheeler, **E2W** = electric two-wheeler, **GW** = gigawatt, **GWh** = gigawatt-hour, **PV** = photovoltaic, **TW** = terawatt

Sources: Solar PV: IRENA Renewable Energy Outlook for ASEAN (2022), InfoLink Consulting (Q1 2023); Batteries: US Geological Survey estimates as of 2022 E2W: A. Mahalana, Z. Yang and F. Posada (2021) "Indonesia transport electrification strategy"', company announcements, McKinsey Center for Future Mobility estimates as of 2022

Shining a Light on Solar PV: Opportunities in Southeast Asia

A. Solar PV Manufacturing Trends

Market Context and Manufacturing Footprint

Southeast Asia is a solar PV manufacturing hub with 2%–3% of the world's polysilicon and wafer capacity and 9%–10% of the world's cells and modules capacity.[10] Production is concentrated in four countries: Cambodia, the Lao People's Democratic Republic (Lao PDR), Thailand, and Viet Nam (Exhibit 3). According to manufacturers present in Southeast Asia today, most manufacturing capacity in the region was established by manufacturers from the People's Republic of China (PRC).

The solar PV module manufacturing value chain comprises four main steps: polysilicon production, wafer production, cell manufacturing, and module assembly. Within this value chain, most larger players are vertically integrated across cell and module production (with several having extended up the value chain to wafer production – e.g., Jinko and JA Solar in Viet Nam, Longi in Malaysia). A few others are specialized in a subset of segments of the value chain in the region (e.g., Maxeon manufactures cells in the Philippines and modules in Malaysia).

Exhibit 3
Southeast Asia accounts for 9%-10% of global cell and module capacity

Solar PV manufacturing capacity, 2022

	Upstream, GT	Manufacturing, GW			
	Polysilicon production **Polysilicon** is crushed, melted and grown into a single crystal ingot	**Wafer production** The **ingot** is then cut, squared, sliced and polished into hexagonal wafers	**Cell manufacturing** The **wafers** are then treated, textured, etched and coated to form solar cells	**Module assembly** **Solar cells** are connected in series to form strings	**Major manufacturers** As of 2022, non-exhaustive
Viet Nam		9	14	34	Jinko Solar, Trinasolar, Longi, Canadian Solar, JA Solar, Dehui Solar, VSUN, First Solar, Maha Solar, Boviet Solar, GW
Thailand			14	11	Canadian Solar, Astroenergy, Talesun, Trinasolar, Ure, Runergy
Malaysia	32	1	20	15	Longi, Maxeon, Risen, First Solar, Jinko Solar, Hanwha
Philippines			1		Maxeon
Singapore			1	2	REC
Cambodia			5	7	ET Solar, NE Solar, Long Energy, BYD, Imperial Star, Solar Space
Indonesia			1	1	Suntech, ICA Solar, Isolar, JSKY, Len, Sankeindo, Adyasolar, Solar Quest, PT Wijaya Karya, Azetsurya, Santini Group
SEA total	~32	~10	~55	~70	
Global share	3%	2%	9%	10%	

GT = gigatons; **GW** = gigawatts; **PV** photovoltaic; **SEA** = Southeast Asia

Notes: Malaysia is the only country in Southeast Asia with significant silica reserves. Wafer production is significantly more capital intensive than downstream production, and is where most intellectual property is concentrated.
Sources: InfoLink Consulting (Q1 2023), manufacturer interviews, company websites and announcements

[10] *InfoLink Consulting (Q1 2023).*

Southeast Asia is largely an exporter of solar PV products today. Its nameplate capacity of 70 gigawatts (GW) dwarfs regional demand of ~3 GW p.a., some of which is also supplied by imports. There are three broad archetypes of producer countries in the region:

- **Established global and domestic suppliers:** Viet Nam, Malaysia and Thailand have large production capacities, and supply both domestic demand and a significant share of global demand (Viet Nam – 5%, Malaysia – 4%, Thailand – 2% of global supply).[11]
- **Export-focused markets:** A key regional example is Cambodia, which has approximately 7 GW of solar PV module production capacity, of which nearly all production is exported to the United States (US) market.[12] Domestic solar PV additions in 2020–2022 have been <100 megawatts (MW) per annum,[13] and partly supplied by imported panels.[14]
- **Domestic-led markets:** A key regional example is Indonesia, which has a sizeable number of small-scale module assembly companies (>10 manufacturers of 30–200 MW capacity each[15]) serving local demand to fulfil national targets for local products.

Global Demand and Export Potential across Geographies

According to the International Energy Agency (IEA),[16] in 2017–2021, Southeast Asian manufacturers supplied one-third of global PV module exports, directed mostly to the US and the European Union (EU).

Demand for imports in Southeast Asia's dominant export market, the US, is expected to shrink as it makes efforts to localize its supply chain through the Inflation Reduction Act (IRA) and other supply incentives. Europe and Southeast Asia are likely the most attractive demand markets to fill this gap, while the ability of regional players to compete in other export markets will depend on attractiveness with regard to key buying factors, e.g., price. (Exhibit 4).

Exhibit 4

Europe and Southeast Asia are likely most attractive future export markets

Net imports from (exports to) global markets: **Current volume, 2022** | **Projected future volume, 2026**[17]

United States	Europe	Latin America, Middle East, Africa	Southeast Asia
17 GW IMPORT	**59 GW** IMPORT	**46 GW** IMPORT	**(64) GW** EXPORT
(11) GW EXPORT	**87 GW** IMPORT	**50 GW** IMPORT	**(72) GW** IMPORT
Strong current demand with trade advantage conferred to SEA (vs. high tariffs and duties in the PRC), but expected to be a shrinking export market due to strong policies to localize its solar PV supply chain.	Demand is strong and growing, and import sources expected to diversify.	Large market, but attractiveness of Southeast Asian products vs. global alternatives (e.g., PRC exports) on key buying factors will need to be assessed.	Although a large net exporter, if able to develop robust regional demand as well, the market will be the most reliable source of stable revenue amid potential export uncertainties.

GW = gigawatts; **PRC** = People's Republic of China; **PV** = photovoltaic; **SEA** = Southeast Asia

Sources: McKinsey analysis, based on supply data from McKinsey Solar PV Tracker and demand data from PV InfoLink (Q2 2023)

[11] IEA. 2022. Special Report on Solar PV Global Supply Chains. p. 27.

[12] Manufacturer interviews, company websites, and press releases.

[13] IRENASTAT. 2022. Online Data Query Tool. 25 March. https://pxweb.irena.org/pxweb/en/IRENASTAT/. Cambodia solar PV installed capacity: 315 MW in 2020, 376 MW in 2021 (+61 MW vs. 2020), 456 MW in 2022 (+80 MW vs. 2021).

[14] Interviews with Cambodian manufacturers and solar developers.

[15] APAMSI (Indonesia Solar Module Manufacturers Association). 2022. Daftar Anggota (Member List). 25 March. https://neo.apamsi.org/keanggotaan/daftar-anggota/.

[16] IEA. 2022. Special Report on Solar PV Global Supply Chains. p. 30.

[17] McKinsey analysis, based on supply data from McKinsey Solar PV Tracker and demand data from PV InfoLink (Q2 2023).

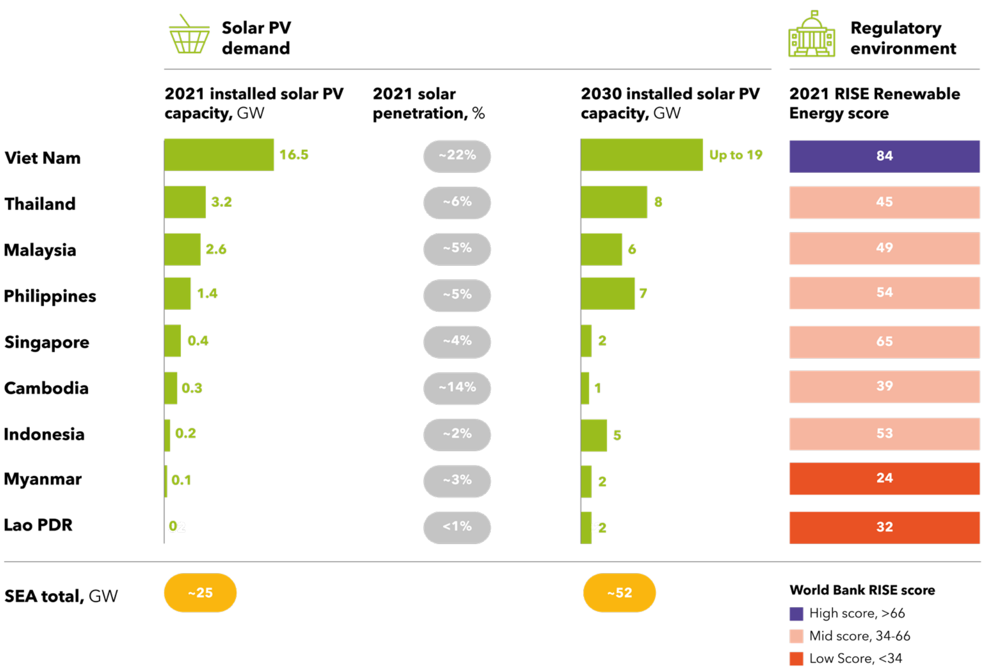
Deep Dive on Export Potential in Southeast Asia: Regional Demand

According to countries' power development plans, solar installed capacity in the region is expected to grow from 25 GW in 2021 to 52 GW in 2030, with an average annual capacity addition of ~3 GW over the period.[18] While the region's module supply capacity is expected to grow as well, demand for imports might persist in individual countries with a smaller manufacturing footprint.

There is likely further room to encourage renewables deployment through policy. Only one country in the region (Viet Nam) scores a 'high' on the World Bank's Regulatory Indicators for Sustainable Energy (RISE) score for renewable energy,[19] suggesting that solar PV demand could further increase among countries that pursue regulations to promote adoption (Exhibit 5).

Exhibit 5

Potential to expand regional demand with supportive regulations



ESMAP = Energy Sector Management Assistance Program; **GW** = gigawatts; **Lao PDR** = Lao People's Democratic Republic; **PV** = photovoltaic; **RISE** = Regulatory Indicators for Sustainable Energy; **SEA** = Southeast Asia

Notes: RISE Renewable Energy index scores countries on 7 indicators relating to renewable energy (RE) policy: legal framework for RE; planning for RE expansion; incentives and regulatory support for RE; attributes of financial and regulatory incentives; network connection and use; counterparty risk; and carbon pricing and monitoring
Sources: Countries' power development plans, RISE (World Bank, ESMAP)

There are five demand drivers for solar PV that stakeholders will need to ensure are in place to develop a robust demand market: greenfield Levelized Cost of Electricity (LCOE) parity; a supportive regulatory environment; mitigation of commercial and operational risk for developers; availability of grid infrastructure; and ability to manage solar intermittency with grid flexibility and storage.

Southeast Asian countries face headwinds on some of these factors, which will need to be addressed. For example, while the Philippines has a supportive regulatory environment for renewables and strong near-term renewable energy (RE) targets, its grid would require investment in capacity expansion to accommodate solar PV capacity additions (Exhibit 6).

[18] *Countries' power development plans.*

[19] *World Bank. 2022. Regulatory Indicators for Sustainable Energy (RISE). https://rise.esmap.org/analytics.*

Exhibit 6
Solar PV demand in the Philippines is hindered by its grid infrastructure

Assessment of key solar PV demand factors in the Philippines

Assessment of The Philippines
Tailwind | Neutral | Headwind *(strong barrier)*

A. Greenfield LCOE parity with other generation sources	**B. Supportive regulatory environment**	**C. Mitigation of commercial and operational risk for developers**	**D. Availability of grid infrastructure**	**E. Ability to manage solar intermittency with flexible grid and storage (longer-term barrier)**
In the Philippines, greenfield solar is cost **competitive** with thermal generation from 2030 for baseload demand. Present high electricity prices are a strong driver of distributed solar PV installation.	**RPS** mandates all utilities to **increase the use of renewable energy by 2.5% per year** from 2023 to 2030. Recent **opening of RE sector to full foreign ownership** expected to drive significant investment. Auction capacity announced for **>2 GW p.a. of additions from 2024-2026.**	Power producers are subject to **volatile spot prices** on the wholesale market, although prices are **likely to be high in near term** due to delayed supply additions. Other risks today include **cost base uncertainty** due to govt. policy changes (e.g., property tax), and **long lead time for land acquisition.**	The Philippines' grid infrastructure is constrained and **unable to accommodate additional solar generation.** Government permits for project development and grid connection take a long time to obtain.	The Philippines has **low supply of quick-start generation and energy storage solutions** (e.g., batteries) on the grid, due to lack of regulation around how they will be used and how suppliers are to be compensated.

ESMAP = Energy Sector Management Assistance Program, **GW** = gigawatt, **LCOE** = levelized cost of electricity, **PV** =photovoltaic, **RE** = renewable energy
RISE = Regulatory Indicators for Sustainable Energy, **RPS** = Renewables Portfolio Standard

Sources: Countries' power development plans, RISE (World Bank, ESMAP)

Deep Dive on Export Potential in Global Markets: Cost Competitiveness

In export markets, cost competitiveness will be critical. The market for solar PV modules is relatively commoditized, and price is a key buying factor for solar developers.

Cost differences between producers are driven by three key factors:

- economies of scale driven by stronger buying power and lower fixed costs (e.g., plant management costs, research and development [R&D] overheads);
- lower material costs driven by integrated value chains and the presence of robust local supply chains for production inputs; and
- lower material and non-material costs driven by lower yield and productivity.

The PRC has the lowest cost of production, enabled by its large scale, integrated value chains and ownership of intellectual property (IP), and operational excellence. At present, leading manufacturing hubs in Southeast Asia (e.g., Malaysia, Viet Nam) are estimated to produce at 15% to 20% higher cost than the PRC (the sales and cost leader), while a 25% to 35% cost increment versus the PRC is expected in less established solar PV markets, such as the Philippines (Exhibit 7).

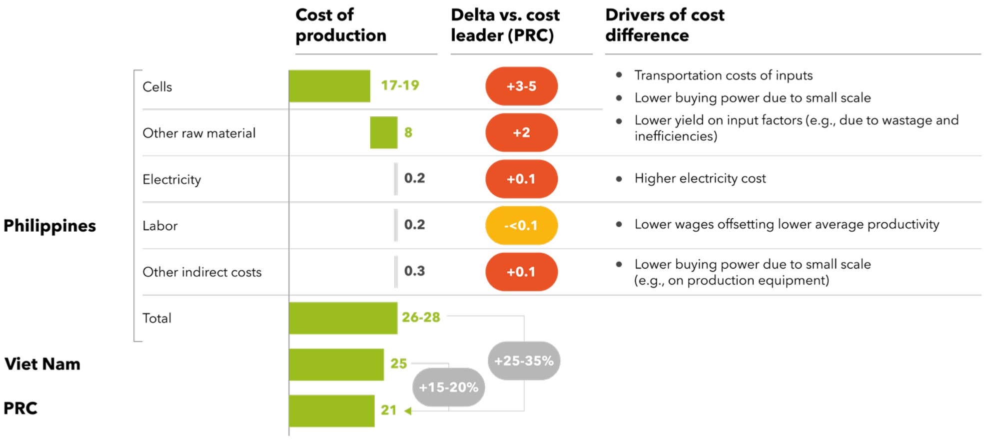
Within Southeast Asia, established manufacturing hubs are most cost effective given their established scale and strong industrial foundations. Other markets in the region are likely to produce at a higher cost, at least while the industry is still nascent, largely driven by smaller scale and lower productivity.

Given their disadvantage on production costs, regional producers may find it challenging to compete in export markets with which Southeast Asia does not enjoy trade advantages versus the PRC.

Exhibit 7

Southeast Asian production costs are 15%-35% higher than the PRC's

Estimated module production costs in SEA vs. global cost leader (PRC), US cents/W, 2022



GW = gigawatt, **PRC** = People's Republic of China, **SEA** = Southeast Asia, **SG&A** = selling, general and administrative, **US** = United States, **W** = watt

Notes: Costs pertain to plant sizes of 10 GW in the PRC, 3 GW in Viet Nam, and hypothetical 1 GW in Philippines, based on the current state of each market. Other indirect costs include depreciation, maintenance, and SG&A costs
Sources: McKinsey analysis based on manufacturer interviews.

Solar farm in Miagao, Iloilo, Philippines | Source: Shutterstock

B. Solar PV Manufacturing: Key Factors for Investment

Key Factors Considered by Manufacturers

In Southeast Asia's industrial centers, there has been significant success in establishing a solar PV manufacturing base.

However, based on manufacturer feedback, there are several barriers to investment in renewables manufacturing in other Southeast Asian markets.

Conversations with stakeholders revealed that they assessed Southeast Asian investment opportunities along four aspects: ease of doing business, availability of low-cost production factors, effective logistics systems, and access to export markets. Successful solar PV hubs demonstrate strengths on most of these dimensions, while other countries in the region may need to address key gaps across these factors to attract investment in the industry.

	DETAILS	EXAMPLES OF COUNTRIES' PERFORMANCE
Ease of doing business	Manufacturers consistently cited political and economic stability and low corruption as fundamental criteria for investment decisions. In addition, effectiveness of import-export processes is critical given the industry's reliance on imported materials and export markets.	On the World Bank's 2020 Ease of Doing Business index, **Malaysia** and **Thailand** rank 12th and 20th respectively, while the **Philippines** ranks 95th (50th percentile) and **Cambodia** ranks 144th (75th percentile).[20] According to the World Bank, border and documentary compliance takes more than four times as long for imports into the **Philippines** (9 days), and three times into **Cambodia** (6 days), than into **Malaysia** and **Thailand** (2 days).[21]
Availability of low-cost production factors	Manufacturers are attracted by fiscal incentives, low wages relative to labor productivity, availability of local supply chain for manufactured inputs (e.g., glass, aluminum frames, chemicals), and stable and cheap electricity supply.	According to a leading Cambodian manufacturer, wages in **Cambodia** are comparable to **Viet Nam**, but due to educational differences, more workers are required to produce the same output, leading to higher labor costs. Manufacturers cited the lack of industrial foundations in **Cambodia** and the **Philippines** as an impediment to reducing input costs by localizing supply chains.
Effective logistics systems	Manufacturers prioritize cost and efficiency of both international freight and inland transportation systems to import materials and export finished products. Efficient systems are critical to the swift fulfilment of orders when buyers face tight deadlines on their solar PV projects.	Manufacturers cited higher costs and wait times to export modules out of the **Philippines** vs. **Malaysia** and **Viet Nam** due to lower container traffic volumes. The **Philippines** also faces challenges with transportation between islands. The new Phnom Penh-Sihanoukville Expressway in **Cambodia** has been cited by manufacturers as a significant improvement to the quality of domestic logistics infrastructure. **Viet Nam**'s land border with the **PRC** is perceived as a significant benefit as delivery time for input materials can be reduced from weeks to days.

[20] *World Bank. 2020. Doing Business 2020. Dataset 'Historical-data---COMPLETE-dataset-with-scores.xlsx' https://www.worldbank.org/en/businessready/doing-business-legacy. Accessed 25 April 2023.*

[21] *Ibid.*

Access to export markets	Historically, manufacturers have been attracted to Southeast Asia due to its ability to access export markets such as the United States and Europe. Given that local demand is still relatively small today, manufacturers prioritize export markets to gain sufficient scale for cost viability.	From 2022 to 2024, producers from **Cambodia**, **Malaysia**, **Thailand**, and **Viet Nam** are exempt[22] from a 14%-15% import tariff on solar PV cells and modules to the US lasting until 2026[23] (except bifacial modules, which are tariff-free from all countries). **Cambodia** and **Indonesia** have a niche position as developing countries eligible for the Generalized System of Preferences (GSP) providing for duty-free entry of goods to the US. GSP eligibility has been cited as a strong incentive for manufacturers to invest in the Cambodian market.

Malaysia is an example market within the region to which manufacturers have been attracted by its ease of doing business, cost-effective production factors, and access to export markets. The country's attractiveness as a production base was enabled by strong non-financial support for investors, industry-academia partnerships to close talent gaps, as well as attractive tax incentives and financing arrangements for green technology.

Case Study 1: **Malaysia: Significant Role of Non-financial Support**

Drivers of investment in solar PV manufacturing in Malaysia

Ease of doing business	***Government support for MNCs***	"Besides policies, the government provides a lot of support to ensure investors are successful." **- Leading manufacturer in Malaysia**
Availability of low-cost production factors	***Low labor costs*** ***Availability of skilled talent***	"We like Malaysia because it was a cross between a straight low-cost play and a high engineering play." **- CEO, SunPower**
	Tax incentives and other financial support	"Low labour costs contribute, but [the 10-year tax holiday] is critical." **- EVP, First Solar**
	Maturity of local supply chain	"Localization of materials here is part of our strategy of continuous cost reduction." **- Plant manager, First Solar**
Access to export markets	***Relationship with export markets***	"Malaysia has attracted multinationals with its warm relations with the West." **- New York Times**

CEO = chief executive officer, **EVP** = executive vice president, **MNCs** = multinational corporations, **R&D** = research and development.

Details of key supporting mechanisms

Strong non-financial support for foreign investors

- Malaysia Investment Development Authority (MIDA) provides "one-stop shop" for foreign companies
- Business facilitation services include talent matchmaking and training, connecting MNCs to local supply chain, coordinating incentive offerings across agencies, and fostering R&D partnerships between universities and MNCs

Industry-academia partnerships to close talent gaps

- Government facilitates collaboration between industry and academia, supports identification of skill gaps, and provides financial support if needed
- Universities and techical schools partner with MNCs to develop curriculum to address needs, and MNCs hire program graduates
- Model is well established from semiconductor industry

Tax incentives and preferential financing arrangements

- Green Technology Financing Scheme offering preferential interest rate and government guarantees for green technology
- Corporate tax break for new large foreign investors, projects of national importance, and high technology companies

Notes: Quotes from identified individuals from New York Times article, other quotes from manufacturer interviews. **Sources:** Expert interviews, New York Times, 23 MIDA, Green Technology Financing Scheme (GTFS).

[22] *K. Martin. 2022.. Solar Panel Import Duties. Norton Rose Fulbright Project Finance. 28 February.* https://www.projectfinance.law/publications/2022/february/solar-panel-import-duties/.

[23] *The White House. 2022. A Proclamation to Continue Facilitating Positive Adjustment to Competition From Imports of Certain Crystalline Silicon Photovoltaic Cells (Whether or Not Partially or Fully Assembled Into Other Products). 4 February.* https://www.whitehouse.gov/briefing-room/presidential-actions/2022/02/04/a-proclamation-to-continue-facilitating-positive-adjustment-to-competition-from-imports-of-certain-crystalline-silicon-photovoltaic-cells-whether-or-not-partially-or-fully-assembled-into-other-produc/.

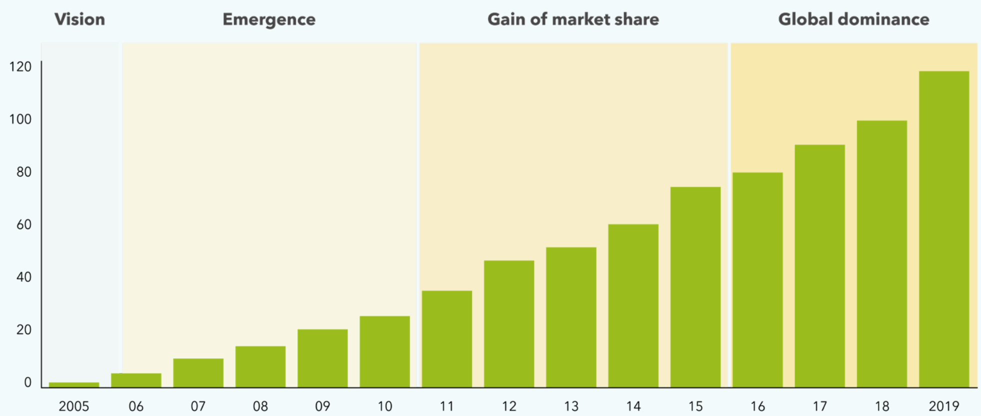
C. Policy Interventions and Supporting Mechanisms to Unlock Opportunities

To focus policy interventions, strategic alignment will be needed at the national level, for example to designate solar PV as a national priority sector and to increase national ambition on renewable capacity additions. At a national level, establishment of strategic partnerships would be key to the implementation of mechanisms to support the industry. Examples of this include government-to-government partnerships (e.g., for trade collaboration to import equipment and materials and export products), business-to-business partnerships as well as partnerships with multilateral and international organizations for monetary support and technical assistance.

The PRC, the global leader in the industry today, is a key example of successful alignment of industrial policy at national level. To drive the targeted development of its solar PV manufacturing capabilities, the PRC set ambitious industry targets and priorities in its Five-Year Plans (FYP). These guided the implementation of manufacturer incentives, allocation of R&D budget, and stimulation of domestic solar PV demand.

Case Study 2: **The People's Republic of China: Solar PV as a National Strategic Priority**

PRC solar module production capacity, GW



Source: IEA (2022) Special Report on Solar PV Global Supply Chains

- **2001–2005 (10th FYP) – Vision:** Introduced vision for industrializing renewable energy technologies, kick-starting central and provincial incentives for solar PV manufacturing.[24]
- **2006–2010 (11th FYP) – Emergence of industry:** Designated silicon refinement as R&D priority, to onshore its solar PV upstream value chain;[25] identified development of cost-effective solar technology as a priority R&D topic within Energy in the 2006 National Medium- and Long-Term Program for Science and Technology Development.[26]
- **2011–15 (12th FYP) – Gain of global market share:[27]** Set national target for 21 GW solar installed capacity[28] to create sustainable demand for domestic industry as solar costs fell;[29] designated the improvement of solar PV technology efficiency as a national priority, with specific efficiency targets.[30]

[24] *K. Bradsher. 2014. Solar Rises in Malaysia During Trade Wars Over Panels. The New York Times. 11 December. https://www.nytimes.com/2014/12/12/business/energy-environment/solar-rises-in-malaysia-during-trade-wars-over-panels.html.*

[25] *IEA. 2022. Special Report on Solar PV Global Supply Chains. p. 106.*

Countries looking to scale solar PV manufacturing would likely need to implement interventions to address any prevailing barriers across some or all of four key dimensions identified in Chapter 2B. In addition, although domestic market strength has not historically been a key decision factor for manufacturers in Southeast Asia, building domestic demand has the potential to provide necessary stability to the industry.

When it comes to building domestic demand, the Philippines saw success in pulling on some of these levers to support the development of its domestic semiconductor industry. The industry grew from a single company in 1979 to become the country's largest export earner in 1996,[31] supported by a strategy centered on export-oriented industrial promotion policies.

Case Study 3: **The Philippines: Learnings from the Semiconductor Industry**

Semiconductor Industry: A Cornerstone of the Philippines' Manufacturing Sector
Key Statistics as of 2021

60%
Total exports from the Philippines annually

US$40BN+
Total value of the industry

3.2M
People employed in the industry

500
Active semiconductor and electronics companies

Sources: Philippines Board of Investments, Department of Trade, SEIPI.[32]

Key supporting policies and mechanisms implemented in the 1980s and 1990s included:

- **Development of Export Processing Zones (EPZ):** In 1979, the opening of Baguio EPZ attracted the first semiconductor manufacturer to set up in the country.[33]
- **Formation of the Semiconductor and Electronics Industries in the Philippines Foundation (SEIPI):** In 1984, SEIPI was established to train industry workers, including facilitating collaboration of SEIPI with other organizations (e.g., UNIDO) to provide technical assistance and training to local engineers.
- **Targeted program of fiscal support for exporters in the 1990s:** Examples of targeted programs include the Export Development Act of 1994, the $500 million Export Development Fund facility by the Central Bank set up in 1994, and the establishment of the Philippine Economic Zone Authority (PEZA), industrial estates and free trade zones in 1995.

[26] *IEA. 2022. Special Report on Solar PV Global Supply Chains. p. 107.*

[27] *The State Council, People's Republic of China. 2006. The National Medium- and Long-Term Program for Science and Technology Development (2006–2020). p. 13. https://www.itu.int/en/ITU-D/Cybersecurity/Documents/National_Strategies_Repository/China_2006.pdf.*

[28] *IEA. 2022. Special Report on Solar PV Global Supply Chains. p. 22. According to the IEA, producers from Germany, Japan, the PRC, the Republic of Korea, and the US each held 15%–30% market share in 2010, but the PRC expanded its capacity twice as quickly as the rest of the world between 2010 and 2015.*

[29] *Government of the PRC, National People's Congress. 2011. 12th Five-Year Plan (2011–2015) for National Economic and Social Development.*

[30] *IEA. 2022. Special Report on Solar PV Global Supply Chains. p. 108.*

[31] *IEA/IRENA Renewables Policies Database. 2022. Solar Power Technology Development 12th Five Year Special Plan. https://www.iea.org/policies/5472-solar-power-technology-development-12th-five-year-special-plan.*

[32] *Oxford Business Group. 2015. New Growth Segments Emerge in the Philippine Electronics Industry. https://oxfordbusinessgroup.com/reports/philippines/2015-report/economy/new-growth-segments-emerge-in-the-philippine-electronics-industry.*

[33] *Cayas, et al. 2021. The Philippines: Your Ally in the Global Chip Race. https://semi.org/sites/semi.org/files/2021-10/The-Philippines-Your-Ally-in-the-Global-Chip-Race.pdf.*

Example 1: Priority Supporting Mechanisms for the Philippines to Unlock the Opportunity in Solar PV Manufacturing

		EXAMPLES OF KEY STAKEHOLDERS (non-exhaustive)	
Dimension	**Priority Mechanisms**	**Public**	**Private**
Increase the ease of doing business	Designate zones for solar PV manufacturing with conducive industrial and import/export policies	Philippine Economic Zone Authority (Agency of DTI)	**Existing Manufacturers:** Maxeon **Prospective Manufacturers:** Trinasolar, Longi, Jinko, Green Wing, JA Solar, Canadian Solar, BoViet Solar, Dehui
	Reduce complexity of the customs process	Department of Trade and Industry	**Solar PV Developers:** Acen, Aboitiz Power, Terra Renewables, Pavi Green, Citicore, San Miguel Corporation, Solar Philippines, First Gen, Meralco
Enhance production factors	Attract established solar manufacturing players to invest in local manufacturing facilities, facilitating on-the-ground transfer of operational excellence and technology	Philippine Council for Industry, Energy, and Emerging Technology Research and Development (DOST-PCIEERD)	**Existing Manufacturers:** Maxeon **Prospective Manufacturers:** Trinasolar, Longi, Jinko, Green Wing, JA Solar, Canadian Solar, BoViet Solar, Dehui
	Partner with industry leaders to establish training programs to upskill workers in designated solar PV manufacturing areas	Commission on Higher Education	**Local Academic and Research Institutions:** MREC, TIP, Philippine Energy Research and Policy Institute **Prospective Partner Academic and Research Institutions:** Shanghai Jiao Tong University, Southeast University, SERIS
	Reduce cost to OEMs through financial incentives (e.g., tax benefits, subsidies, grants) and/or provision of resources (e.g., land / building / other infrastructure)	Department of Finance	**Existing Manufacturers:** Maxeon **Prospective Manufacturers:** Trinasolar, Longi, Jinko, Green Wing, JA Solar, Canadian Solar, BoViet Solar, Dehui
Increase local market potential	Accelerate investment in expansion of grid capacity to enable higher renewables penetration	Department of Energy NREB	**Solar PV Developers:** Acen, Aboitiz Power, Terra Renewables, Pavi Green, Citicore, San Miguel Corporation, Solar Philippines, First Gen, Meralco

Should the Philippines aspire to establish its solar PV industry, such supporting mechanisms would be critical to competitiveness: it is estimated that workforce training and operational excellence, together with achievement of 3-5 GW scale, could enable a 5% to 10% reduction in the Philippines' production costs to a level comparable with regional leaders. Achieving this cost competitiveness would be key to the viability of the industry and to unlocking its potential benefits for the country.

Similarly, measures in Cambodia could target labor productivity factors, given the drag on export competitiveness observed from lower labor effiency. Just by increasing labor productivity to reach regional benchmarks, Cambodia can improve its solar PV production costs by 10% even at the current scale of production.

D. Solar PV Manufacturing: "Size of Prize"

Scaling solar PV manufacturing has the potential to create significant economic and social value for the region. Investment in a manufacturing industry adds to its gross domestic product (GDP) and creates jobs during both its construction phase (i.e., facility development and expansion) and operation phase. Such impacts are cascading (example box): through direct impact from the construction, equipment purchase, and operations; indirect impact via supply chains, with higher potential impact the more localized the supply chain is; and induced impact, with increased spending driven by income changes of employees in the value chain.

For illustration, this study analyzed the potential "size of prize" in 2030 associated with developing the solar PV manufacturing industry in the Philippines to an ambitious but realistic scale.

Example 2: "Size of Prize" for the Philippines

- The Philippines could aspire to establish 3–5 GW of scaled module assembly facilities by 2030, with ~50% of production supplying domestic demand
- 3-5 GW scale will likely be a key success factor (enabling economies of scale), alongside skills transfer and workforce training to achieve operational excellence
- To achieve this, **investment of $150 million to $250 million** would be required over 3-5 years
- Realization of this ambition has the potential to generate, in 2030:
    - **$100 million to $175 million uplift in GDP**, of which $65 million to $115 million direct, $23 million to $43 million indirect and $13 million to $20 million induced
    - **8,000 to 12,000 new jobs created**, of which 4,000 to 7,000 are direct, 3,000 are indirect, and 1,000 to 2,000 are induced
    - **$100 million to $140 million in annual cost savings** from operational improvements

Note: For the purpose of this analysis, direct impact includes costs of expansion (i.e., the investment spending on construction and equipment) and expected revenue change from expanded operations; indirect impacts include follow-on impacts on the supply chain arising from initial impacts; and induced impacts measure the spending on consumer goods and services from income changes of employees directly and indirectly affected by the value chain.

[34] *V. Cabreza. 2020. Economic Sone Expansion to Boost BLISTT. Business Inquirer. 9 March. https://business.inquirer.net/292128/economic-zone-expansion-to-boost-blistt.*

CHAPTER 3

Charging Up the Battery Manufacturing Industry in Southeast Asia

A. Battery Manufacturing Trends

Market Context and Manufacturing Footprint

The battery value chain comprises six main steps: mining, refining, precursor/cathode manufacturing, cell manufacturing, battery pack manufacturing, and battery recycling.[34]

Southeast Asia has significant potential to establish an end-to-end battery value chain, given its rich critical mineral resources and strong interest from global industry players to establish a domestic manufacturing footprint.

Several downstream players, including local and global cathode and cell manufacturers, have expressed interest in establishing production facilities in the region. Examples of such players include VinES in Viet Nam; LG, CATL, and POSCO in Indonesia; EVE in Malaysia; and DuraPower, Energy Absolute, and Gotion in Thailand (Exhibit 8). The establishment of these production facilities can lead to the creation of a more robust and sustainable battery industry in the region, provide job opportunities and contribute to economic development. Additionally, the expansion of the downstream value chain can increase the competitiveness of the region's battery industry by supporting at-scale production, which can in turn help Southeast Asian manufacturing hubs capture a larger share of the global market.

Exhibit 8

To date, battery cell manufacturing players have announced commitments in Southeast Asia, amounting to a total of approximately 60 GWh capacity by 2030

Manufacturing capability — Limited or no volume; Cathode, ktpa; Cell, GWh; Nickel; Cobalt; Manganese; Copper

	Critical mineral production, Thousands MT (% of global production)	Production output (2030 announced capacity) Cathode, ktpa	Production output (2030 announced capacity) Cell, GWh	Example of manufacturers
Viet Nam	Manganese ~120 (0.6%)	2	5	VinES, Sumimoto
Indonesia	Nickel ~1000 (37%); Copper ~760 (4%); Cobalt ~2 (1%)	130	35	LG, CATL, POSCO, Lopal
Malaysia	Manganese ~320 (2%)		15	EVE
Thailand			4	Durapower, Energy Absolute, Gotion
Philippines	Nickel ~370 (14%); ~5 (3%)			San Miguel Corporation
Other Southeast Asia	Manganese ~250 (1%)			
SEA Total		~130	~60	

GWh = gigawatt-hour, **MT** = megatonne, **SEA** = Southeast Asia

Notes: Brunei Darussalam, Cambodia, Myanmar, the Lao People's Democratic Republic, and Singapore, are not featured in the exhibit due to limited battery demand, mineral reserves, and production output; production output is based on announced projects only.
Sources: McKinsey Battery Insights, McKinsey Power Model, McKinsey Center of Future Mobility, IEA Southeast Asia Energy Outlook 2022, company announcements.

[35] *While the supply of used Li-ion batteries in Southeast Asian countries is expected to grow strongly (e.g., 90% p.a. in Thailand) in the coming years, current volumes of batteries reaching end of life or being scrapped from facilities locally may not yet be sufficient to satisfy the capacity of a mechanical battery recycling plant and therefore are longer term horizon investment opportunities (post 2040).*

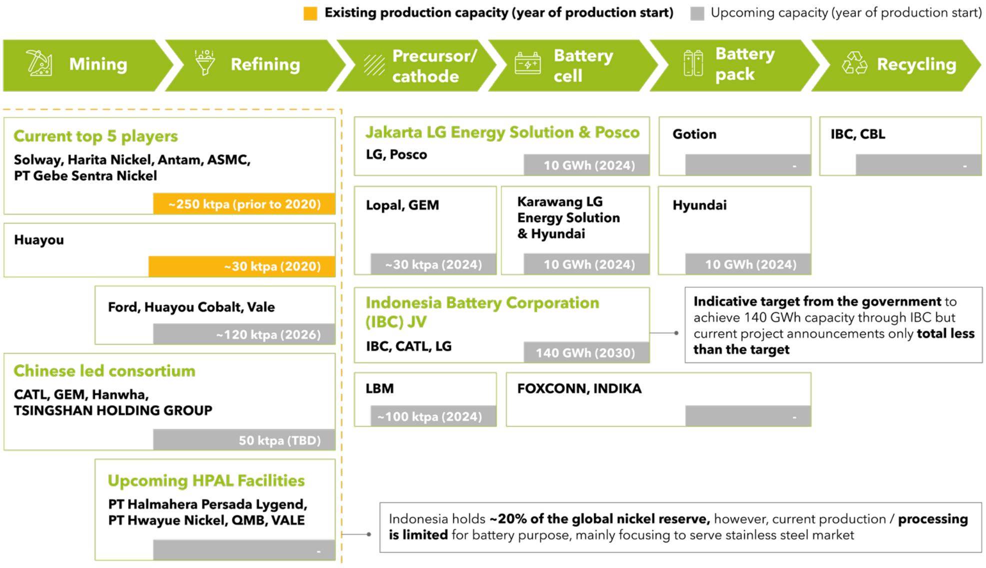
There are currently two prominent battery technologies in the market: Nickel Manganese Cobalt (NMC) and Lithium Iron Phosphate (LFP). Southeast Asia is naturally advantaged to develop an NMC technology-focused battery ecosystem given the region's vast reserves of nickel (approximately 25% of global reserves), which is the main raw material for NMC batteries.[35]

Indonesia alone possesses the lion's share of Southeast Asia's nickel reserves (approximately 21% of global reserves), making it an especially attractive opportunity for developing an NMC technology-focused battery ecosystem. Additionally, there has been strong commitment from global players to invest in building a domestic battery value chain ($15 billion in total investments to date[36]) and strong government support. The Ministry of State-Owned Enterprises in Indonesia (BUMN) has indicated an aspiration to achieve a domestic production capacity of 140 GWh by 2030[37] (Exhibit 9).

Exhibit 9

The Indonesian government has indicated an aspiration to develop 140 GWh in battery cell manufacturing capacity by 2030, by establishing an end-to-end value chain

Existing and planned NMC battery value chain developments and key players in Indonesia (not exhaustive)



Notes: Based on announced nameplate capacity; some projects have limited information on committed capacity
Sources: McKinsey Battery Insights, McKinsey Power Model, McKinsey Center of Future Mobility, IEA Southeast Asia Energy Outlook 2022, United States Geological Survey, International Copper Study Group, company announcements

Global and Southeast Asia Battery Demand

Demand for battery manufacturing output from Southeast Asia is expected to be led by exports to other regions (e.g., US, Europe), despite growing regional demand. Based on the current trajectory of demand, global demand for batteries is projected to increase by approximately 25% per year to 4.5 terawatt-hours (TWh) by 2030. NMC technology currently dominates more than half of total global battery demand and is expected to grow at approximately 20% per year (Exhibit 10).

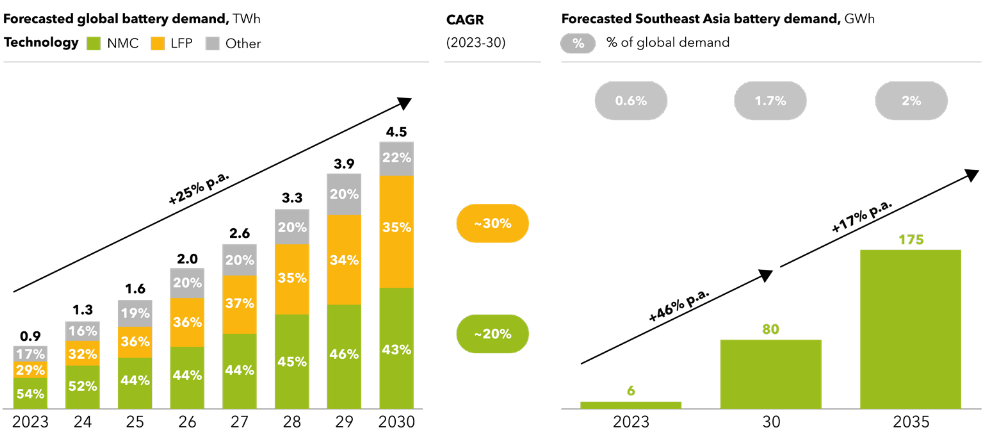
While Southeast Asia is expected to contribute only a small portion of the global market (less than 5%) over the coming decades, the region is anticipated to experience significant demand growth in absolute terms. It is expected that Southeast Asia's demand will grow at an annual rate of over 40% until 2030, reaching approximately 75-80 GWh. This demand is expected to double over the next 5 years to 150-175 GWh in 2035 (Exhibit 10).

[36] G. Bhutada. 2022. The Key Minerals in an EV Battery. Visual Capitalist. 2 May. https://elements.visualcapitalist.com/the-key-minerals-in-an-ev-battery/#:~:text=%231%3A%20Lithium%20Nickel%20Manganese%20Cobalt,for%20longer%20ranges%20in%20EVs.

[37] Reuters. 2023. Investments in Indonesia's Nickel Industry. EuroNews. 6 February. https://www.euronews.com/next/2023/02/06/indonesia-electric-timeline; J. Go. 2022. Indonesia Attracts $15 billion of Investment in the EV Supply Chain. FDI Intelligence. 28 April. https://www.fdiintelligence.com/content/news/indonesia-attracts-15bn-of-investment-in-the-ev-supply-chain-80942.

[38] Indonesia Battery Corp (IBC). 2021. IBC Targets 140 GwH Battery Production in Total by 2030. 26 November. https://www.indonesiabatterycorp.com/en/news/ibc-targets-140-gwh-battery-production-in-total-by-2030.

Exhibit 10
NMC battery has over 50% share of the global battery demand and is projected to grow at more than 20% annually. However, Southeast Asia accounts for only a small portion of the total demand

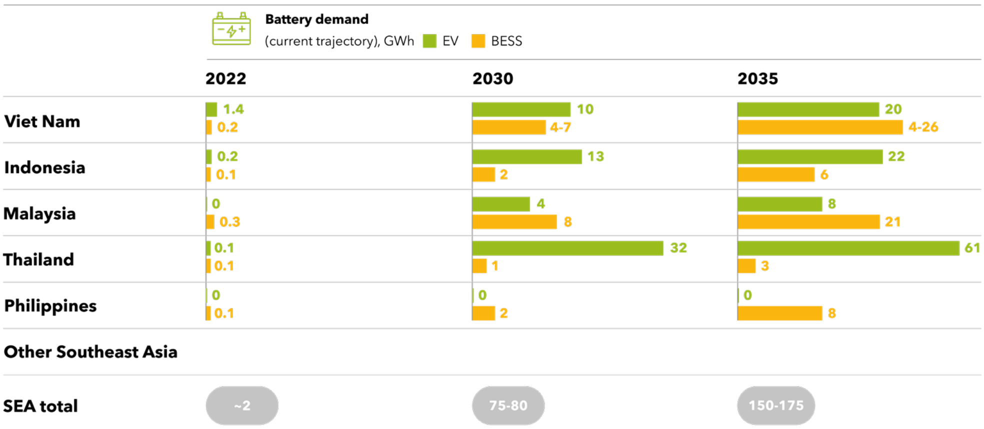


CAGR = compound annual growth rate, **GWh** = gigawatt-hour, **LFP** = lithium, ferrum, phosphate, **NMC** = nickel, manganese, cobalt, **p.a.** = per annum, **TWh** = terawatt hour

Notes: Other" technologies include Lithium-ion Manganese Oxide (LMO), Lithium Nickel-Cobalt-Aluminum Oxide (NCA), and Lithium Manganese Nickel Oxide (LMNO) batteries
Sources: McKinsey Battery Insights.

The demand for batteries in Southeast Asia is primarily driven by two segments: EV batteries and battery energy storage systems (BESS). In some countries like Indonesia, Thailand, and Viet Nam, the growth of EVs is the main driver of battery demand due to high vehicle demand and the potential for vehicle electrification. Conversely, demand is primarily driven by BESS in countries like Malaysia and the Philippines, which offer a more competitive levelized cost of storage (LCOS) (Exhibit 11), owing to the high potential for renewable energy and higher existing electricity costs from the grid in those countries.

Exhibit 11
Demand is expected to accelerate in some Southeast Asian countries over the next decade



BESS = battery energy storage systems, **EV** = electric vehicle, **GWh** = gigawatt-hour

Notes: Brunei Darussalam, Cambodia, the Lao People's Democratic Republic, Myanmar, and Singapore are not featured due to limited battery demand, mineral reserves, and production output to date. Lower bound based on Vietnam's PDP 8 announced in May 2023; upper bound based on McKinsey Battery Insights using cost optimization approach per country. 2030 and 2035 estimates from PDP 8 based on multiplying the 2030 share of BESS in total approved (BESS and pumped hydro) storage with 2035 total approved storage, assuming average 4 hour battery energy storage duration.
Sources: McKinsey Battery Insights, McKinsey Power Model, McKinsey Center of Future Mobility, IEA Southeast Asia Energy Outlook 2022, United States Geological Survey, International Copper Study Group

To realize or exceed these countries' domestic demand potential, the following five key factors need to be in place: a strong push for vehicle electrification, LCOS competitiveness with fossil fuel-based energy sources, stable prices of commodities to be used as battery raw materials, technology developments in favor of domestic value chain growth (e.g., cost competitiveness of NMC technology relative to LFP technology, and technology know-how development in refining and battery cell manufacturing), and policies to promote battery manufacturing.

Among Southeast Asian countries, Indonesia appears particularly well-positioned to benefit from several factors conducive to domestic market expansion: policies supporting vehicle electrification (e.g., a national target for all two-wheelers sold to be electric by 2040), a stable price outlook of commodities (class 1 nickel used for battery applications), and positive policies to promote manufacturing (e.g., tax benefits for building battery manufacturing facilities). Furthermore, the country could unlock further demand growth by addressing some demand barriers, such as improving LCOS competitiveness to drive demand of BESS and ensuring the scalability of refining and cell manufacturing technologies (Exhibit 12).

Exhibit 12

Assessment of Indonesia: strong growth potential with opportunities to improve LCOS competitiveness and technology adoption

A. Vehicle electrification

EV sales in Indonesia is expected to **grow by over 50% p.a.** until 2030.

Government has recently announced **EV subsidy policies** (~10-40% price discount).

B. Levelized cost of storage (LCOS)

Indonesia **LCOS for solar + battery (8-12-hour storage) is expected to be competitive with gas by 2030 and with coal post-2040** - driven by decreasing cost of materials and production scale.

C. Prices of commodities

The **falling price of critical minerals for batteries** (e.g., lithium, cobalt, and copper) makes batteries more affordable - produced with lower cost.

"Class 1" nickel price is expected to remain stable (as it has premium), hence, attractiveness for nickel refining is expected to be high.

D. Technology innovation / adoption

While global MC share is expected to decline from ~50% to ~40% by 2030 due to competition with cheaper LFP technology, absolute **NMC demand is expected to still grow at ~20% p.a. until 2030.** Within Indonesia, MC has <30% share in E4W sales - maintaining share will require cost competitive production.

Potential technology development in battery cell / pack manufacturing as global players start to establish facilities in Indonesia.

Currently limited upstream technology adoption for **nickel refining / processing** for battery applications.

E. Policies to promote battery manufacturing

Policies have been put in place, both to generate demand (e.g., subsidy) and **encourage production/ supply** (e.g., tax benefits) -aligned with government aspiration to create an end-to-end battery eco-system.

Assessment of Indonesia

Tailwind Neutral Headwind *(strong barrier)*

EV = electric vehicle, **LFP** = lithium, ferrum, phosphate, **NMC** = nickel, manganese, cobalt

Sources: Press search, McKinsey analysis

Cost Competitiveness

To foster growth in the battery industry in Southeast Asia, it is particularly important to target global export markets given the domestic market is growing from a smaller base. In addition, battery manufacturing countries in Southeast Asia can strive to maintain cost competitiveness to compete effectively with other global manufacturers, as customers (e.g., EV OEMs) consider price a significant factor when making purchasing decisions.

The cost competitiveness of battery manufacturers is mainly driven by four factors:

- **Vertical integration and access to low-cost raw materials:** Raw materials account for approximately 40% of total cell production cost, leading major cell manufacturers (e.g., CATL, Panasonic, and LG Chem) to pursue integration upstream (e.g., into mining and refining) to secure access to these materials.
- **Scale of production:** Manufacturing at sub-scale volumes (i.e., below 10 GWh) can be less competitive due to the high labor and energy costs involved. Larger production scale significantly improves cost competitiveness by around 20%.

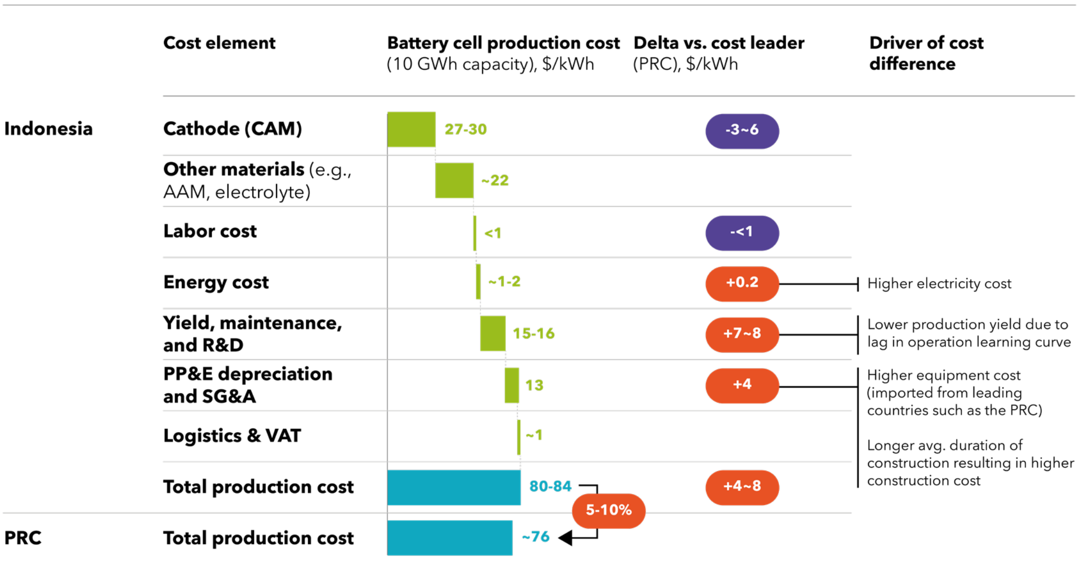
- **Production yield:** During the initial few years of operation, battery manufacturers typically experience a low yield of approximately 20%–30%. It is critical to accelerate the learning curve to attain stable production with yields of over 90% within 4 years or less, in line with leading benchmark manufacturers (e.g., in the PRC).
- **Proximity to or bulk contracts with equipment and technology/electronics suppliers:** Being located close to or having bulk contracts with equipment and technology/electronics suppliers can result in cost savings on both capital expenditures (CAPEX) and raw materials used in battery cell production.

Indonesia provides an illustrative example (Exhibit 13). The cost simulation for Indonesia assumes a fully integrated value chain and production at scale, in line with the Government of Indonesia's ambitious aspiration of producing 140 GWh by 2030. However, this alone may not suffice for Indonesia to be economically competitive compared to leading global battery manufacturers such as the PRC, as the overall costs are estimated to still be 5%–10% higher. To bridge the cost gap, strategies must be developed to address the third and fourth key factors mentioned above, which include accelerating the learning curve of operations (to improve production yield) and reducing CAPEX on property, plant, and equipment (PP&E).

Accelerating the learning curve is paramount as it is expected to bring Indonesia's cost of battery cell manufacturing in line with or below the production cost of the leading benchmark country, the PRC. This entails learning from experienced players and implementing best-in-class operation systems. Successful battery companies have partnered with experienced manufacturers, allowing them to adopt and scale their "know-how" by importing skilled workforces. Additionally, since different factories may have different setups and specific processes, it is also essential to establish an operation system that creates an environment for fast and continuous learning. This can be achieved through robust due diligence and root cause analysis capabilities.

Exhibit 13

Example of cost competitiveness simulation exercise: Indonesia cost of battery production is expected to be 5%-10% higher than the PRC's



AAM = anode active material, **CAM** = Cathode Active Material, **GWh** = gigawatt-hour, **kWh** = kilowatt-hour, **PP&E** = property, plant and equipment, **PRC** = People's Republic of China, **R&D** = research and development, **SG&A** = selling, general, and administrative, **VAT** = value added tax

Notes: Assessment based on NMC811 battery technology
Sources: McKinsey Battery Insights

B. Battery Manufacturing: Key Factors for Investment

Key Factors Considered by Manufacturers

Leading players in the battery industry, such as CATL, Panasonic, and LG Chem, have an established presence in the global market, possessing long-standing experience and unparalleled manufacturing scale. As a result, Southeast Asian nations will likely need to attract such global manufacturers, with the expertise to be competitive, rather than to rely solely on local players. Interviews with manufacturers looking to expand to Southeast Asia have revealed several key factors that determine the attractiveness of markets for investment. These include the scale of domestic demand, competitiveness of manufacturing, export potential, infrastructure and logistic network, and transparency in policy development and government effectiveness.

KEY FACTOR (in order of importance)	**DESCRIPTION**	**EXAMPLES OF SOUTHEAST ASIAN COUNTRIES' PERFORMANCE** (not exhaustive)
Scale of domestic demand	Current size of market, potential growth, and policies to generate demand. Manufacturers emphasize that establishing a robust customer base within the country is crucial for their financial viability and long-term survival, particularly during the early stages of production.	**Indonesia** is anticipating strong growth potential in the battery industry, with an estimated demand of around 15 GWh by 2030, despite the current limited demand size of less than 0.5 GWh in 2022. On the other hand, the **Philippines** is expecting a lower growth potential in domestic demand, with an estimated demand of around 2 GWh by 2030. **Indonesia** has also introduced subsidies to incentivize the purchase of electric two-wheelers (E2W) (or conversion of internal combustion to E2W) and electric four-wheelers (E4W) and further generate demand.
Overall competitiveness of manufacturing	General competitiveness of the manufacturing industry is influenced by factors such as proximity to mineral sources, availability of ecosystem partners, access to equipment suppliers, production factors, and business-friendly regulations. Manufacturers have particularly underlined the significance of vertical integration for battery makers, especially in the coming years, to attain cost efficiencies.	**Indonesia** and the **Philippines** hold approximately 21% and 4% of the world's nickel reserves, respectively. Both countries have also established upstream industries, including mining and refining, which are crucial to secure access to critical minerals. To incentivize the development of battery production facilities, the Government of **Indonesia** has provided tax benefits for manufacturers, while the Government of the **Philippines** has provided similar incentives, albeit less aggressively. According to manufacturers, **Indonesia** and the **Philippines** are facing challenges related to limited availability of local talent, including engineers and scientists, as well as technological knowledge critical for ensuring operational excellence and cost competitiveness in the manufacturing of battery cells. This shortage of expertise can pose significant barriers to the development of a robust and sustainable battery industry in these countries.

Export potential	The ability to access markets with high demand for batteries and satisfy customer requirements. Manufacturers intending to expand their operations in Southeast Asia are striving to achieve large-scale production, even though domestic demand in the region is limited. To succeed, they will also need to tap into the export.	**Indonesia** and the **Philippines** may face challenges in capturing demand from overseas original equipment manufacturers (OEMs), due to the limited ability of local mining companies to meet environmental, social, and governance (ESG) standards.
Infrastructure and logistics network	The infrastructure readiness to support the battery supply chain is a critical concern for manufacturers, as it can significantly impact the efficiency and cost-effectiveness of their operations. According to manufacturers, infrastructure plays a critical role not only in facilitating the domestic supply chain but also in supporting exports. They emphasize that the state of infrastructure can significantly impact their overall costs.	**Indonesia** faces limitations in its transportation infrastructure, particularly in terms of railway capacity and ports, which can pose challenges for the transportation of both raw materials and finished products. For instance, manufacturers mentioned that the country has inadequate railway capacity to transport goods from production facilities to port hubs. This can result in delays and inefficiencies in the supply chain, hindering the country's ability to fully realize its economic potential.
Transparency in policy development and government effectiveness	The degree of transparency in the government's policies regarding the manufacturing sector's advantages, and the efficacy of the administration in promoting a favorable business environment. Manufacturers' perception of conducting business in a country is influenced by the transparency and effectiveness of the government.	**Indonesia** scored 34 out of 100 in terms of corruption perceptions index based on Transparency International.[38] However, it is worth noting that the country has made some progress in enhancing its government effectiveness. **Indonesia**'s ranking in the Business Environment Index has decreased from 60th place during the period of 2018–2022 to 58th place in the current period of 2023–2027.[39] Although there have been notable advancements in areas such as taxes, infrastructure, and labor markets, the country's ranking is hindered by legal ambiguity, corruption, and bureaucratic obstacles.

39 *Transparency International. Indonesia. https://www.transparency.org/en/countries/indonesia.*

40 *Based on Business Environment ranking by Economist Intelligence Unit.*

C. Policy Interventions and Supporting Mechanisms to Unlock Opportunities

The PRC is widely considered to be at the forefront of battery manufacturing today. The country's success story is marked by its "all-in" approach, which entailed strong government support for the sector and the cultivation of local champions who were instrumental in building a fully integrated value chain. The PRC's battery manufacturing development can be succinctly summarized in three key stages (refer to Case Study 4 on the PRC): firstly, setting a national strategy and safeguarding the survival of early entrants, followed by establishing an end-to-end value chain while expanding demand, and finally stabilizing demand while maintaining market competitiveness.

Case Study 4: **The People's Republic of China: "All-in" Government Push to Raise Local Champions and Build an End-to-end Battery Value Chain**

Set national strategy to invest in battery industry and guarantee demand to compensate cost (~2000-2008)

National ambition and strategic decision to break away from ICE technology and to invest in the battery industry:

- Made decision to develop **local manufacturing champions** rather than to invite global leaders1
- Prioritized battery technology development as part of national scientific research and economic blueprint

Generated demand through policies, starting with public sector (e.g., buses, taxis and other urban service vehicles) e.g., through "Ten Cities, One Thousand Vehicles" program

- Ensured **survival of early players** (main source of revenue)
- **Demonstrated the feasibility and benefits of EVs** to develop public awareness
- **Spurred early infrastructure development**

Expand demand and build end-to-end manufacturing capabilities (~2008-2020)

Expanded policies to generate demand (e.g., subsidy for private EVs and requirement for energy storage in grid) and **encourage manufacturing/supply** (e.g., tax rebates)

Protection policies for local manufacturers – subsidies for "whitelisted" local manufacturers

Government-led **development of integrated value chains** by securing access to raw materials e.g., investment in critical minerals mine (e.g., lithium, cobalt) – ensuring competitive cost of manufacturing

Partnership development with foreign OEMs/offtakers (e.g., BMW, Tesla) to gain global recognition for market expansion, improve operations and ensure compatibility

National workers upskilling program – financed ~USD 15bn for vocational training targeting 50M people

Stabilize demand and maintain competitiveness (2020+)

Policies shift to stabilize demand and ensure continuous cost improvement from industries – e.g., phase out EV subsidies and start dual-credit policy[2]

Secure market competitiveness by strengthening end-to-end value chain – investment in battery cells R&D and securing more access to raw materials outside the People's Republic of China for future growth

KEY FACTORS OF THE PEOPLE'S REPUBLIC OF CHINA'S SUCCESS IN DEVELOPING BATTERY MANUFACTURING:

1. **Early aspiration alignment at national level to go "all-in"** – including strategic decision e.g., to raise local champions
2. **Strong government push through policies** in both generating demand and encouraging manufacturing investment
3. **E2E value chain integration** – to enhance cost competitiveness
4. **Partnership development with global players** – allowing further global market expanson and operation improvement
5. **Continuous policy evaluation** to ensure effectiveness of implementation

Note:
1. Resulted in several local champions in the later years (e.g., CATL)
2. Policy incentivizing car makers to lower average fuel consumption of cars produced, and to manufacture more "New Energy (non fossil fuel) Vehicles"

Addressing challenges identified in the key success factors mentioned in section 3B and learning from leading countries, such as the PRC, Southeast Asian nations can adopt or enhance several priority supporting mechanisms to scale up their battery manufacturing capabilities. Achieving this goal will necessitate the participation of diverse stakeholders, including public entities like ministries, and private players in mining and refining segments, as well as downstream manufacturers.

Example 3: Priority Supporting Mechanisms for Indonesia to Unlock the Opportunity

		EXAMPLES OF KEY STAKEHOLDERS (non-exhaustive)	
Dimension	**Priority Mechanisms**	**Public**	**Private**
Maintain and accelerate growth momentum	Ensure implementation of "promised policies" (e.g., EV subsidy, internal combustion engine vehicle (ICEV) ban in certain year) to drive demand	Ministry of Industry, Ministry of Finance, Ministry of Energy and Mineral Resources, Ministry of Transportation	Potential battery players across value chain
Develop competitive advantage	Orchestrate vertical integration from mining/refining to battery cell manufacturing steps in value chain	Ministry of Industry, Ministry of State-Owned Enterprises, and Ministry of Energy and Mineral Resources Public funding organizations	Potential battery players across value chain Local and global mining and refining companies Private funding organizations
	Facilitate partnership dialogues between prospective battery manufacturers in Indonesia and leading global manufacturers and tech enterprises to expedite operational learning	Ministry of Industry, Ministry of Energy and Mineral Resources, Ministry of Finance, Ministry of State-Owned Enterprises Public funding organizations	Potential battery players across value chain Private funding organizations
	Develop education plan with educators, industry players (e.g., battery manufacturers) and global technical experts to build continuous pipeline of sufficient skilled workers e.g., targeted curriculum enhancement and internship programs for vocational school and universities	Ministry of Education, Ministry of Industry Public Universities and Vocational Schools	Private universities and vocational schools Potential battery players across value chain
Stability to export and gain market access	Facilitate trade agreements with potential countries (e.g., Japan, Thailand, United States, Viet Nam) to secure offtake agreements for battery cells	Ministry of Trade and Ministry of Foreign Affairs	Potential battery players across value chain
Strengthen logistics infrastructure	Develop potential battery industrial zones and trade hubs e.g., near battery production facilities and nickel mines (e.g., Morowali)	Ministry of Public Works and Public Housing and Ministry of Transportation Public funding organization	Potential battery players across value chain Private funding organizations

D. Battery Manufacturing: "Size of Prize"

Expanding battery manufacturing in Southeast Asia has the potential to generate substantial economic and social benefits for the region. This includes a potential boost in gross domestic product (GDP), job creation, cost savings for meeting battery demand, and avoidance of emissions to support countries' net-zero ambitions.

Example 4: "Size of Prize" for Indonesia

To achieve the Government of Indonesia's aspiration of 140 GWh in battery production by 2030, an investment of approximately $15 billion over the next 5–10 years would be required.

The successful attainment of this ambition has the potential to generate the following benefits for Indonesia's economy in 2030:

- **$8 billion–$10 billion uplift in GDP**, of which $1 billion–$2 billion direct, $6 billion indirect, and $1 billion–$2 billion induced
- **530,000–545,000 new jobs created**, of which 10,000 is direct, 300,000–310,000 indirect, and 220,000–225,000 induced
- **$45 million–$80 million in cost savings** from import substitution
- **The avoidance of 2 million tons of carbon dioxide equivalent in direct emissions** by replacing grid electricity, primarily generated from coal and gas, with BESS and fuel consumption on vehicles with EV batteries

Note: For the purpose of this analysis, direct impact includes costs of expansion (i.e., the investment spending on construction and equipment) and expected revenue change from expanded operations; indirect impacts include follow-on impacts on the supply chain arising from initial impacts; and induced impacts measure the spending on consumer goods and services from income changes of employees directly and indirectly affected by the value chain.

Electric lithium-ion car battery pack | Source: Shutterstock

CHAPTER 4

Electric Two-Wheeler Manufacturing: The Race to Electrify Southeast Asia's Streets

A. Electric Two-Wheeler Manufacturing Trends

Market Context and Manufacturing Footprint

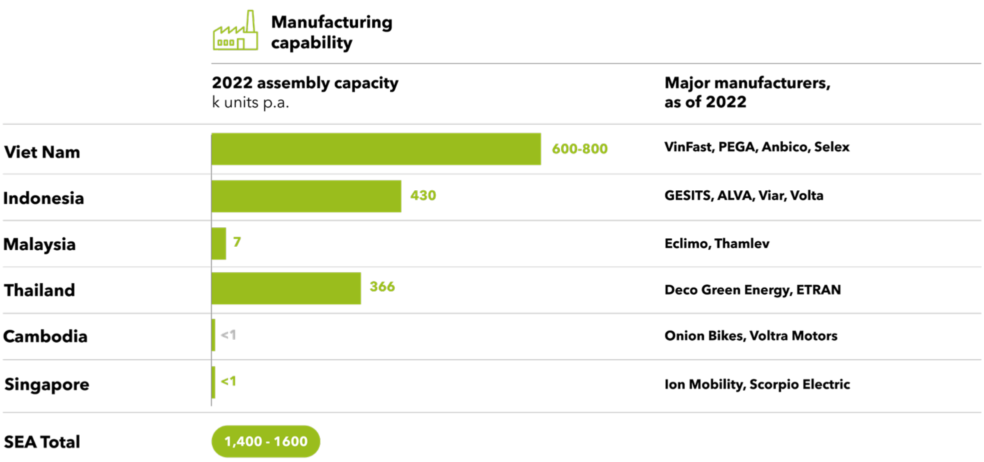
The E2W manufacturing value chain comprises of two main segments: component manufacturing and vehicle assembly. Southeast Asia had 1.4-1.5 million unit production capacity for E2W assembly in 2021 and this could grow to ~4.5 million[40] unit annual capacity by 2030 if the region were to be self-sufficient to meet regional demand. Many OEMs assemble E2Ws in Indonesia, Thailand and Viet Nam, with most being startups or regional firms. (Exhibit 2)

Component manufacturing remains nascent, with some assemblers like VinFast in Viet Nam manufacturing motors in-house and planning to assemble controllers in the future. While major Tier-1 suppliers have a limited electric component manufacturing footprint in Southeast Asia, they have a sizeable manufacturing footprint of other ICE components also used in E2W assembly (e.g., brakes, chassis), leveraging their deep roots in traditional automotive manufacturing in the region.

Exhibit 14

1.4-1.5 mn units annual assembly capacity with Viet Nam having largest assembly capacity

E2W manufacturing capacity in Southeast Asia and major manufacturers in the region



E2W = electric two-wheeler, **ICCT** = International Council on Clean Transportation, **ICE** = internal combustion engine, **OEM** = original equipment manufacturer

Notes: Based on McKinsey analysis of announced assembly capacity by players. Capacity for Viet Nam is sourced from industry report that captures capacity for assembly of E2W alongside bicycles and ICE 2Ws. Figures are sized down by OEM to reflect estimated E2W assembly capacity

Sources: Press search, company websites, ICCT

[41] *Assumes that domestic demand will be met by manufacturers in the region operating at full utilization. Refer to Exhibit 3 for domestic demand projections and sources for figures.*

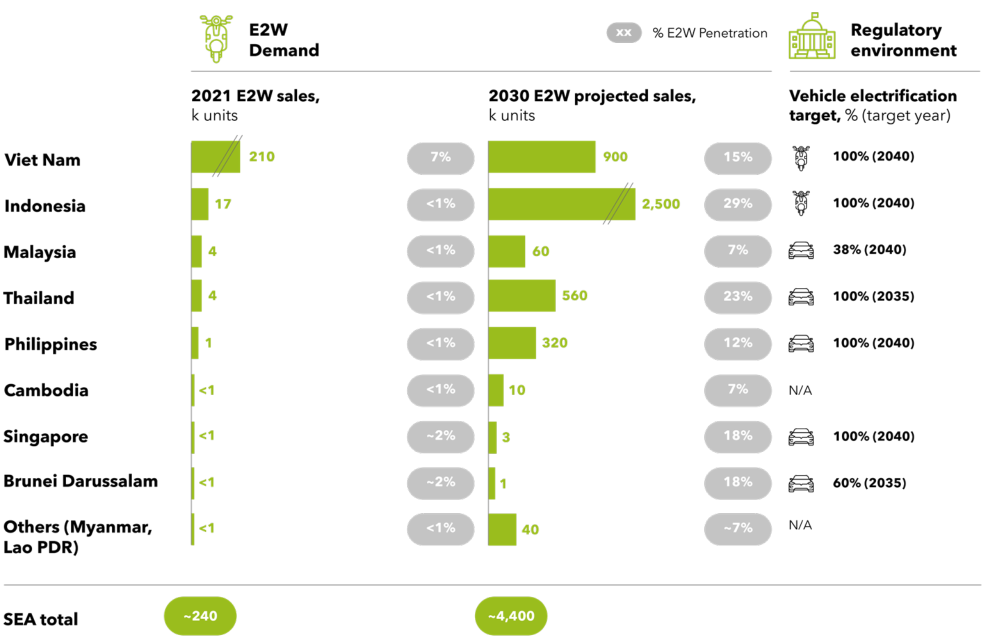
Due to large domestic demand in some markets (e.g., Indonesia, Viet Nam), players in each market are expected to predominantly supply to the local market, with some minor exceptions (e.g., Thailand has a growing ambition to serve overseas markets such as Australia, Japan, and New Zealand with premium segment E2Ws). There are three broad player archetypes of manufacturers in the region:

- **Startups and regional firms:** New entrants have entered Southeast Asia such as Gesits in Indonesia, Deco in Thailand and Pega in Viet Nam. Several start-up companies commenced their operations by importing and distributing E2Ws prior to investing in their manufacturing infrastructure. Furthermore, there are regional enterprises, including VinFast in Viet Nam, that have undertaken the production of E2Ws.
- **Global E2W OEMs:** PRC OEMs that lead global sales of E2Ws have established manufacturing facilities in Southeast Asia. Yadea manufactures E2Ws in Viet Nam but only imports and distributes in Indonesia.
- **ICE 2W Incumbents:** ICE 2W incumbents, such as Honda and Yamaha, dominate the 2W market in Southeast Asia. They currently have limited footprint for manufacturing E2W and offer a limited E2W portfolio of products.

Southeast Asia E2W Demand

Regional demand for E2Ws is expected to grow from 200,000 to 300,000 units in 2021 to ~4.5 million units in 2030. Governments in the region have announced a combination of ambitions and/or targets for electrification of transportation modes, driven by the need to control pollution, mitigate climate change through emissions reduction and reduce reliance on fossil-fuel imports. These targets have the potential to create a significant upside in demand beyond 2030. For instance, Viet Nam is projected to realize 15% E2W penetration by 2030, rising to 100% in the following decade were the country to realize its target of 100% E2W sales penetration by 2040 (Exhibit 15).

Exhibit 15
~4.5 mn unit market projected in 2030 with Indonesia emerging as the largest market by 2030
Southeast Asia's E2W demand and government vehicle electrification targets



E2W = electric two-wheeler, **EV** = electric vehicle, **Lao PDR** = Lao People's Democratic Republic, **N/A** = not applicable. **IKD** = incompletely knocked down, **OEM** = original equipment manufacturer

Notes: Indonesia 2030 sales projection accounts for EV subsidy and reduction in fuel subsidy; assumes incentives will cease in mid 2020s. Sales figures in Viet Nam are inclusive of low-speed vehicles while sales figures in other countries are exclusive of low-speed vehicles. Vehicle electrification targets by country include targets as per regulations and standards, government announcements, budgetary commitments, Nationally Determined Contributions to the Paris Climate Agreement or national climate plans, and government goals or objectives (unofficial targets) as set out in a policy document such as a deployment roadmap or strategy. Indonesia and Viet Nam have targets specific to 2W/motorcycles while Brunei Darussalam, Malaysia, the Philippines, Singapore, and Thailand , have targets which apply to electric vehicles in general
Sources: McKinsey Center for Future Mobility, McKinsey Global Energy Perspective, Expert interviews.

Seven key demand factors are required to realize or exceed this projected demand in Southeast Asia: parity in total cost of ownership between E2W and ICE 2W, availability of adequate charging infrastructure (e.g. battery swapping stations), OEMs having adequate capacity to meet current and projected domestic demand, products in the market being customer-centric and meeting consumer needs, supportive government policies and regulations to drive demand and supply, absence of consumer preference for specific brands, and readily available vehicle financing and distribution.

Countries like Indonesia could unlock further demand growth by addressing some demand barriers. Examples include improving the availability of customer-centric products, E2W financing options, and distribution channels (Exhibit 16).

Exhibit 16
Indonesia has room to develop customer-centric products, E2W financing options and distribution channels

Assessment of E2W demand factors in Indonesia

Assessment of Indonesia
Tailwind | Neutral | Headwind *(strong barrier)*

A. TCO parity (E2W vs ICE 2W)	**B. Infrastructure readiness** (e.g., availability of battery swapping infrastructure)	**C. Availability of OEM supply**	**D. Availability of customer - centric products**	**E. Regulatory push**	**F. Branding and quality assurance**	**G. Financing availability & distribution**
TCO competitive E2W products are available for **some B2C segments,** however **performance gaps exists between E2Ws and ICE 2Ws** within each segment.	Indonesia has **3,000 battery swapping stations** and the Ministry of Energy and Mineral Resources **targets 67,000 stations by 2030,** although infra-structure is relatively limited today.	Current production **capacity of ~430k units** per year is **sufficient to meet cur-rent demand** of ~4k units per year. However, **this capacity will not be sufficient to meet projected demand** of at least 2,500k units per year from 2030.	**Incumbent OEMs have limited footprint** for E2W manufacturing and limited portfolio of E2Ws. Barriers to purchase by consumers in Indonesia (e.g., B2B players) include **high upfront price, and concerns around battery reliabil-ity and safety of E2Ws.**	**7mn IDR demand subsidies** for E2Ws. Apart from **0% import duties on IKD parts, supply side incentives are limited.**	Consumers perceive incumbent OEMs (with ICE models) to have better quality products, **thus limiting demand growth for E2Ws assembled by local OEMs** (e.g. startups). ~80% of Indonesian consumers quote **brand as a key buying criterion.**	**Lack of vehicle leasing programs offered by start-up OEMs** (e.g. leasing of batteries) due to the lack of financial resources to offer services down the value chain. **Distribution is a challenge for emerg-ing OEMs** (vs incum-bent Japanese OEMs with extensive dealer network).

B2B = business-to-business, **B2C** = business-to-consumer, **E2W** = electric two-wheeler, **ICE 2W** = internal combustion engine two-wheeler, **IDR** = Indonesian rupiahs, **IKD** = incompletely knocked down, **OEM** = original equipment manufacturer

Notes: Current demand refers to demand in 2021.
Sources: McKinsey analysis which includes total cost of ownership comparison between popular ICE 2Ws and available E2Ws, Ministry of Energy and Mineral Resources, consumer surveys, Press Search.

B. Electric Two-Wheeler Manufacturing: Key Factors for Investment

Key Factors Considered by E2W Manufacturers

Southeast Asia has existing assembly capacity of around ~1.5 million units per year with Viet Nam, Indonesia, and Thailand having the most capacity with 600,000–800,000, 430,000, and 370,000 unit capacity in 2022, respectively. Despite these early investments, manufacturers perceive hurdles to scale up in the region. In our conversation with these manufacturers, we learn that they evaluate eight key factors when establishing footprint in a country and gaps are perceived in the Southeast Asian countries.

KEY FACTOR (in order of importance)	**DESCRIPTION**	**EXAMPLES OF SOUTHEAST ASIAN COUNTRIES' PERFORMANCE** (not exhaustive)
Scale of domestic and export demand	Robust and growing domestic demand is a key priority for manufacturers, along with favorable trade policies in the country where their manufacturing site is located. Export potential can also be increased through free trade agreements with high-volume or premium product markets.	**Indonesia** is projected to have the largest domestic demand with 2.5 million unit sales in 2030, while sizeable demand is also expected in **Viet Nam** and **Thailand** (900,000 and 650,000 unit sales in 2030, respectively). Current volumes are perceived to be low compared to major global markets like the **PRC**. **Thailand** and **Viet Nam** appear well-positioned to be exporters of E2Ws due to extensive free trade agreement coverage with key demand markets.
Potential for return on investment	Manufacturers seek to generate positive earnings as soon as possible to pay back the investment in setting up manufacturing facilities.	Local manufacturers in **Thailand** and **Indonesia** typically post negative earnings in the first 4 to 5 years as they price vehicles at or below cost to maintain competitiveness with comparable ICE models. Manufacturers in **Viet Nam** perform relatively better in the low-end product segment, mainly due to the use of cheaper parts and outdated technology (e.g., lead acid batteries). However, manufacturers in **Viet Nam** targeting the middle and premium segments price their products at or below cost.
Ease of doing business	Manufacturers look for developed road/ port infrastructure, industrial land availability, government policies supporting manufacturing, and streamlined business processes.	**Viet Nam** offers very limited incentives to support E2W manufacturers. **Thailand** provides receivables financing and corporate income tax (CIT) and import duty exemptions amongst other supporting mechanisms, however, manufacturers perceive these incentives to be temporary. Road infrastructure around industrial zones and port infrastructure is well developed in **Indonesia**, **Thailand**, and **Viet Nam**. Land availability is a challenge in **Indonesia**.

[42] *Economist Intelligence Unit. Business environment. https://country.eiu.com/article.aspx?articleid=2023177585&Country=Indonesia&topic=Business&subtopic=Business+environment&subsubtopic=Rankings+overview (accessed April 2023).*

[43] *World Bank. Worldwide Governance Indicators. Data updated in 2022. https://info.worldbank.org/governance/wgi/Home/Reports (accessed April 2023).*

[44] *Government of Indonesia, Ministry of Energy and Mineral Resources. 2021. EV Program Overcomes Gasoline Imports. 12 December. https://www.esdm.go.id/en/media-center/news-archives/ev-program-overcomes-gasoline-imports-official-says.*

[45] The Nation Thailand. *2022. Plugging into the Future with EV Mobility. 13 May. https://www.nationthailand.com/special-edition/40015527.*

		According to Economist Intelligence Unit's Business Environment ranking,[41] **Indonesia** has dropped from 60 in 2018–2022 to 58 in 2023–2027 while **Thailand** and **Viet Nam** are ranked at 61st and 62nd percentile respectively, in terms of government effectiveness (index by World Bank[42]).
Ecosystem availability	Manufacturers take into account the charging infrastructure (e.g. swapping networks) and component supplier maturity to ensure that their products can be produced and sold efficiently.	**Indonesia** targets an ambitious ~67,000[43] swapping stations by 2030 while **Thailand** targets 1,450[44] by 2030. However, current deployments are limited in **Indonesia**, **Thailand**, and **Viet Nam**. Well established Tier 1 supplier ecosystem in **Thailand** and **Viet Nam** due to existing ICE 2W industry. Suppliers for critical components, such as motors, controllers and converters, are nascent.
Availability of talent	Labor availability, productivity, and skill level, as well as the availability of local engineering talent, are all critical factors that manufacturers consider when evaluating potential manufacturing sites.	Labor costs in Southeast Asia are low compared to other E2W supplier countries (e.g., **PRC**). Labor salaries per month are \$250, \$360, and \$450[45] in **Viet Nam**, **Indonesia**, and **Thailand**, respectively.
Logistics and transportation cost	Outbound and inbound logistics costs are a significant consideration for manufacturers when selecting a manufacturing location.	**Indonesia**, **Thailand**, and **Viet Nam** each have well-developed industrial and supplier parks that help in keeping logistics and transportation costs low. Outbound logistics continues to be challenging in **Indonesia** due to geography (e.g. islands). **Viet Nam**'s land border with the **PRC** is perceived as a significant benefit as delivery time for input materials can be reduced from weeks to days.
Tech obsolescence	Manufacturers are hesitant to make investments when the future of the underlying technologies of their products is uncertain (e.g. prevalence of NMC batteries in future in uncertain due to battery chemistry developments).	While NMC has 50% to 60% share of global battery demand,[46] this is forecasted to drop to ~40% by 2030 with LFP projected to gain market share. This trend can limit demand for nickel in EV production in **Indonesia**.
Competition from incumbents	Manufacturers consider whether local ICE 2W incumbents are transitioning to capture this market.	Incumbent OEMs have captured over 85%[47] of the 2W market in **Viet Nam**, **Thailand**, and **Indonesia**. These OEMs have not introduced a broad portfolio of E2W products in these markets as they seek to avoid cannibalization of their ICE 2W business in which they have made significant investments.

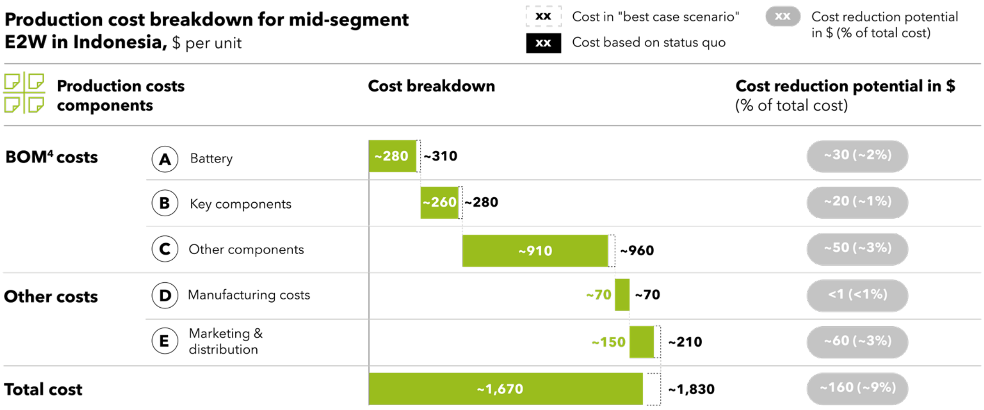
Deep Dive: Potential for Return on Investments

In Southeast Asian countries such as Indonesia, Thailand, and Viet Nam, manufacturers often set their product prices at or below production cost in order to capture market share. As the upfront price of a vehicle is a key buying factor in most Southeast Asian markets, manufacturers need to leverage cost levers to improve their financial health. Cost differences between vehicle assemblers are driven by four key factors:

- **Localization of components:** Local manufacturing of batteries (cells and packs) and key components (e.g. motors, controllers, and chargers) can realize cost advantages compared to relying on importing these parts from abroad.
- **Scale of production:** Production at larger volumes can help realize economies of scale due to bulk purchase discounts on bill of materials (BOM) parts and distribution of marketing and distribution costs over more quantity of vehicles.
- **Duties on imported parts:** Fluctuations in import duties on completely knock-down (CKD) incompletely knocked down (IKD) parts can adversely impact costs.
- **Improvements to labor productivity:** Training and knowledge transfers can help realize marginal benefits in manufacturing costs.

Countries like Indonesia could leverage these factors to realize up to 9% cost reduction largely driven by the localization of components and scale of production (Exhibit 17).

Exhibit 17
Localization of manufacturing and scale effects can reduce the costs by up to 9% in Indonesia
Cost breakdown for mid-segment E2W in Indonesia and factors to achieve cost competitiveness



BOM = bill of materials, **E2W** = electric two-wheeler, **kW** = kilowatt, **MCU** = microcontrollers

Notes: Key components refer to Motor (<4 kW), MCU and Charger (1 kW) while Other components refer to plastic Injection for body, MCU, Elec. Component, Brake, Frame, Speedometer, Suspension, Wheel and others. Analysis for status quo assumes that all parts are imported into the country and production is sub-scale (~200,000 assembly capacity). Analysis for "Best case scenario" assumes that Battery is manufactured in the country with key/other components continuing to be imported and scaled operation (~400,000 to 500,000 plant size). Other industry trends are not considered (e.g., battery cost reduction over time). Factors that reduce the costs in a Best Case Scenario include localization of battery cell and pack, scale effects (on battery cost, key and other components costs (due to bulk purchasing) and marketing and distribution costs) and labor productivity improvements.
Sources: McKinsey analysis based on expert interviews.

Key Factors Considered by Component Manufacturers

Manufacturing of components critical for E2W assembly—motors, controllers, and converters, is limited in Southeast Asia. VinFast in Viet Nam is one such player that manufactures motors for E2Ws in-house. Similar to E2W assemblers, component manufacturers seek a strong domestic demand, ease of doing business, supply chain partner availability and availability of talent when choosing a location for manufacturing. Present assembly volumes in Southeast Asia are deemed to be insufficient to justify investing in component manufacturing in the region.

[46] *A. F. Medina.. 2021. Hiring Costs in ASEAN.* ASEAN Briefing. *4 October.* *https://www.aseanbriefing.com/news/hiring-costs-in-asean/.*
[47] *Global battery demand figures by cathode sourced from McKinsey Battery Insights.*
[48] *Based on McKinsey analysis.*

C. Policy Interventions and Supporting Mechanisms to Unlock Opportunities

Countries looking to scale E2W manufacturing would need to implement interventions across some or all of the eight key dimensions mentioned in 2B. To enable this, strategic alignment will be needed at the national level, e.g., national policies to accelerate phase out of ICE 2Ws, upgrade grid and charging infrastructure, and establish technical standards (e.g., for battery swapping and charging).

Countries like Indonesia can develop a wide range of priority supporting mechanisms to alleviate concerns of current and potential manufacturers across the value chain. For instance, the Ministry of Energy could work with technology developers in the industry and state-owned enterprises with real-estate[48] (e.g., Pertamina and PLN) to install a network of battery swapping infrastructure that will alleviate consumer concerns around refueling.

Example 5: Priority Supporting Mechanisms for Indonesia to Unlock the Opportunity

		EXAMPLES OF KEY STAKEHOLDERS (non-exhaustive)	
Dimension	**Priority Mechanisms**	**Public**	**Private**
Increase scale of domestic demand	Continue to offer financial incentives, such as subsidies on E2W purchases, to incentivize demand	The President and Coordinating Ministry of Maritime and Investment	Industry players across value chain, associations, organizations
	Limit ICE 2W use/ownership, remove fuel subsidy	Ministry of Transportation, Ministry of Finance	Industry players across value chain, Industry associations
	Support development of secondhand market	Ministry of Transportation	
Generate attractive potential for return on investment	Exemption of import duties and tax	Ministry of Trade	Industry players across value chain, Industry associations
	Provide incentives to manufacturers such as land parcels and production-linked incentives	Ministry of Industry, Ministry of Trade	
Enhance ease of doing business for new entrants	Align national infrastructure development priorities (e.g., ports, railway build out, inter-island transport networks) and upgrade road and port infrastructure connecting special economic areas	Ministry of Public Works and Housing, Ministry of Industry	Industry players across value chain, Industry associations
Establish adequate infrastructure and E2W ecosystem	Provide component manufacturers incentives such as land parcels, exemption of import duties and tax to accelerate total cost of ownership (TCO) parity and to further incentivize manufacturing	Ministry of Industry, Ministry of Trade	Industry players across value chain, Industry associations

[49] *Access to lands and buildings facilitates provision of physical space for charging stations and required power infrastructure.*

	Install swapping infrastructure through PLN and provide incentives on energy price to network operators	Ministry of Energy and Mineral Resources	Industry players across value chain, Infrastructure providers, Pertamina, PLN
	Upgrade grid infrastructure and promote energy supply from renewable energy sources	Ministry of Energy and Mineral Resources	Funding organizations
Improve quality of talent pool	Partner with industry leaders to establish training programs to upskill workers in designated E2W manufacturing areas	Ministry of Industry	Industry players across value chain, Industry associations, research and academic institutes
Streamline logistics & transport costs	Designate industrial zones for E2W manufacturing hubs and incentivize manufacturers to set up operations in these areas	Ministry of Industry	Industry players across value chain, Industry associations
	Develop industrial cluster of component suppliers	Ministry of Industry	
Avoid E2W tech obsolescence	Align national E2W manufacturing strategy with NMC batteries manufacturing strategy	The President, Coordinating Ministry of Maritime and Investment, Ministry of Industry	Industry players across value chain, Industry associations
Enabling manufacture of E2Ws across the industry	Introduce and regulate Zero Emission Vehicles (ZEV) sales mandates and Average Fuel Economy (e.g. CAFE) regulations	The President, Coordinating Ministry of Maritime and Investment, Ministry of Industry, Ministry of Transportation	Industry players across value chain, Industry associations

D. Electric Two-Wheeler Manufacturing: "Size of Prize"

The scaling of E2W manufacturing in Southeast Asia has the potential to create significant economic and social value for the region. This includes the potential for a GDP uplift, job creation, national cost savings to meet battery demand, and emissions avoided to support countries' net-zero aspirations.

Example 6: "Size of Prize" for Indonesia

- Indonesia could aspire to establish **>2.3 million unit annual production capacity** by 2030, which would address 90% of domestic demand
- To achieve this, **investment of ~$610 million** over the next 5 to 7 years would be required
- Realization of this ambition could potentially generate:
  - **$3.5 billion to $4 billion uplift in GDP**, of which $610 million to $615 million direct, $2,330 million to $2,340 million indirect, and $920 million to $925 million induced
  - **355,000 to 375,000 new jobs created**, of which 15,000 to 20,000 direct, 215,000 to 225,000 indirect, and 125,000 to 130,000 induced
  - **$130 million cost savings** from localizing production and scaling effects; and
  - **0.5 million tons of carbon dioxide equivalent ($MtCO_2e$) direct emissions avoided** from shifting from Tank-to-Wheel ICE 2W emissions to Grid emissions for E2Ws

Note: For the purpose of this analysis, direct impact includes costs of expansion (i.e., the investment spending on construction and equipment) and expected revenue change from expanded operations; indirect impacts include follow-on impacts on the supply chain arising from initial impacts; and induced impacts measure the spending on consumer goods and services from income changes of employees directly and indirectly affected by the value chain.

Electric scooter with charging cable | Source: Shutterstock

CHAPTER 5

Power in Partnership: Exploring Opportunities for Regional Collaboration

Southeast Asia has a strong history of intraregional collaboration toward its collective objectives. ASEAN institutions have achieved an impressive record in fostering trade, investment, and economic integration, and a shared green agenda is now taking increased prominence in cooperation.[49] There is significant potential to build upon this foundation to address prevailing challenges in renewable equipment manufacturing and unlock the opportunity of scaling-up domestic production across the region.

Across E2Ws, batteries, and solar PV, Southeast Asian countries can benefit from regional trade collaboration across the value chain. Enabling trade between countries on raw materials and products could help to ensure a sustainable supply-demand balance, build scale, and lower the cost of production within the region. Examples of potential for regional trade include:

- **Electric Two-Wheelers:** Raw materials (e.g., electronic components); products (e.g., motors, controllers, completely built up (CBU) vehicles)
- **Batteries:** Raw materials (e.g., nickel or cobalt from the Philippines, battery cells or packs from Indonesia and the Philippines); products (e.g., battery packs from Indonesia and Viet Nam)
- **Solar PV:** Raw materials (e.g., wafers, electronic components, other manufactured components from Malaysia and Viet Nam); products (e.g., cells and modules from Cambodia, and the Philippines)

Countries could also collaborate to deliver regional improvements in workforce quality and distribution. Manufacturers interviewed for this study noted a gap in workforce skills and productivity between established manufacturing hubs and emerging economies in the region. This was identified as a key barrier preventing investment in the latter (e.g., Cambodia, the Philippines,). There are opportunities for countries to co-develop plans to strengthen regional workforce quality, for example, to develop partnerships between education institutions and manufacturers, or to encourage regional talent mobility to provide manufacturers access to wider talent pools.

Building out the interconnection of the ASEAN Power Grid could also support the deployment of renewable generation in the region. Government-to-governmnent partnerships can facilitate higher build out of solar PV capacity by connecting Southeast Asian countries with lower renewables potential to those with abundant supply. For example, Singapore has signed agreements with four neighboring countries (Cambodia, Indonesia, the Lao PDR, and Malaysia)[50] to support its target to import up to 4 GW of low-carbon electricity from the region by 2035. According to the IEA, regional integration and multilateral power trading can also increase power system flexibility by expanding balancing areas and enabling efficient resource sharing.[51] This will be a critical enabler of renewables deployment, especially as renewables share increases.

There is also potential for harmonization of technical standards in the region, particularly for the electric two-wheeler industry. The development of region-specific technical standards for vehicles and charging and swapping stations would make it easier for OEMs to develop products that could address needs in multiple countries.

[50] *ADB. 2023.* Asian Economic Integration Report 2023: Trade, Investment, and Climate Change in Asia and the Pacific; *and ADB 2023.* ASEAN and Global Value Chains: Locking in Resilience and Sustainability.

[51] *Lao PDR and Malaysia: 100 MW electricity import pilots; Indonesia: memorandum of understanding (MOU) on renewable energy cooperation, including investments in the development of renewable energy manufacturing industries in Indonesia and cross-border electricity trading projects between Indonesia and Singapore; Cambodia: MOU on energy cooperation, including conditional approval to import 1 GW of renewable energy*

[52] *IEA. 2022.* Southeast Asia Energy Outlook.

Actions to realize the region's full potential in renewable energy manufacturing are not for governments and ASEAN alone. Concerned efforts are required across policy, financing, investment, and technical spheres—engaging public institutions, industry, academia, philantrophic, and multilateral actors working in collaboration. Such an "ecosystem approach" might usefully target a few areas of cross-cutting priority:

- convening and attracting global players for investment and collaborations with local players, and supporting government-to-government partnerships;
- support to build a pipeline of sufficiently skilled workforce by leveraging the capacity of government, universities, research institutions, global technical experts and industry players;
- support to improve ESG standards, including developing standardized framework for ESG reporting;
- galvanizing private sector investments and financial sector assistance to support scale up of manufacturing; and
- policy advisory targeted at improving the ease of doing business for manufacturers and relevant industry players

Exhibit 18
Scale-up of renewable energy manufacturing in Southeast Asia

EXAMPLE NOT EXHAUSTIVE Policy Financing Business support Coordination

ASEAN = Association of Southeast Asian Nations, **ESG** = environment, social and governance, **NGO** = non-governmental organization

Sources: Elaborated from ASEAN Center for Energy and McKinsey analysis

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ADB is committed to achieving a prosperous, inclusive, resilient, and sustainable Asia and the Pacific, while sustaining its efforts to eradicate extreme poverty. Established in 1966, it is owned by 68 members—49 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

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