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# ASEAN-IGF Minerals Cooperation:

Scoping study on critical minerals supply  
chains in ASEAN



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### **ASEAN-IGF Minerals Cooperation: Scoping study on critical minerals supply chains in ASEAN**

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## Preface

In support of the energy transition and regional growth, the Association of Southeast Asian Nations (ASEAN) is taking steps to boost its minerals cooperation to develop and promote the region as a sustainable mineral-investment destination. As part of this effort, ASEAN has collaborated with the Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF) to undertake exploratory research to understand the implications of the energy transition for the ASEAN mineral sector, with a particular focus on the minerals and metals that are critical for the transition.

The *Scoping Study on Critical Minerals Supply Chains in ASEAN* aims to identify enabling policy areas for the development of selected critical minerals value chains to support ASEAN countries in contributing to the transition to a low-carbon future. The analysis would directly apply to areas relating to the ASEAN Minerals Cooperation Action Plan's Programme Areas on Trade and Investment in Minerals (TIM) and Sustainable Minerals Development (SMD). The study also provides policy recommendations for ASEAN policy-makers to consider, including suggestions to further build capacity.

Among the number of important and timely topics, this scoping study covers an overview of key issues likely to drive the digital transformation and the energy transition. It also describes the minerals and metals critical to achieving these objectives and current initiatives led by selected member countries to develop their critical minerals supply chains. A review of existing research and studies conducted in selected ASEAN Member States (AMS) on the scope and development of strategic and critical minerals supply chains in the region was undertaken, and the resulting analyses provided a set of potential options for ASEAN policy-makers to consider in their discussions and design of regional supply chain initiatives.

The preparation and final conception of this scoping study involved consultations with AMS and the ASEAN Secretariat through a series of forums, meetings, and intersessional circulations. As a follow-up to this scoping study, in-depth research covering a selection of priority areas will be carried out, and the plan is for the initial findings to be presented at the forthcoming ASEAN meetings on minerals in November 2023.

**The views and recommendations presented in this report do not necessarily represent those of the relevant agencies in the AMS, ASEAN, the ASEAN Secretariat, and the IGF, and do not impose any binding obligations on them.**

Ultimately, this study is the product of its authors. They alone are responsible for any errors or omissions, as well as for the findings and recommendations.



## Executive Summary

The ongoing energy transition requires the increasingly rapid deployment of renewable technologies, including solar panels, wind turbines, electric batteries, and electric vehicles. It will also require significant enhancement to today's electricity grids. In parallel, the digital transformation is fundamentally changing the global socio-economic structure, first, through the rapid scale-up of consumer electronics and digitalization of daily activities and second, through manufacturing shifts in Industry 4.0 methods, including industrial robotics and additive manufacturing. These transformations are underpinned by fundamental expansions in data warehousing and connectivity. However, the increases in demand for minerals and metals essential to the production of these technologies will require an unprecedented ramp-up in the extraction, refining, and recycling of "critical minerals," a term increasingly used (but not universally adopted) for the metals needed for the manufacturing of green, digital, and advanced technologies.

The twin energy and digital revolutions present significant opportunities for the Association of Southeast Asian Nations (ASEAN). ASEAN Member States are major producers and refiners of many of the metals and minerals needed to enable these transitions, but they are also important manufacturing hubs with high potential to further integrate into advanced global supply chains while adopting these technologies domestically and regionally.

The sophistication of economic structures and stages of development vary substantially among ASEAN members, featuring globally significant mining countries; manufacturers of electronics and automotive, and renewable technologies; and a world-leading financial and innovation hub. ASEAN countries have experienced a meteoric economic rise in the last few decades, driven by their integration into global manufacturing value chains. These advancements have helped spur socio-economic development, bringing large segments of their populations out of poverty. The parallel revolutions are now providing a significant two-fold opportunity: first, in the expansion of mining production, and second, in the integration and upgrading of critical mineral manufacturing value chains, leading to the further integration of ASEAN economies.

This scoping study presents the state of ASEAN critical minerals value chains. First, the paper presents an overview of how critical or strategic minerals can be defined and classified, including for ASEAN Member States. The twin energy and digital trends are examined within the context of ASEAN countries, showing both the necessity for them to rapidly adapt their energy systems and the opportunities emerging for their economies. The paper then assesses the wider critical mineral value chains, assessing exploration activities, production, refining, manufacturing, and recycling segments and providing an overview of both national and regional initiatives and approaches to critical mineral value chain and upgrading.

Across ASEAN, despite falling exploration spending, the primary production of critical minerals has increased remarkably in the last decade, and a few countries have rocketed up the value chain, moving from miners to manufacturers of batteries and electric vehicles. This paper assesses the policy, business, market, and trade landscape in the region, finding significant levels of already-existing economic integration but also strong prospects for the ASEAN region to maintain its role as one of the "factories of the world" while moving into more high-value-added products. Various countries, such as Thailand and Indonesia, aspire to become major automotive producers, while Singapore is at the forefront of research, development, innovation, and global finance.



Environmental, social, and governance aspects are also reviewed, demonstrating the importance of the interaction between ASEAN extractive and manufacturing industries and the wider socio-enviro-economic landscapes necessary to meet global standards and foster opportunities for development. Moreover, the scoping study briefly assesses both geopolitical and broader trends in the global mining and clean manufacturing segments, which impact ASEAN countries' ability to develop their own critical mineral value chains.

The scoping study then provides examples of how to conceptualize possible pathways forward and the rationale for selecting the key priority mineral value chains. To illustrate this, three increasingly ambitious value chains are demonstrated, including concrete steps and policy recommendations, which could significantly boost ASEAN economies through further regional integration. The three examples of an integrated electric battery and vehicle value chain, recycling, and advanced industries are presented, including the necessary policy dimensions required. The study concludes by providing recommendations and pathways forward for ASEAN Member States, ASEAN as a region, and the ASEAN Secretariat.



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## List of Abbreviations and Acronyms

<b>AMS</b>	ASEAN Member States
<b>AMCAP</b>	ASEAN Minerals Cooperation Action Plan
<b>ASEC</b>	ASEAN Secretariat
<b>ASEAN</b>	Association of Southeast Asian Nations
<b>ASEAN Plus Three</b>	ASEAN countries plus China, Japan, and South Korea
<b>ASM</b>	artisanal and small-scale mining
<b>ESG</b>	environmental, social, and governance
<b>EU</b>	European Union
<b>EV</b>	electric vehicle
<b>FDI</b>	foreign direct investment
<b>HPAL</b>	high-pressure acid leaching
<b>ICE</b>	internal combustion engine
<b>ICT</b>	information and communications technology
<b>IEA</b>	International Energy Agency
<b>IGF</b>	Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development
<b>Lao PDR</b>	Lao People's Democratic Republic
<b>li-ion</b>	lithium-ion
<b>NMC</b>	nickel manganese cobalt
<b>OEM</b>	original equipment manufacturer
<b>PV</b>	photovoltaic
<b>R&amp;D</b>	research and development



## 1.0 Introduction

The rapid adoption and expansion of digital technologies and a transformative structural shift to greener, more renewable energy systems will require extracting and processing an unprecedented quantity of raw metals and minerals (International Energy Agency [IEA], 2021). For the high-growth countries of the Association of Southeast Asian Nations (ASEAN) metal and mineral production, refining, and downstream manufacturing value chains provide significant economic opportunities considering the region's economic potential and growing domestic demand driven by a rapidly increasing population and rapid rates of growth, construction, and overall economic development.

ASEAN's 10 Member States (AMS)<sup>1</sup> differ in terms of levels of development, industrialization, and economic structures. The region features producers and refiners of several globally significant minerals and metals, strategic manufacturing hubs, and financial centres with strong pre-existing links and the potential for stronger regional integration and cooperation.

These features make it possible for AMS to position themselves and the region at the forefront of the dual energy and digital transitions, not just as suppliers of raw or semi-processed materials but as advanced manufacturing hubs capable of leveraging downstream products for both domestic utilization and global exports. While the region is well positioned to take advantage of and expand its mineral and industrial value chains, ASEAN's success depends on ensuring a smooth, sustainable, and well-governed development of these sectors to ensure ASEAN countries do not simply become sacrifice zones for the energy and digital transitions happening elsewhere.

As part of the Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development's cooperation with ASEAN on Phase 2 of the ASEAN Minerals Cooperation Action Plan (AMCAP), this scoping study surveys the state of play of the region's critical mineral sector, as well as downstream industries closely linked to the digital and energy transitions. The report provides an overview of critical mineral definitions before presenting the key forces and trends that will impact the ASEAN region in the coming years and decades. The various stages of the region's critical mineral value chains are then presented, including the latest developments across key metals and AMS. The report then explores key considerations impacting ASEAN's critical mineral value chains, including regulations,

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<sup>1</sup> The 10 AMS are Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (PDR), Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam.



market conditions, governance, geopolitics, and global mineral and economic trends. The report provides three possible value chain options and associated policy recommendations as examples or case studies for further discussion with AMS. Finally, the study concludes by providing policy recommendations and ways of conceptualizing the critical mineral value chain development process.



## 2.0 Key Considerations for Defining Critical and Strategic Minerals in the ASEAN Context

In recent years, an increasing number of minerals and metals have been considered “critical” or “strategic” by many countries. However, the definitions of **what** critical and/or strategic minerals are, **which** minerals are critical or strategic, and what criticality means vary largely between different countries, regions, and levels of analysis.

### 2.1 Overview of Critical Minerals and Definitions

To date, there is no universally or globally adopted definition or list of critical minerals, as this depends on various factors, including, importantly, where countries or regions are within the given supply chain at a given point in time.<sup>2</sup> To identify which minerals and metals could be defined as critical or strategic, there are generally two main considerations.

First, minerals and metals may be considered “critical” when they serve as **significant direct inputs** to important actual or planned industrial activities but are not available domestically. Countries are therefore subject to **high import dependency**, especially if they do not produce that mineral or metal. A key element in this definition is the **vulnerability** of the supply chain due to risks associated with supply. This definition is largely adopted by European countries, the United States, and Japan, for instance. The main strategy, in this case, is ensuring the **security** of supply and addressing **risks of disruption**.

Advanced industrial manufacturing has traditionally required significant amounts of mineral inputs, and with the global trend toward greener industrialization and digitalization, mineral-intensive output demand will grow significantly in the coming decades. Given the complexity of advanced industrial production and the fragmentation of global production, many advanced manufacturers rely on mineral imports to maintain their industries. Such reliance becomes more important with episodes of mineral-producing countries imposing export bans or embargoes (e.g., China’s rare-earth element embargo in 2010). Hence, new

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<sup>2</sup> The importance or criticality of some minerals may change over time as technologies change or as substitutes are found.



industrial policies have proliferated, such as national critical mineral strategies aimed at ensuring the stability and diversification of mineral supply via a variety of methods, including enhanced cooperation and trade diplomacy, innovation and substitution, recycling, domestic nearshoring of mining industries, and other means.<sup>3</sup> Whether due to a lack of domestic natural resource reserves (e.g., Japan) or due to the offshoring of historically strong mining sectors (e.g., the European Union [EU], the United States, and the United Kingdom), many governments now recognize maintaining stable mineral value chains as a key strategic imperative (European Commission, 2023; Government of the United Kingdom, 2022; Ministry of Economy, Trade and Industry, 2020; U.S. Geological Survey, 2022).<sup>4</sup> For industrialized producer countries, criticality combines economic and security imperatives. It primarily means securing supplies for domestic manufacturing industries to ensure economic competitiveness but is also a national security imperative due to the mineral intensity of advanced defence technologies.

Second, minerals and metals may be considered critical when they are present in **abundance** and the country has a **strategic interest** in using its **dominant position** to gain a **competitive advantage** or develop the industrial capacity to participate in global supply chains. Countries that are key producers of those minerals also utilize the term “strategic mineral” or “strategic asset.” Their objective is to assert their dominant position as key suppliers of minerals in global supply chains. The main strategy here is **value capture**.

For countries in this category, the criticality of certain minerals lies in the opportunity to increase production, spur domestic economic development, and possibly attract investment into more advanced domestic value chains. Several countries have published their own critical mineral strategies. Those countries aim to capitalize on strengthened demand and encourage further investment in the mining sector, as well as in processing, refining, and downstream industries. Notably, Australian and Canadian critical mineral strategies emphasize the strength of their sectors and focus on portraying themselves as stable and trustworthy partners to international consumers, an objective they pursue through extensive networks of international partnerships and initiatives (Department of Industry, Science and Resources, 2022; Government of Canada, 2022a).

However, the forecasted increase in demand for critical minerals also presents a sizable opportunity for formerly mostly extractive economies across Latin America, Africa, and Asia, with numerous countries and regional blocks announcing intentions or programs to encourage the expansion of mining production. While, historically, mining booms in those regions have not necessarily led to significant improvements in socio-economic development, many countries now look to capitalize on their domestic reserves to encourage further investment not only in the mining sector but also in downstream value-added industries.

Although the lens through which criticality is defined varies widely among countries and regions, there are significant overlaps in the criteria used to identify a given mineral as “critical.” Table 1 summarizes key criteria and related issues that are relevant when defining minerals and metals as strategic or critical.

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<sup>3</sup> Lists of critical minerals often contain between 30 and 50 minerals, reflecting the large number of metals needed for advanced manufacturing.

<sup>4</sup> Further security and geopolitical considerations related to the wider mineral and technologies value chains are discussed in Section 6.3.



**TABLE 1.** Defining critical or strategic minerals

<b>Criteria retained to define critical or strategic minerals</b>	<b>KEY ISSUES</b>
Role in industry	<ul style="list-style-type: none"> <li>• Relevance for specific sectors considered strategic for economic development or for national security</li> <li>• Critical for current and future industrial activities (direct inputs to industries)</li> <li>• Important across different supply chain stages</li> <li>• Crucial for some types of technologies, high-tech industrial production, and emerging innovation</li> <li>• Key for environmental performance</li> </ul>
Primary production capacity	<ul style="list-style-type: none"> <li>• Existence of domestic endowment or share of domestic primary production in global production</li> <li>• Level of resource dependence on third countries</li> <li>• Degree of concentration of production in few countries</li> <li>• Degree of corporate concentration of mineral production</li> <li>• Scarcity of resources (including due to depletion)</li> </ul>
Supply chain dependence	<ul style="list-style-type: none"> <li>• Degree of competition globally</li> <li>• Position in supply chain</li> <li>• Degree of supply chain concentration</li> <li>• Problematic supply due to limited primary sources (i.e., production only as by-products)</li> </ul>
Substitutability	<ul style="list-style-type: none"> <li>• Uniqueness of chemical properties</li> <li>• Extent to which minerals are replaceable in technologies</li> <li>• Availability of secondary sources (e.g., from recycling)</li> <li>• Recovery limitations (e.g., from mine wastes and tailing)</li> </ul>

Source: Authors' own calculations, based on Blengini et al., 2017; IEA, 2021; U.S. Geological Survey, 2022; U.S National Research Council, 2008.

More broadly, changes at the global level (e.g., climate change, the energy transition, the digital transformation, etc.) have significant implications for the demand and supply of minerals and metals—and, therefore, for their strategic importance.

These implications are particularly relevant in the context of the energy transition required to limit global warming. Due to the growing acknowledgement and acceptance of the mineral intensity of the energy transition, critical minerals are most often defined as minerals that are used to create “essential components in many of today’s rapidly growing clean energy technologies” (IEA, 2021). Intensified production of solar panels, wind turbines, hydrogen electrolyzers, electric vehicles (EVs), enhanced electricity grids, and energy systems will require a significant ramp-up of mining production (at existing sites and through greenfield projects) and a shift to recycling and circular economy approaches (Benchmark Source, 2022b; Yeh, 2022).



An important element to consider in defining criticality is to examine the overlap between the technologies that have industrial potential in the ASEAN region, against the minerals and metals that are in high demand. Table 2 provides a brief overview of selected technologies relevant to the energy transition and the digital and the fourth industrial revolution. It maps these technologies against key minerals and metals in high demand that have been identified as “critical” by key industrial countries (e.g., the United States and European countries) and by key producing countries (e.g., Canada and Australia) (see Appendix A for a complete list of critical minerals and metals of the EU, the United States, the United Kingdom, Canada, and Australia). The list is not exhaustive but shows that ASEAN countries have current or future production of most key minerals and metals needed for the digital and energy transitions.



**TABLE 2.** Mapping energy, digital, and defence technologies against selected ASEAN-produced minerals (2020)

Mineral	Batteries	Fuel cells	Wind turbines	Traction motors	Photovoltaic	Robotics	Drones	3D printing	Information and communications technology	Defence	Trend (2015–2020)
Nickel	●	●			●	●	●	●		●	↓↓↓
Tin	●				●	●	●		●	●	↑↑
Bismuth						●	●		●		↑↑↑
Tungsten						●	●	●		●	↓↓↓
Rare-earth elements		●	●	●		●	●		●	●	↓↓↓
Zircon		●				●	●	●	●	●	↓↓↓
Antimony						●	●				↓↓↓
Copper	●	●	●	●	●	●	●	●	●	●	↑
Manganese	●	●	●	●		●	●	●	●	●	↓↓↓
Cobalt	●	●	●	●	●	●	●	●	●	●	↑
Gold	●	●				●	●		●	●	↑↑
Aluminum	●	●	●	●	●	●	●	●	●	●	↓↓↓
Titanium	●	●				●	●	●	●	●	↑
Silver	●	●			●	●	●		●	●	↓↓
Silicon	●	●		●	●	●	●	●	●		↓
Lead	●	●	●		●	●	●		●	●	↓↓↓
Iron	●	●	●	●	●	●	●	●	●	●	↓↓↓
Graphite	●	●				●	●		●		↓↓↓
Zinc					●	●	●			●	↑↑
Tantalum						●	●				↑↑↑
Chromium		●	●			●	●	●	●	●	↓↓↓
Magnesite	●	●				●	●	●	●	●	↑↑↑

Icons indicate ASEAN's share of global production. ● : >10%, ● : 5%–10%, ● : 1.5%–5%, ● : <1.5%.

Trends indicate the magnitude of change in the share of global production.

↓↓↓\↑↑↑: large change, ↓↓\↑↑: medium change, ↓\↑: low change.

Several of the listed technologies require additional minerals not listed in the table due to spatial constraints. Notably, these are lithium and platinum group metals.

Sources: Bobba & Schatz, 2020 ; Reichl et al., 2022.



## 2.2 ASEAN and Critical Minerals

There is currently no ASEAN-wide adopted definition of critical or strategic minerals. Definitions of what minerals are critical or strategic at the ASEAN level are still being shaped, given the widely heterogeneous nature of AMS, including the varying levels of development in the mining, refining, industrial, and broader economic sectors. ASEAN has a two-fold role as an important metal and mineral producer as well as manufacturer and increasingly larger consumer and adopter of advanced industrial goods needed for the energy and digital transformations. Concurrently, ASEAN's globally strategic location, its significance across a variety of mineral value chains, its rapid uptake of transformational technologies, and its susceptibility to climate change all make it crucial to define what critical minerals mean to AMS and the region.

In each country, the maturity of the level of understanding of—and engagement with—the topic and definition of critical minerals and downstream value chains varies. The economic structures and compositions of Cambodia, Lao PDR, Myanmar, and Viet Nam (known collectively as the CLMV countries), for example, vary widely.

**Cambodia's** mining vision is guided by the National Policy on Mineral Resources 2018–2028, which highlights some of the country's mineral potential and the potential for further exploration work. In the short to mid-term, and as a minor producer of minerals, classifications of what critical minerals mean can focus on both expected production capacity expansion and the utilization of minerals within Cambodia's growing manufacturing segments.

For **Lao PDR**, where minerals and metals have traditionally accounted for large shares of outputs and exports, definitions of which minerals can be classified as critical should focus on the producer aspect but will also require more geological exploration work and scoping of the mineral requirements for the economy. The National Green Growth Strategy of the Lao PDR till 2030 focuses on the mining and mineral sectors as opportunities for further economic and social development but must also incorporate robust definitions.

In **Myanmar**, an increasingly significant producer of several critical minerals, the exploration and production dimensions must be assessed to discern how further export potential and value capture can be realized and whether the extractive and refining sector can be expanded in a socially and environmentally conscious way.

**Viet Nam** potentially holds significant reserves and already produces a number of minerals considered critical by other countries or regional groups. Definitions and characterizations of criticality should assess the nature of the sector and potential for further exploration and extractive activity. Viet Nam's Mineral Resources Strategy to 2020, with a Vision toward 2030 emphasizes the potential of the sector and domestic value addition, but definitions of criticality will also need to account for the rapid pace of economic growth and increasing need for material inputs for the burgeoning manufacturing sector. Assessments therefore must be made of current and projected domestic industrial consumption patterns to ensure supply is adequately secured, including for metals and minerals produced outside of the ASEAN region.

The six more established AMS also vary in terms of their extractive and manufacturing sectors. Brunei and Singapore possess no notable mineral reserves, while Indonesia and the Philippines are globally significant mineral producers. Concurrently, however, Malaysia, Thailand, and Singapore are already globally established manufacturers—including of highly



advanced products—while Indonesia and the Philippines are also rapidly entering downstream manufacturing segments. As such, all these AMS must consider the wider framing and classifications of criticality and must adopt robust definitions to further the competitiveness of their mining and manufacturing sectors through either/or value capture and by enabling a steady supply of minerals.

In the case of **Brunei**, a major fossil fuel producer with no significant mineral deposits, defining which minerals are strategic or critical can hinge not only on forthcoming industrial plans but also on the potential of localizing value addition and/or recycling capabilities within the country. This will require high levels of coordination and planning with other AMS.

As ASEAN's most important mining and processing member, **Indonesia**, although traditionally acting as a producer, has recently pursued robust policies aimed at adding value to its mineral production, including through vertical integration into advanced value chains (battery and EVs) (Huber, 2022). Indonesia's definitions of what constitutes critical or strategic minerals may therefore take a broader, longer-term view of increasing exploration, production, and refining capacities, with a view to positioning itself even more as a key global supplier but also as an increasingly important consumer of critical minerals, some of which (e.g., lithium) are not commercially exploited in the country or the ASEAN region. An assessment of the evolution of domestic manufacturing capabilities and the ability to avoid supply risks or disruptions is therefore crucial.

**Malaysia** acts as both a significant producer and consumer of a variety of metals and minerals, requiring careful analysis of several classifications of criticality. Definitions can focus on both geological and production potential and planning, as well as expected increases in the sector. Malaysia has also unveiled its National Mineral Industry Transformation Plan 2021–2030, which includes pillars on downstream value addition and technology and innovation, with a view to significantly increasing the sector's economic contribution (Malaysian Investment Development Authority, 2021). Considering this, definitions of criticality should also focus on taking stock of industrial plans and requirements and the resulting supply and dependency risks stemming from these.

**The Philippines** has a globally significant extractive sector, with planned expansions across both the extractive and refining sectors. Concurrently, there are plans for domestic value additions and the expansion of manufacturing capabilities across several sectors. Classifying minerals as critical or strategic might therefore require a dual approach focusing on capturing value from the elevated demand for minerals and ensuring limiting exposure to supply risks to enable domestic industries to operate.

While **Singapore** has no domestic mineral reserves, the metals and minerals sector plays an important role in the economy. Additionally, given the processing, recycling, and manufacturing sectors in the country, classifications and definitions should consider supply and dependency risks, as well as evolving global trends and the longer-term technological landscape, given strong in-country research and development (R&D) capabilities. Further alignment with other AMS is also crucial to ensure a steady supply and tap into regional synergies.

**Thailand** has not traditionally been a major metallic mineral producer but is rapidly scaling up its industrial and manufacturing capabilities with a globally significant automotive sector (among others). Criticality and definitions of key required minerals should focus not only on



the possible expansion of mineral exploration and the extractive sector but also, crucially, on ensuring supply for its growing industries and avoiding dependency risks.

While not every AMS may choose to have a comprehensive critical/strategic mineral strategy, they should ensure that the final selection of which minerals are considered critical or strategic closely matches the nature of their extractive sector, global demand, domestic industrial needs, and forecasted value. So far, at the regional level, ASEAN has formalized dialogue and regional development initiatives through the Minerals Cooperation platform, with “the development of the minerals sector in ASEAN [being] key to the socio-economic development of the region” (ASEAN, n.d.-a). Since 2005, the Ministerial Meeting on Minerals and the 5-year AMCAP have been coordinated, but they have not yet seen the level of strategic integration present in other geographies. The difference in the AMS’ level of engagement with critical minerals, as well as the varying nature of their mining and industrial sectors, means that an ASEAN-wide regional definition must take into consideration all these characteristics to ensure value chain and strategic policies can have diffuse benefits for all members.<sup>5,6</sup> Specifically, this means including minerals that i) provide value to members’ economies, either as sources of export revenue or ii) are used as inputs for downstream segments (including processing, manufacturing and recycling), also taking into consideration also regional abundance and availability (including from secondary and advanced recovery) as well as import requirements.

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<sup>5</sup> It is worth noting that, for example, copper (which is sometimes not considered “critical”) is still one of ASEAN’s major sources of export revenue, despite the region’s globally minor share of production. As AMS (and countries globally) contemplate exploration and further investment, it is important to consider that the demand and total value of many “traditional” minerals will remain substantially larger than most critical minerals in the future.

<sup>6</sup> Compared to, for example, nickel and tin, where several AMS dominate global production shares.



## 3.0 Trends Shaping the ASEAN Region

ASEAN members and the region have collectively experienced rapid economic development and growth, with rising rates of investment, manufacturing, export, and integration into global value chains. Poverty rates have been brought down from over 47% in 1990 to 15% in 2015, and the region has made notable progress on a number of Sustainable Development Goals, with key documents such as the ASEAN Community Vision 2025 charting the way forward. While the region experienced disruptive socio-economic shocks due to the COVID-19 pandemic and the general global economic slowdown, longer-term projections still assume the region will grow at a real growth rate of 4.9% between 2020 and 2030 and 3.2% between 2030 and 2050 (IEA, 2022d).

Nonetheless, the economic trajectory that AMS will take is highly dependent on policies related to the two key global challenges of the coming decades: the energy transition and the digital transformation. Economic growth, progressive industrialization, and larger energy demand, coupled with rising incomes, greater consumer spending, and digitization, will all be significant factors in the future of ASEAN. The next two sections provide a brief overview of the key transformations and challenges facing the ASEAN region and links to mineral value chains.

### 3.1 The Energy Transition

Tackling climate change and reducing greenhouse gas emissions is the most important challenge facing humanity in the coming decades. Ensuring a rapid decrease in fossil fuel consumption and the decarbonization of economies is crucial at the global level, particularly in the ASEAN region, which is already experiencing climatic impacts. Four out of 10 AMS already rank within the 15 countries that are most at risk from climate change, with Myanmar and the Philippines the second and fourth most affected, respectively.<sup>7</sup> Given the high growth expectations, ASEAN as a region will experience a significant transformation of its energy sector in the coming decades. On a positive note, AMS responsible for half of the carbon dioxide emissions have pledged net-zero emissions by 2050, but a long road lies ahead in the region's energy transition.

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<sup>7</sup> Between 2000 and 2019, Myanmar ranked as the second most affected, the Philippines as fourth, Thailand as ninth, and Viet Nam as 13th (GermanWatch, 2020).



ASEAN established the ASEAN Centre for Energy under the Energy Cooperation platform to support the economic growth and environmental sustainability of its Member States. Regional integration and cooperation will be fundamental to ensuring energy security, speeding up multilateral power trading (through the ASEAN Power Grid), boosting innovation, and supporting the development of energy infrastructure. The ASEAN region is poised “to become a major market for clean energy technologies” (IEA, 2022c, p. 127). Given the regional significance of minerals fundamental to the energy transition, several AMS are already well positioned to take advantage of the increasing demand for key technologies. As a major producer of solar panels (Malaysia and Viet Nam) with the 11th-largest automotive production sector globally (Thailand), ongoing plans to build up vertically integrated battery and EV value chains (Indonesia), and a strong entrepreneurial and financing landscape (Singapore), ASEAN could become a globally significant supplier of clean energy technologies, both internationally and regionally.

The IEA’s *Southeast Asia Energy Outlook 2022* predicts that under a Sustainable Development Scenario, electricity demand will grow by 280% by 2050, 85% of which will be generated through renewable energy technologies, requiring the deployment of 1,100 GW of renewable energy sources within the next three decades (IEA, 2022c). Electrification should occur in key sectors, including transportation and industry, and might lead to the additional demand of 330 TWh, which would entail a rapid deployment of EVs, although adoption rates still differ from country to country. Energy efficiency measures, such as the introduction of heat pumps and rigorous standards for boilers and industrial equipment, can decrease electricity demand, and thus costs and emissions.

While several ASEAN countries have young fleets of coal-fired power plants and are installing additional coal-combusting capacity, the rapidly decreasing costs of renewables and the specificity of ASEAN Member State geography<sup>8</sup> will lead to large-scale deployments of both on- and off-grid solar and wind. These deployments will require over 45 GW of battery storage and have to integrate variable renewable sources into the electricity. Similarly, the International Renewable Energy Agency’s analysis of renewable potential by 2050 estimates that renewables could compose most of the electricity grid, saving ASEAN countries over USD 160 billion in energy costs and leading to cumulative savings of over USD 1.6 trillion in direct and indirect expenditures (International Renewable Energy Agency & ASEAN Centre for Energy, 2022).

These transitions will require concerted and targeted efforts to increase the total investment in the energy sector, as well as the broader enabling infrastructure, and reduce investment costs through improved regulatory and financing frameworks, encouraging larger private sector investment and introducing greater flexibility into traditional power purchase agreements. Incentives need to be geared toward renewable energy and infrastructure investments, grid upgrading and the smart electrification and progressive decarbonization of key end-use sectors. Renewable technologies, including EVs, are significantly more mineral-intensive than fossil fuel-powered infrastructure (IEA, 2022b), providing opportunities for ASEAN, where members produce significant amounts of the needed minerals.

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<sup>8</sup> “The modular and scalable nature of solar PV [photovoltaic] and wind should mean they are reliable and cost-effective solutions for Southeast Asia, which includes a unique mix of islands, peninsulas and pockets of densely populated areas, separated by uplands and mountainous areas” (IEA, 2022a, p. 96).



## 3.2 Digital Transformation and Revolution

Rapid technological progress and improvements in connectivity have unleashed the global digital transformation. The rapid adoption of digital technologies across all segments of society has revolutionized societal interaction, business, banking and finance, commerce, logistics and trade, industrial processes, health, education, and many other areas that form the bedrock of modern economies and societies. Importantly, the digital revolution can also provide an inclusive growth and development model for the region. ASEAN has already taken major steps to integrate populations and economies into the digital age. The organization has prioritized the digital economy and information and communications technology (ICT) as key pillars in several planning and policy documents, including the *ASEAN Economic Community Blueprint 2025*, *Masterplan on ASEAN Connectivity 2025*, *E-ASEAN Framework Agreement*, *ASEAN ICT (AIM) Masterplan 2020*, *ASEAN Digital Masterplan (ADM) 2025*, and the *Consolidated Strategy on the Fourth Industrial Revolution for ASEAN*, among others.<sup>9</sup> Partnerships also exist with China, India, and a variety of organizations, including, for example, the World Economic Forum (Lee & Adam, 2022).

Disruptive digital technologies have already had a sizable impact on ASEAN populations and economies. Throughout the COVID-19 pandemic, this transformation rapidly progressed as all facets of life and business around the world moved online. This was also the case in the ASEAN region, which added 40 million new Internet users in 2020 alone (Bishop, 2022). Research across the region found that connectivity facilitated economic recovery and made local economies more resilient (Lee & Adam, 2022). The region already features a high rate of Internet, cellular, and social media penetration, with popular cellular usage rates in Singapore, Malaysia, Thailand, and Indonesia surpassing 70%, and social media usage between 59% and 81% of the population, far above South Asia or other emerging markets (Chen, 2020). The Philippines (25%) and Malaysia (23%) registered the highest one-year e-commerce retail growth in the world, and e-commerce has been a key driver of economic growth (Zaman, 2022). The region has an active e-start-up scene that spread across key disruptive industries, including in the ride-sharing segments, where Grab (Singapore) and Gojek (Indonesia) both had valuations of over USD 10 billion in 2020 (Chalermpong et al., 2022). Similarly, e-finance and e-banking have expanded across the region, although further uptake is needed by larger segments of the population.

In Industry 4.0 robotics and manufacturing, ASEAN is expected to dramatically increase adoption. Singapore already hosts the second-largest number of industrial robots per 1,000 workers, with an advanced R&D sector contributing to cutting-edge research. Thailand's robotics adoption rate is 160% higher than its wage levels would predict, with further adoption expected at the fourth-highest rate globally (Laakso, 2020). Thailand's 2018 Eastern Economic Corridor project envisioned expenditures of over USD 6 billion (out of a total of USD 45 billion) to Industry 4.0 technology adoption, including robotics, with tax breaks for investors importing advanced manufacturing technology (Asian Robotics Review, n.d.). In additive manufacturing (3D printing), Thyssenkrupp envisions increasing adoption in the ASEAN region in the next decade, with potential for value addition and integration, especially in the manufacturing segments, adding up to USD 100 billion in unlocked value by 2030 (Singhal et al., 2019).

<sup>9</sup> See <https://orcasia.org/2022/05/digitization-in-asean-role-of-india-and-china/>



The ASEAN Digital Masterplan 2025 (ASEAN, 2021b) and the Consolidated Strategy on the Fourth Industrial Revolution for ASEAN envision rapid adoption, with significant effects on governments, businesses, and societies in the region (ASEAN Secretariat, 2021). ASEAN governments will play a fundamental role in creating enabling environments and incentivizing investments from private actors to drive “Industry 4.0 transformation through investing in digitalization of manufacturing, using advanced manufacturing solutions, building smart factories and establishing R&D facilities, technology hubs, and centres of excellence in the region” (Lee & Adam, 2022).

The continued digitalization of ASEAN and the further deployment of digital technologies will require extensive mineral inputs. Despite increasing connectivity, large parts of rural populations across ASEAN will require the roll-out of more broadband access and further integration (Ong Keng Yong, 2017). The ongoing transformation of industry and the adoption of the Internet of Things across society and Industry 4.0 technologies in manufacturing will require producing more remote sensors, using more robotics, expanding additive manufacturing (3D printing) capabilities, and further integrating the digital and physical worlds. Many of these technologies will also find applications in the future of the ASEAN mining sectors. In the energy sector, the rapid expansion of grid infrastructure, smart grids, and smart meters will require the significant deployment of advanced technologies. Finally, underpinning these installed capacities will be increasingly large data inflows, and the further digitalization of economies will necessitate the addition of mineral-intensive data warehousing capacity.



## 4.0 ASEAN Mineral Value Chains

Several AMS play significant roles at various stages of various mineral and associated manufacturing value chains. Metals and mining outputs also account for significant shares of ASEAN Member State export baskets, albeit with variations between producers and refiners. The metals and mining (and quarrying) sectors are also important contributors to the GDPs and labour markets of most AMS. Over the course of the last decade, mining and quarrying accounted for between 8% and 9% of Indonesia's GDP and 3% of Thailand's. The mining sector has not traditionally acted as a major job provider due to its larger capital than labour intensity (a trend that is due to continue with the automation of mining production), but it still accounted for 1%–2% of employment in Malaysia, Myanmar, and Indonesia (ILOSTAT Explorer, 2022).<sup>10</sup> Moreover, the broader metals and mining sector has had varying but often significant levels of local impact.

While no definition of critical or strategic minerals has yet been adopted at the ASEAN level, the following sections and the scoping report at large focus on metallic commodities with the greatest economic, strategic, and political significance for the ASEAN region, not only from the production or refining but also from an advanced manufacturing perspective.<sup>11</sup>

While Section 6 goes into more detail on the state of ASEAN Member State economies and potential, it is crucial to highlight the broad range of existing capacities and capabilities across mineral and manufacturing value chains present in ASEAN countries. The region features globally significant mining and refining countries but also crucial energy and digital technology manufacturers and world-leading centres of research, development, and financing.

Strong manufacturing capabilities for energy and digital technologies already exist in Singapore, Malaysia, Thailand, and Viet Nam. Thailand is the largest automotive producer in the region and a new entrant to the EV segment, and Viet Nam, Malaysia, and Indonesia are all developing their own EV industries. Malaysia and Viet Nam are both important electronics producers with significant upsides and capabilities, as well as globally significant major solar PV panel producers. Singapore is a global financial and R&D hub, with a strong presence from

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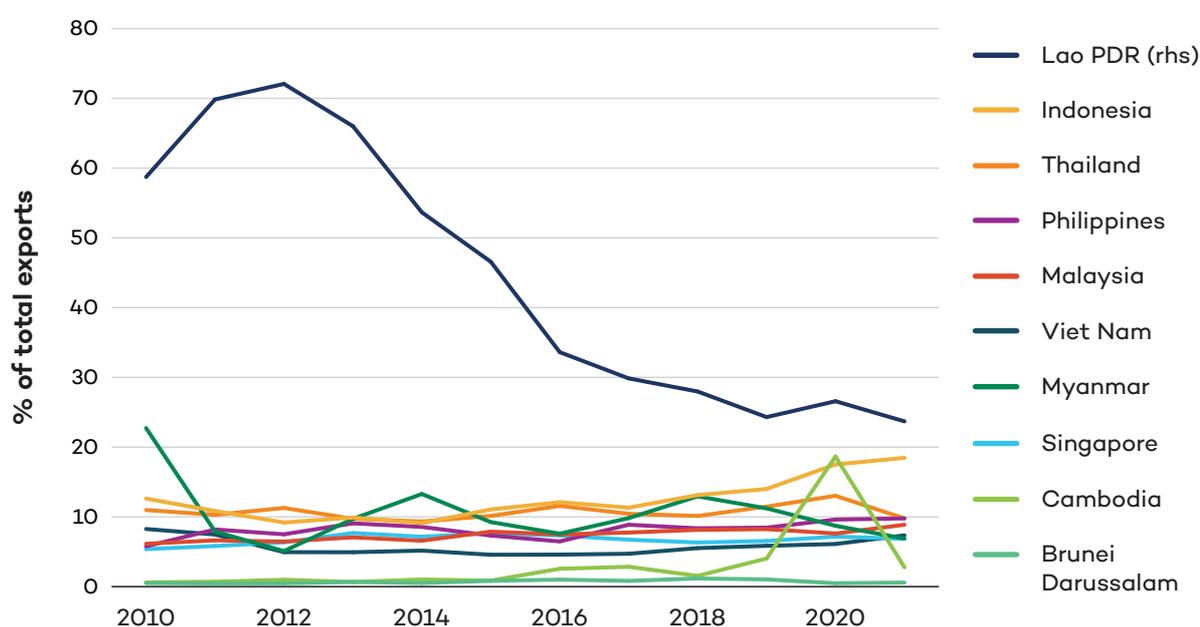
<sup>10</sup> Figures were taken from "Mining and quarrying; Electricity, gas and water supply"; Brunei had the highest contribution labour contribution at over 7%, but this stems mostly from the country's oil and gas sector.

<sup>11</sup> The production of over 40 commodities (including metallic, non-metallic, and energy) was recorded in 2020, with the main production data source from [www.world-mining-data.info](http://www.world-mining-data.info).



global leaders across key advanced industries, as well as a major shipping and logistics hub. The true synergies, however, stem from furthering regional integration with smaller ASEAN members. Cambodia and Lao PDR already have some manufacturing capabilities and are integrated into existing regional value chains, but they can also further participate through their services sectors. Brunei’s unique position and location, coupled with abundant energy resources, could be used not only for energy-intensive mineral processing or recycling but also for IT or telecommunications services, complementing other regional value chains. While country-specific coordination will be based on the selected value chains and specificities, it is key to bear in mind the existing capacities and further cooperation potential across mining and manufacturing value chains when choosing the direction of travel or crafting policies.

**FIGURE 1. ASEAN mining, metals, and metallurgy exports as a share of total exports<sup>12</sup>**



Source: Author’s own calculations based on ASEAN Stats Data Portal

The following sections cover the five main stages of critical mineral value chains in ASEAN: 1) reserves and exploration, 2) production, 3) processing and refining, 4) downstream production and manufacturing, and 5) secondary production and reuse. Data availability varies across countries and stages of the value chain, a fact consistent with the assessment of the AMCAP-III, which highlighted regional data availability (Programme Area IV Minerals Information and Database) as an area of focus.<sup>13</sup> While the scoping report does not cover all minerals and countries comprehensively, the following sections provide case studies and examples of AMS involvement and strategies across the various stages of the value chain.

<sup>12</sup> The exports of minerals statistics are composed of Section 5: Mineral Products (without HS27, which lists coal, oil, and gas products); Section 14: Pearls, precious stones, precious metals; and Section 15: Base metals and articles of base metals. Lao PDR is on the right-hand side due to very high values.

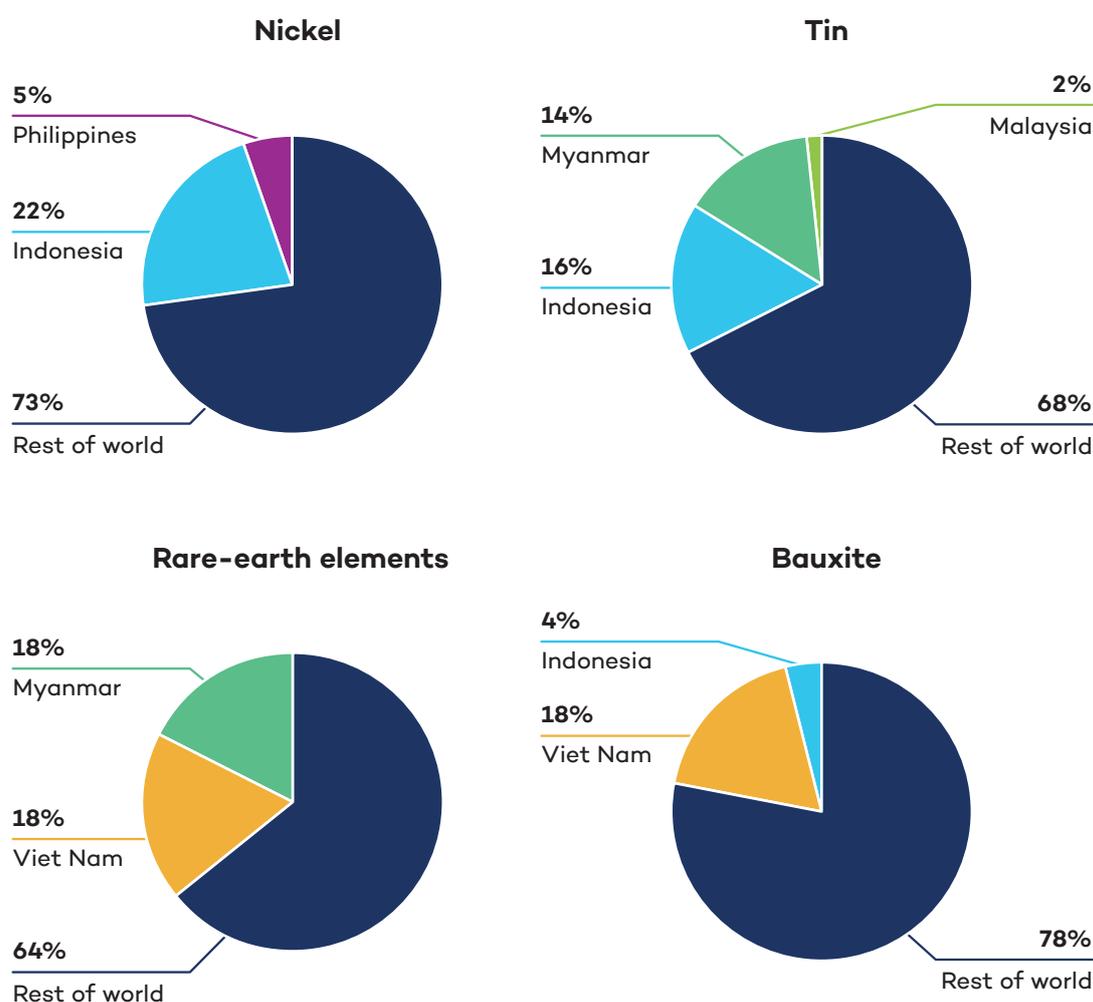
<sup>13</sup> See: <https://asean.org/book/asean-minerals-cooperation-action-plan-2016-2025-amcap-iii-phase-2-2021-2025/>



## 4.1 Reserves and Exploration

The ASEAN region boasts world-class reserves of several key minerals, including nickel, tin, rare-earth elements, bauxite, and others. Many of these reserves have not yet been fully commercially explored. For example, Viet Nam has some of the largest rare-earth element deposits globally, while reserves of cobalt have been identified (and are being slowly exploited) in Indonesia and the Philippines. However, good geological data on the region is scarce, which prohibits bolstering investment in the exploration and production stages of the mineral value chain (ASEAN Secretariat, 2022).

**FIGURE 2.** Reserves of selected minerals



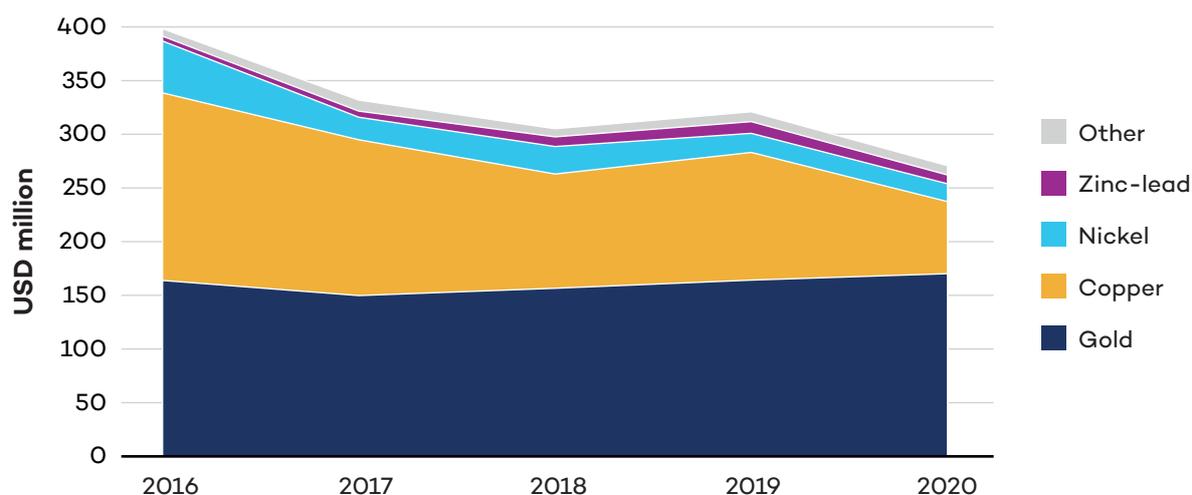
Source: U.S. Geological Survey, 2022, author's own calculations

Mineral exploration budgets in ASEAN have been declining in both absolute and globally relative terms in the past decade, especially in the grassroots/greenfield exploration stages, despite global growth in exploration expenditure. Major mining companies are underrepresented, and the region only attracted roughly USD 200 million in exploration expenditure out of a global total of USD 8.3 billion in 2020 (ASEAN Secretariat, 2022). While regional gold exploration budgets remained relatively constant between 2016 and 2020,



copper and nickel exploration spending has dropped markedly. While overall exploration budgets in the region dropped by over 32%, the declines for copper and nickel reached over 61% and 65%, respectively. The bulk of all exploration budgets (56%) was registered at existing mines, with grassroots and late-stage exploration only accounting for roughly 22% and 21% in 2020, demonstrating investor wariness in greenfield exploration (S&P Global Market Intelligence, 2021).<sup>14</sup> Indonesia, which represents a significant portion of total exploration budgets, witnessed a decline of roughly two thirds since the early 2010s, although it is unclear what shares are allocated to Class I and II nickel exploration.

**FIGURE 3.** East Asian exploration budgets for selected metals



Source: S&P Global Market Intelligence, 2021; author's own calculations.

The decline in exploration budgets in the ASEAN mineral sector has been attributed to aspects relating to regulation, governance, sustainability, and overall data availability. Additionally, recent trends, such as responsible sourcing, environmental and emissions aspects, waste management, and the growing importance of the social licence to operate, have affected the attractiveness of the sector to foreign investors.<sup>15</sup>

While all these factors have led to dwindling FDI and exploration budgets in the ASEAN mining sector in the past decade, the FDI trend slightly reversed in 2021, with almost 12% of intra-ASEAN FDI allocated to mining and quarrying, up from just 4% of FDI in 2020, driven by Thailand, Indonesia, and Viet Nam. While FDI from extra-ASEAN countries has not yet substantially materialized in the mining and quarrying sectors, policy changes in some countries are leading to the addition of new capacity.

Indonesia's government published an amendment to the Mining Law in 2020, which seeks to rapidly expand the mining sector by easing licensing procedures and scrapping exploration fees while focusing on domestic exploration and geological prospecting, as well as on downstream value addition (Deloitte, 2020). While exploration expenditure has been

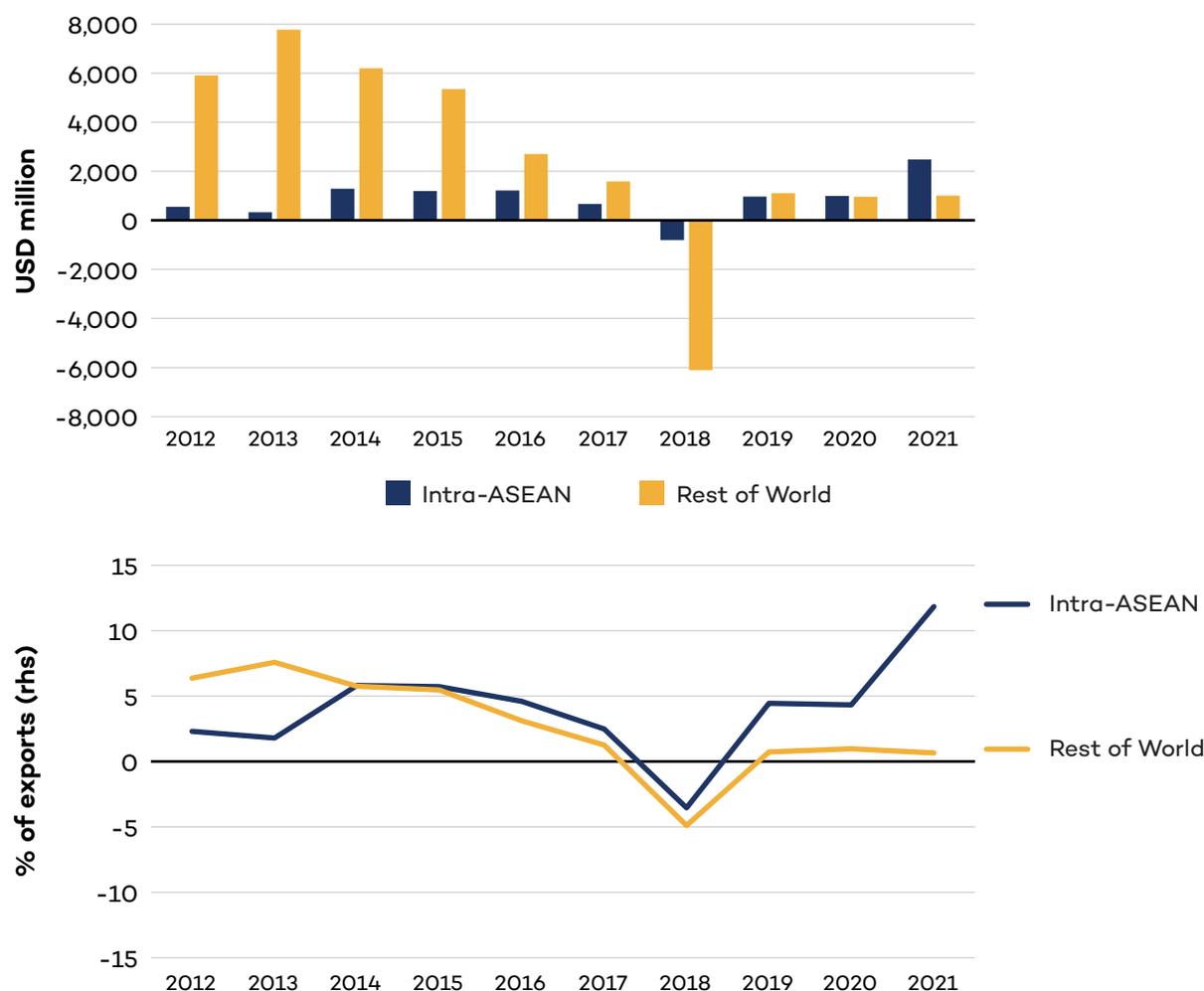
<sup>14</sup> S&P Global Market Intelligence, 2021.

<sup>15</sup> See, for example, Minerals Council of Australia, 2020; New Frontiers: ASEAN, Minerals Council of Australia, Canberra, Australia. <https://www.minerals.org.au/news/new-frontiers>; ASEAN Secretariat, 2022; Yunis & Aliakbari, 2022.



decreasing, some brownfield projects are being expanded, including the Grasberg copper mine. Malaysia’s National Mineral Industry Transformation Plan 2021–2030 has a pillar dedicated to mineral resources mapping and inventory, as well as to the improvement of data availability (Malaysian Investment Development Authority, 2021).

**FIGURE 4. Inward foreign direct investment (FDI): Mining and quarrying**



Source: Author’s own calculations based on ASEAN Stats Data Portal

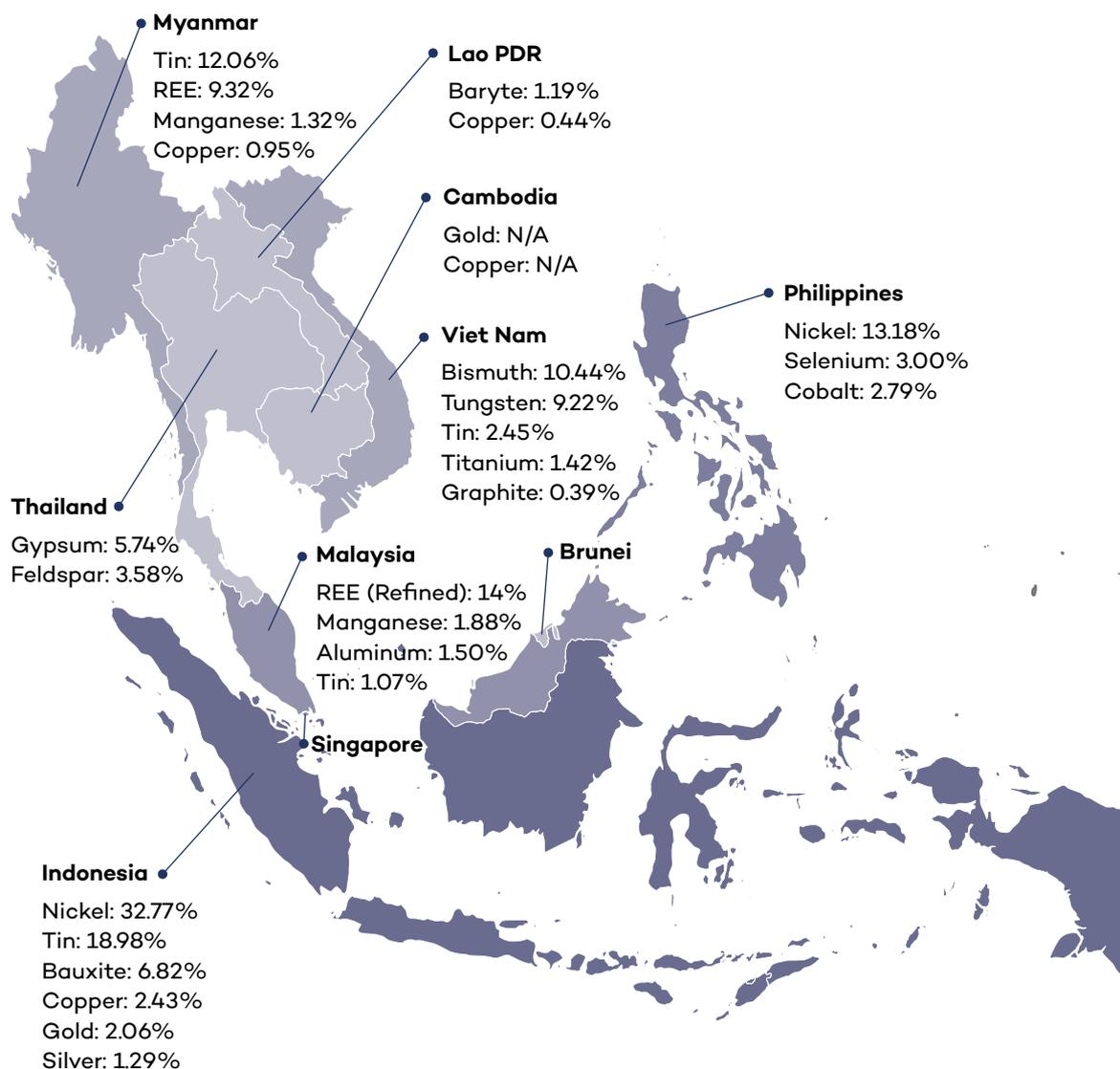
## 4.2 Metal and Mineral Production

ASEAN countries cumulatively produce almost 47% of global nickel and 35% of global tin, with high production shares for a range of other critical minerals, including bismuth, tungsten, rare earths, and bauxite. Absolute production values grew significantly for a variety of metals between 2015 and 2020, often outpacing global increases in production rates. Nickel, rare earths, and manganese production more than doubled,<sup>16</sup> with ASEAN progressively holding ever-larger shares of global production.

<sup>16</sup> Absolute production also more than doubled for antimony, kaolin, lead, and bentonite.



**FIGURE 5. Country-level production of selected minerals as % of global production (2020)**



Note: Brunei has the potential for supply chain expansion, and Singapore is a major importer.

Source: Author's calculations based on Reichl & Schatz, 2022.

**Indonesia** is the region's foremost mining country: the world's largest producer of nickel, the second largest of tin, and fifth largest of bauxite, as well as a litany of other metals and minerals.<sup>17</sup> Indonesia rapidly scaled up its production of key minerals between 2015 and 2020, with a production increase of 530% in nickel and an almost 5,400% increase in bauxite output.

The Indonesian government has begun prioritizing domestic value addition in some minerals, enacting export bans on unprocessed ores, most notably nickel. Indonesia has discussed export restrictions and export bans on several raw minerals in the past decade, introducing temporary partial bans on several minerals in the 2010s (including nickel in 2015 and 2016).

<sup>17</sup> Indonesia is also the largest producer of steam coal globally, a mineral that is not covered in this report.



In 2020, it again prohibited exports of raw nickel and debated taking a similar strategy with other metals, including tin, bauxite, and copper (Suroyo & Nangoy, 2021). The export ban and its impacts are further discussed in the following section. Nonetheless, capacity expansions are expected, with the IEA predicting that in a 2060 net-zero path scenario, the value of Indonesia's critical mineral production could reach USD 30 billion by 2030, or even USD 70 billion by 2050 if Indonesia's global market shares increase. Indonesia stands to profit substantially from the energy transition, both at the domestic and global levels (IEA, 2022a).

**TABLE 3.** Selected raw mineral production

Mineral	ASEAN as % of the world (2015)	ASEAN as % of the world (2020)	ASEAN absolute production trend (2015–2020)	Rest of world production trend (2015–2020)
Nickel	28.11%	46.84%	101.35% ↑	-10.64%
Tin	42.26%	34.84%	-29.67% ↓	-3.72%
Bismuth	25.67%	10.44%	-66.90% ↓	-1.94%
Tungsten	4.94%	9.37%	88.84% ↑	-5.22%
Rare earths	0.64%	9.35%	2550.31% ↑	-64.81%
Bauxite	10.13%	7.93%	0.86%	31.90%
Copper	4.82%	4.30%	-4.26% ↓	8.00%
Manganese	2.03%	3.95%	133.89% ↑	18.07%
Cobalt	3.08%	3.06%	-12.75% ↓	-12.17%
Gold	4.17%	2.9%	-28.35% ↓	4.33%
Aluminum	1.20%	1.83%	72.24% ↑	12.23%
Iron	0.34%	0.61%	87.15% ↑	4.40%

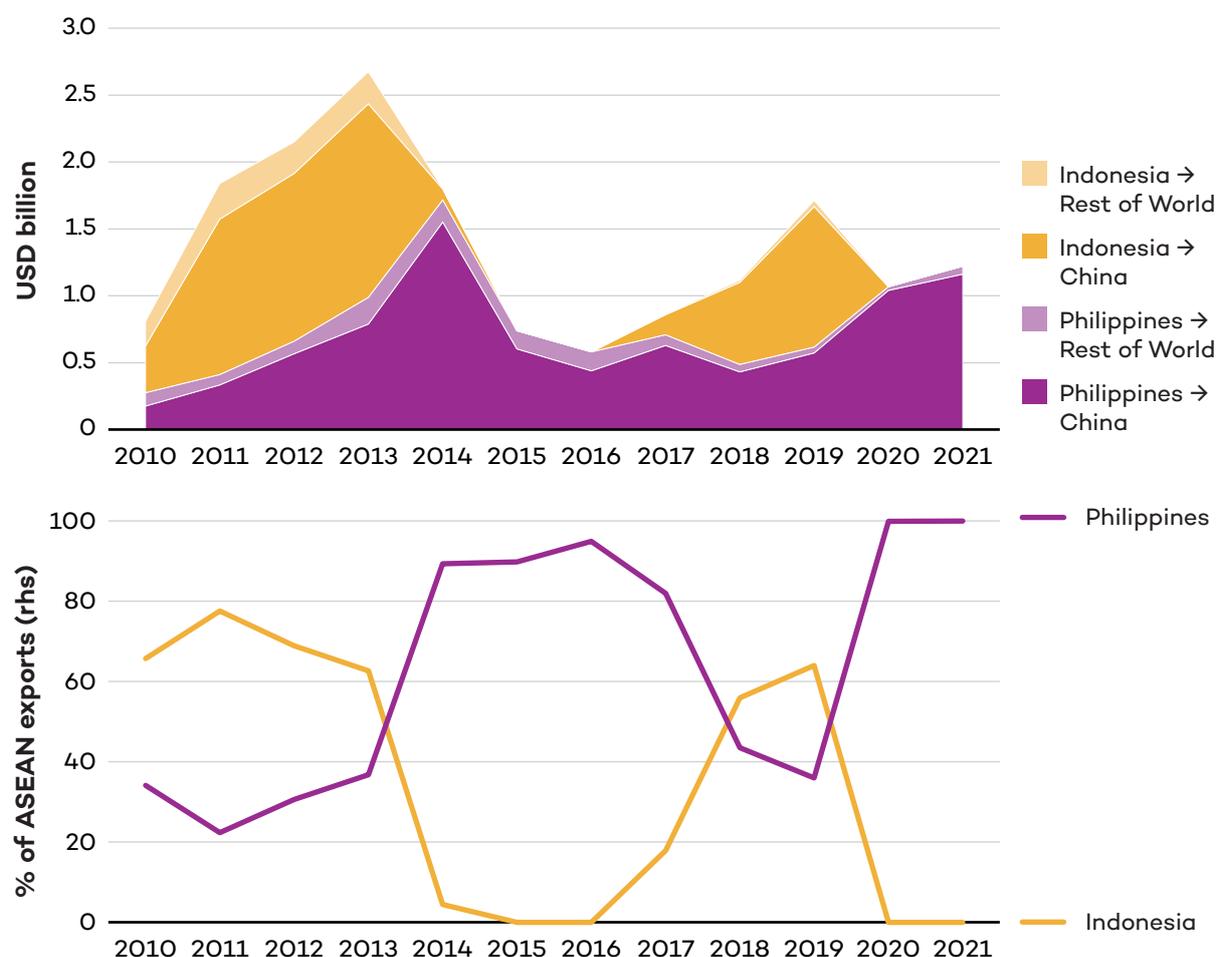
Note: ↑ indicates minerals where ASEAN countries increased production and the production increase trend was larger in the rest of the world.

Source: Author's calculations based on World Mining Data, full production statistics in Annex 2.

The **Philippines** is the other globally significant miner in the ASEAN region. The country is the world's second-largest producer of nickel and the sixth-largest producer of cobalt, with large expansion potential, given changes in governmental policy toward the mining sector. The Philippines' nickel production has been progressively increasing in the past few years, reaching a 6-year high and replacing Indonesia as China's biggest nickel ore supplier (Dela Cruz, 2021).



**FIGURE 6.** Indonesia’s and the Philippines’ raw nickel exports



Source: Author’s own calculations based on ASEAN Stats Data Portal

In 2021, the Philippines lifted its long-standing bans on new underground mines and open-pit mines, announcing 10 new nickel mines due for commissioning in 2022 (IEA, 2022d). These decisions were driven by the Philippines’ significant mineral deposits, including nickel, cobalt, and copper, and the possibility to profit from increased demand, with the government looking to triple the size of the mining sector by 2027, despite backlash and concerns regarding environmental and governance aspects (Mitchell, 2022).

**Malaysia** is the regional leader in aluminum, iron, and manganese production. The country was previously a globally significant producer of bauxite, but the government issued a moratorium on mining in 2016 after several environmental and regulatory issues. While the moratorium was lifted in 2019, production did not fully recover to previous levels (Reuters, 2019). The contribution of the mining and mineral-based manufacturing sectors grew throughout the 2010s, reaching a peak of 0.7% and 2.6% of GDP, respectively, accounting for more than 15,000 jobs (Ministry of Energy and Natural Resources [Ke TSA], 2021). Malaysia’s iron ore exports have also increased progressively, despite the bolstering of a domestic steel sector in the Malaysia–China Kuantan Industrial Park, an initiative that did not lead to the development of strong linkages to the local economy (Camba et al., 2022). In comparison,



**Thailand's** primary mining sector has mostly focused on non-metallics and fossil fuels, with little domestic metallic production, despite promising reserves.

**Viet Nam** is the world's second-largest producer of both bismuth and tungsten and has seen its mining sector grow substantially over the past decade, increasing production in 15 out of the 24 minerals data is available for, with its metals and mining export value increasing by 240% (ASEAN Stats Data Portal, n.d.).<sup>18</sup> The primary production sector has, however, been hampered by relatively low investment rates due to uncertainty regarding regulation and other governance issues.

**Myanmar** has scaled up production in several minerals between 2015 and 2020, including copper (180%), lead (101%), zinc (133%), manganese (807%), and rare earths (9,030%), and was the third-largest producer of both rare earths and tin in 2020, although the production outputs of the latter have been decreasing. Copper and gemstones—especially jade—mining is important to the local economy. Myanmar has also significantly increased its extraction of a number of rare-earth elements, mostly in the Kachin state. All production is exported to China, with Myanmar now becoming China's largest source of rare earths after the reduction of Chinese domestic production due to quotas and crackdowns on illegal mining.

**Lao PDR** and **Cambodia, despite similarities in size**, have very different mining sectors. Lao PDR's metals and mining sector has boosted fiscal revenues and was responsible for 30% of inward FDI between 2003 and 2012 (Herdanado & Yonemura, 2020). The country boasts two copper–gold projects, of which the larger, Sepon, has some of the highest copper ore rates registered globally (Basov, 2017). While Lao PDR had the highest share of metal and mining exports as a contribution to total exports out of all AMS during the last decade, these contributions dropped significantly from 59% in 2010 to only 24% in 2021. Cambodia has not traditionally had a strong mining sector, with very little formalized metals mining. While artisanal and small-scale mining for gold and gemstones has existed for decades, Cambodia awarded its first large-scale commercial gold mining licences in 2018, with production beginning in 2021 (Open Development Cambodia, 2020). While **Brunei** and **Singapore** have no notable domestic metallic production, metals play a significant economic role, especially in the case of Singapore. Metals and minerals form a key part of Singapore's import shares and are widely used in the country's manufacturing sectors. Singapore's role as a regional hub also enables significant potential for FDI into other ASEAN countries' mineral sectors.

## 4.3 Refining and Processing

ASEAN plays a key role in the refining and processing of several locally mined critical minerals. The refining and processing sector has been dynamic, with several countries ranking within the top five globally in mineral processing, with significant output growth rates over the past decade. While in some countries the localization of refining and processing sectors has been more organic, several ASEAN countries have pursued policies, including raw ore export bans, to encourage the nearshoring of refining, albeit with mixed results across different metals and countries.

In 2020, the region cumulatively contributed roughly 2% of global aluminum output, 3% of smelted and refined copper, and 2.2% of steel production but held globally meaningful output rates for refined rare earths (14%), ferronickel (16.4%), smelted nickel (25.5%), and

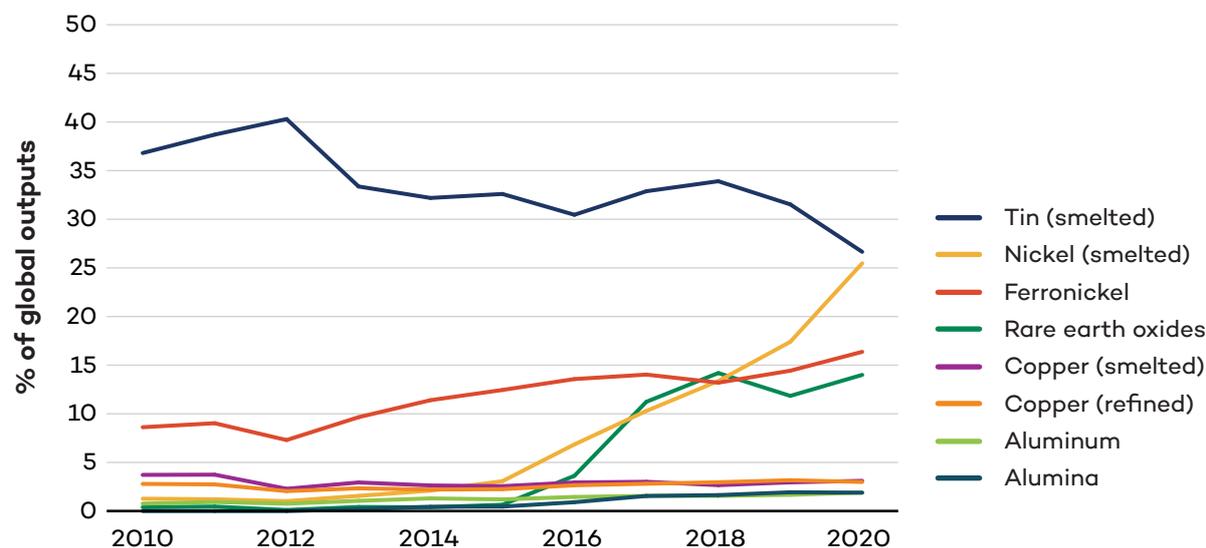
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<sup>18</sup> Including refined and simple downstream metallic products.



tin (26.6%), despite the latter's progressive decline both in absolute and relative terms over the last decade. Importantly, **the region has captured** a growing share of **global processing and refining of key critical minerals**, as value addition plays an increasing role in national development and industrial strategies.

**FIGURE 7.** Refining and smelting of selected metals as % of global outputs



Source: Author's own calculations based on British Geological Survey n.d.

Given the high number of countries pursuing some sort of domestic refining, the rest of this section presents an analysis in two parts. First, due to its prominence, it focuses on Indonesia's recent policy of upgrading its nickel sector, and second, it examines case studies from the remaining ASEAN countries.

### 4.3.1 Indonesia: Raw ore export bans and capacity additions

Indonesia ranks as the most significant processing country in the region for several metals. It is responsible for the most regional output of smelted nickel, smelted tin, and ferronickel. It is also the second-largest global producer of the first two and the third-largest of the latter. Indonesia increased its output of smelted nickel by almost 3,300% between 2010 and 2020. Capacity additions and additional production in Indonesia drove a further 10% increase in output between 2020 and 2021 (IEA, 2022d).

Indonesia's refined nickel output has increased dramatically due to a series of announced and eventually implemented ore bans, although this contrasts heavily with similar policies enacted in the bauxite sector. The 2009 Mining Law announced the banning of raw exports of nickel and bauxite—two minerals for which Indonesia was the most significant global producer—by 2014. Demand for both metals was increasing rapidly due to growing Chinese consumption.

The Indonesian government announced similar policies for both sectors: it lowered duties on processing capital goods imports and introduced key tax breaks for the localization of processing operations (in addition to the raw ore bans themselves). Indonesia's high nickel ore grade, its global primacy in reserves and production, and the calibration of smelters in China specifically to the type of Indonesian nickel encouraged Chinese investors to accept the ban



and invest in setting up operations in Indonesia, which is reflected in the outputs and exports of ferronickel in years following the ban.<sup>19</sup> Nine smelters were built by mid-2017, with many more coming online since then.

Meanwhile, in the bauxite sector, other countries, including Malaysia and Australia, ramped up production and increased exports to China, filling the gap left by Indonesia. The lack of existing downstream processing capacity, the high costs of developing forward linkages from bauxite, and ready alternate sources of bauxite resulted in a lack of interest in constructing downstream refining capacity, although long-term impacts are yet to be determined (Lebdioui & Bilek, 2021).

In 2020, exports of raw nickel were prohibited again, a few years ahead of schedule, and the government discussed options to take a similar strategy with other metals, including tin, bauxite, and copper, in the near future with the view of increasing the share of domestic value addition, although analysts estimate that USD 1.3 billion in investments would be required to expand bauxite refining capacity to absorb domestic production (IEA, 2022d; Suroyo & Nangoy, 2021).

The 2020 nickel ban is part of Indonesia's larger strategy to vertically integrate its extractive sector from ore to batteries, with a view to also produce EVs.<sup>20</sup> This required Indonesia to also develop high-pressure acid leaching (HPAL) projects to ensure processed nickel is of the purity required for battery manufacturing. Firms have committed over USD 30 billion to further develop the Indonesian nickel supply chain, most notably at the Morowali and Weda Bay Industrial Parks, mostly financed by Chinese companies.<sup>21</sup> The first two HPAL projects began production in mid-2021 and early 2022, with a combined capacity of 100,000 tonnes of nickel and 12,000 tonnes of cobalt as a by-product. More capacity additions were announced by various (mostly Chinese) companies, with a view to further extending the production of cobalt and nickel, including nickel mattes to be used for batteries (IEA, 2022d). The Morowali site is also relevant for battery manufacturing, which is discussed further in the report.

### 4.3.2 Other Countries: Varying levels of policy involvement and activities

In terms of refining and processing, **Malaysia** is crucial to both the ASEAN and global markets. In 2020 Malaysia was the second-largest global processor of rare earths behind China, exclusively through the Lynas Advanced Material Plant, an Australian company settled in Pahang, for which it imports rare-earth minerals from Australia.<sup>22</sup> While there is no domestic rare-earth element ore production, Malaysia accounted for roughly 12% of global refined production in 2020. The company is one of the few fully integrated rare-earth producers outside of China, and, given the global rush to diversify supply, it recently received a USD 120 million contract from the Pentagon to start a refining project in the United States. While Lynas'

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19 The ban was later relaxed and then reinstated in 2020.

20 Arguments have, however, been made that the raw ore ban and mandatory smelting have created an oligopolistic situation wherein economic power lies with the smelters, forcing miners to sell their raw production at ever-cheaper prices, often leading to cost-cutting through illegal mining and environmental and social violations (Camba et al., 2022).

21 The Morowali Industrial Park especially has seen the lead Chinese company Tsingshan develop some minor linkages to the local economy, but key technical positions and management are still filled by Chinese staff (Camba et al., 2022).

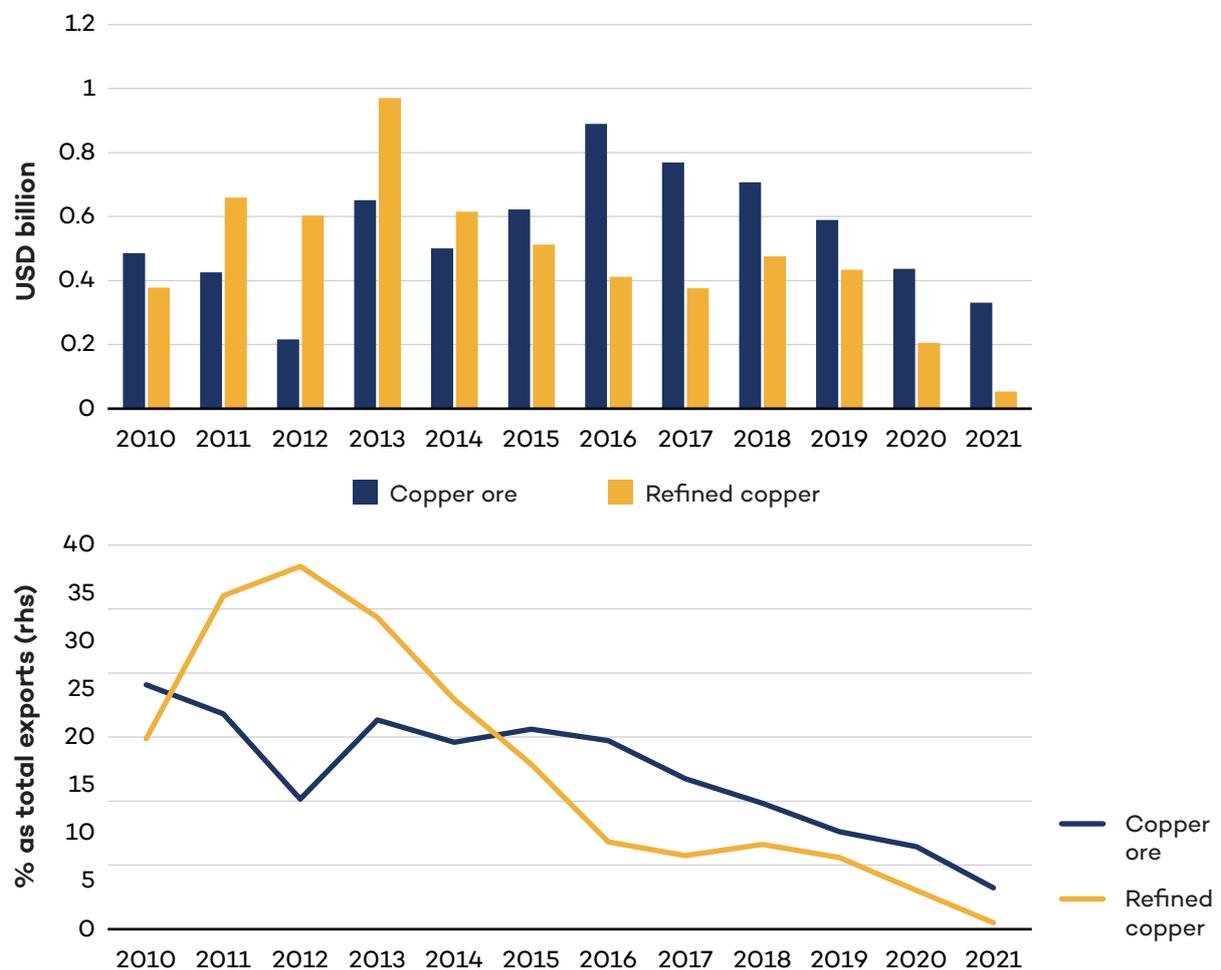
22 While Myanmar is a major producer of rare earths, this supply is exported directly to China.



Malaysia project has proven to be a crucial source of rare-earth supply diversification, there has been controversy over long tax holidays, the environmental and social consequences of production, and the issue of waste disposal.

Malaysia has several aluminum smelters, with production having increased by over 1,500% between 2010 and 2020. Aluminum trade has increasingly contributed to Malaysia's export revenues, which increased from USD 250 million in 2020 to over USD 5.3 billion by 2021, with China and other ASEAN countries as the largest trade partners. Aluminum is also retained domestically for further value addition in products used in various industrial applications.<sup>23</sup> The Sarawak economic development authority has identified aluminum as one of the 10 key industry pillars to boost socio-economic development, aiming to attract higher investment in Sarawak's smelters.

**FIGURE 8. Lao PDR copper exports**



Source: Author's own calculations based on ASEAN Stats Data Portal, n.d.

The **Philippines** has not been as proactive as Indonesia with regard to domestic value addition but nonetheless has some refining and processing capabilities. Currently, there are four gold processing plants, two nickel processors, and one copper refiner and smelter (Government

23 China is the world leader in aluminum smelting, with over 56% of global output in 2020.



of Canada, 2022b). Following the lifting of the mining moratorium in 2021, three major gold–copper projects are currently being assessed. The new Philippine administration has mentioned the possibility of using tax instruments to encourage domestic refining, but no concrete plans exist (Parrocha, 2022).

**Thailand** and **Viet Nam** have some refining and processing capacities, including tin smelters, and Viet Nam has significantly grown its steel industry, with a 350% increase between 2010 and 2020; it now ranks as the 14th-largest steel producer globally (British Geological Survey n.d.).

**Myanmar's** copper refining sector displayed significant growth over the past decade, increasing exports from USD 50 million in 2010 to USD 943 million in 2020, with a progressively larger relative share in the export basket before a prominent decline to exports of “only” over USD 300 million in 2021 (ASEAN Stats Data Portal, n.d.). In comparison, **Lao PDR's** copper production and refining sector has been progressively declining. While the company MMG operates a project on Sepon that produces unwrought refined copper, the output of both primary production and refining at the national level decreased by over 30% between 2010 and 2020 (British Geological Survey, n.d.; author's own calculations). Regulations regarding domestic refining obligations have decreased FDI in the mining sector and decreased its attractiveness over time (Herdanado & Yonemura, 2020). While exports of copper ores and refined copper accounted for roughly 45% of all export value in 2010, this decreased to only 5% in 2021, with almost all production and exports of copper ores flowing to China.

While **Singapore** does not currently process or refine any critical minerals, it is a major importer of minerals from the region (and globally), acting as a gold refining and trading hub, with metals and minerals accounting for important segments of both imports and exports. While **Cambodia** and **Brunei** currently have no meaningful refining, smelting, or mineral value-addition capabilities, potential does exist for the expansion of activities, especially in Brunei, where abundant energy sources could be utilized for highly energy-intensive smelting processes.

## 4.4 Downstream Production and Manufacturing

ASEAN countries have already begun using domestic critical minerals and refined mineral products in advanced downstream industries. The region has a long-standing history of high technology and electronics production, which contributes significantly to GDP, exports, FDI, and employment. Some of the countries are already highly present and crucial in several downstream value chains, both regionally and globally:

- Malaysia and Viet Nam are the second- and third-largest manufacturers of solar PV panels (IEA, 2022c).
- Thailand is the world's 11th-largest automotive manufacturer (IEA, 2022c).
- Various countries across the region have set and commercialized EVs.
- Singapore is integrated into the corporate and R&D processes of several high-value segments of a variety of advanced technology industries.

Given the wide range of possible value chains, the following section will focus on the developments in the battery and EV value chains, where initiatives and strategies have mushroomed across the region.



## 4.4.1 Lithium-Ion Battery Value Chains

The global energy transition emphasizes rapid electrification of all viable end-use sectors, as well as the deployment of utility-scale grid storage, which massively increases the forecasted demand and utilization of electric batteries. The lithium-ion (li-ion) battery—and its various chemistries (see Box 1)—is expected to be the battery of choice for key end-use sectors, including electric mobility (more details in the following section), energy storage, and the rapidly expanding global consumer electronics market. Currently, available global production capacity lags behind expected demand, but significant expansions in capacity are already announced, planned, or in construction.

### BOX 1. BATTERY CHEMISTRIES AND ASEAN MINERALS

Since their commercialization, li-ion batteries have revolutionized the world of electronics and have enabled the rise of EVs. Various battery chemistries exist, with different energy densities, discharge rates, and life cycles, and each is optimal for different applications. The current high-end li-ion cathode chemistry is the NMC811 (nickel manganese cobalt in proportions of 8:1:1), which uses significantly less cobalt than some of its predecessors. Innovation was spurred by the high prices of cobalt as well as the environmental and social impacts of mining in the Democratic Republic of the Congo. Various NMC chemistries currently operate in EVs, including the NMC532 and NMC622, but also the alternate lithium iron phosphate, whose utilization has increased in both passenger vehicles and electric buses in past years and which does not require cobalt. Further innovation is expected in the li-ion battery cathode chemistry segment, with substitute battery types (solid state, metal air, and others) also showing signs of promise.

The ASEAN region is already a key producer of most li-ion minerals, including nickel, manganese, iron, and cobalt, through Indonesia's new HPAL projects; it is also increasingly a producer of cobalt. However, the key ingredient in every li-ion battery, lithium, is not commercially mined in ASEAN and will have to be imported, most probably from Australia, South America, Sub-Saharan Africa or China.

*Source: McKinsey & Company, 2021.*

Indonesia's value-addition policies, coupled with the availability of battery minerals (including nickel obtained from HPAL, cobalt, and other minerals), have seen a rapid scale-up not only in ambition, with Indonesia's government looking to enter the sector, but also in concrete policy and investments to encourage vertical integration in the sector. Presidential Regulation No. 55/2019 mandated the creation of a domestic EV industry, which quickly materialized. In 2021, four state-owned companies joined up to create the Indonesian Battery Corporation to oversee the move up the value chain to local development of battery and EV industries.

Arguments have centred on the high value addition that batteries provide (90 to 150 times the value of raw ores), domestic demand, and export potential, but questions remain regarding the required expertise and R&D technologies that will be needed to ensure state-of-the-art battery production. On the latter point, CATL, one of Chinese's foremost battery companies, agreed in early 2022 to launch a fully integrated USD 6 billion battery value chain in Indonesia. In addition, plans to invest a further USD 9 billion into the entire EV battery value chain have been announced by LG Energy Solution, the second-largest EV battery



manufacturer, in conjunction with Hyundai and the Indonesian government (IEA, 2022d). While the impact is yet to be determined, additions in capacity could see Indonesia supply over 12% of the total global demand for batteries by 2035, with a significant impact on domestic GDP and job creation (Suherman et al., 2021).

#### 4.4.2 EV Value Chains

The global demand for EVs is expected to increase rapidly in the coming years and decades, with various countries and regional blocks already pledging to ban the sale of internal combustion engine (ICE) vehicles in the 2030s. EVs are significantly more mineral-intensive than classic ICEs and contain many of the minerals already produced and refined by AMS. Across ASEAN countries, the EV sector has caused a flurry of activity from countries looking to integrate themselves into the EV value chain. Indonesia and Thailand are at the forefront of building EV industries (in the case of Indonesia, a fully integrated value chain), while Viet Nam, the Philippines, and Malaysia all have plans for manufacturing or assembly. A summary of policies is shown in Table 4.

**TABLE 4. ASEAN EV policies**

Country	Incentives		Infrastructure		Demand		Industrial development		Others	
	Subsidy/tax	In use	Strategy/ support	Special fleet	Shared mobility	Manufacturing	Assembly	R&D/capacity building	Business model	Int'l. support
Thailand	✓		✓		✓	✓	✓	✓	✓	✓
Malaysia	✓		✓		✓	✓	✓			
Philippines	✓	✓	✓		✓	✓	✓	✓	✓	✓
Indonesia	✓		✓	✓	✓	✓		✓		✓
Viet Nam	✓		✓	✓	✓	✓	✓			✓

Source: Khan et al., 2022.

Governments across the region have announced both demand- and supply-side policies to spur the infant sectors. Several countries have already announced (non-binding) EV adoption targets, including on both the demand and supply sides (Khan et al., 2022).



On the demand side, these policies are related to EV adoption and the building-up of infrastructure, including

- **Brunei:** 10% of fleet stock and 60% of new sales by 2035.
- **Malaysia:** 100% of all private transport vehicle stock and 40% of all public transport is to be electrified or fuelled by compressed natural gas/liquefied petroleum gas/ biofuel by 2030.
- **Singapore:** 100% of new car and taxi sales are to be clean energy by 2030.

Malaysia's state-owned TNBES has partnered with the governmental Malaysia Green Technology Corp to spur the roll-out of EV charging stations (ChargEV, 2019), a policy also actively pushed in Singapore, which has the most ambitious adoption targets in the region. Its National Electric Vehicle Centre aims to speed up adoption and ensure that Singapore has a fully renewable fleet by 2040 (ReportLinker, 2022). Incentives for consumers can also be found in the Philippines Comprehensive Roadmap for the Electric Vehicle Industry, which introduces tax exemptions and discounts, as well as the streamlining of vehicle registration processes (Baker McKenzie, 2022). The 2022 February subsidy program in Thailand also announced subsidies for consumers. And in Indonesia, some adoption is already present due to popularization by ride-sharing apps.

On the supply side, Thailand, Indonesia, the Philippines, and Viet Nam have all either officially or unofficially entered the EV manufacturing space, with often ambitious goals (Khan et al. 2022):

- **Indonesia:** 20% of vehicle production is to be either EVs or hybrid by 2025, and there are plans for 13 million electric motorcycles by 2030.
- **Thailand:** Production by 2025 is to cumulatively reach 250,000 passenger EVs and 3,000 electric buses; 30%–50% of all vehicles produced by 2030 are to be electric.

While Thailand is the most established car manufacturer in the region and the 11th-largest automaker globally, Indonesia has started entering the industry through an integrated ore-to-EV value chain, which has yielded significant investments from Chinese companies (as previously mentioned in the li-ion battery section). Thailand has been most actively exploring the possibility of EV manufacturing for the last decade. The country follows a multi-pronged strategy that includes setting up collaborative initiatives between the private sector and academia, such as the Electric Vehicle Association of Thailand, focusing on international collaborations for joint ventures. In 2022, TÜV SÜD opened a battery-testing centre in Thailand, which was announced in 2019 as the “largest and most modern test centre for li-ion batteries in the ASEAN region” (Hampel, 2022). Importantly, the Thai energy conglomerate TPP has established a joint venture with Foxconn, looking to start production in 2024, and the government has announced packages with strong financial incentives across the entirety of the EV value chain, including subsidies, tax cuts, and import duty exemptions. However, the government and the Thai automotive industry must now also work on ensuring that domestic component suppliers can reorient some of their production to guarantee that they can keep supplying the booming sector in order to generate value and positive spillovers (Mohamad & Songthavephol, 2020).

Meanwhile, Singapore has attracted activity in the R&D sector, with Hyundai opening an innovation centre and minor 30,000 vehicle/year production line, including the company's first “smart factory” utilizing advanced Industry 4.0 capabilities and acting as the technological



frontier in the EV space (Gek, 2022). Hyundai and LG Energy Solutions are also heavily invested in building up production facilities in the Indonesian EV market. Interestingly, Viet Nam's VinFast EV automaker has relocated its HQ to Singapore to help with an upcoming initial public offering but is also investing in a USD 2 billion EV production facility in the United States, where the state of North Carolina has pledged financial incentives (Guild, 2022).

While some questions remain regarding the scale of domestic market absorption given the high costs of passenger EVs, the 2- and 3-wheel segments, as well as electric buses used in public transportation, could have higher uptake rates. Importantly, given the higher emissions intensity required to construct an EV (compared to an ICE), ASEAN countries looking to adopt EVs must also ensure that charging stations are powered by renewable electricity to drive down EV life-cycle emissions.

## 4.5 Reuse and Secondary Production

While most of the global increase in mineral demand will have to be filled by increases in extractive activities, secondary production and reuse will also play a fundamental role. While recycling rates vary heavily by mineral and across regions, innovation in recycling technologies and capabilities for a variety of products has seen several projects come online in the last few years, including in the ASEAN region.

At the cutting edge of the recycling field, there is sizable potential for the reuse of metals in a variety of sectors. Reuse in the European steel-making industry has already reduced waste through by-product recovery, driven by novel research and innovation and contributing to saving raw materials, reducing emissions, and creating a circular economy for steel (Branca et al., 2020). Studies have also been conducted on the reuse of steel and aluminum components in more systematic ways (Cooper & Allwood, 2012). For manufactured end products, the reuse or repurposing of some electronics products can limit the need for additional production by finding utilization in other sectors. For example, EV batteries can be reused for grid electricity storage or in individual home electricity storage (Hive Power, 2022). The IEA estimates that recycling and reuse of only EV and energy storage batteries have the potential to decrease primary supply requirements by 12% by 2040 (IEA, 2021).

In 2019, AMS collectively generated over 3.5 million tonnes of e-waste, with an expected increase in the coming years and decades as the region further develops economically, leading to higher usage of consumer electronics, household appliances, EVs, and technology in general. However, currently, only four AMS (Cambodia, Malaysia, Singapore, and Thailand) have national e-waste legislation or policies in place (Forti et al., 2020). As a region, Asia (including but not limited to ASEAN) has lagged behind other regions in rates of recycling of most minerals, with only 11.7% of e-waste recycled compared to 42.5% in Europe (Leonida, 2022). Secondary production of highly recyclable metals, such as aluminum and copper, accounts for only 2.5% and less than 1% of total refined consumption in the ASEAN region, respectively, significantly below global rates (IEA, 2022c). These low rates of recycling are further exacerbated by strict policies on scrap imports in Malaysia, which decrease investment potential in recycling plants, among other factors.

Given the region's prominent role in other electronic value chains and expectations regarding increasing e-waste, various studies have explored recycling for other minerals. These options include rare-earth recycling from e-waste in Malaysia (Joseph et al., 2019) and the techno-



economic potential of recovering rare earths from coal ash, which could be catalyzed by Indonesia's removal of the substance from the hazardous waste category (Das et al., 2018).

By 2030, over 2.5 million tonnes of li-ion batteries are due to reach end-of-life, but current global recycling capacities can only cover 0.7 million tonnes. Given AMS' ambitions and further vertical integration in the li-ion battery and EV value chains, the possibility of battery recycling localization has gained traction in various AMS. While some li-ion battery chemistries (e.g., lithium-iron-phosphate) have less valuable metals and pose a challenge to battery recycling economics (IEA, 2022d), economically feasible battery recovery and recycling processes already exist and are envisioned to form a key part of shifts to more sustainable circular economy approaches. Singapore launched the first battery recycling plant in the ASEAN region in 2021, which is capable of processing 14 tonnes or 280,000 smartphone batteries per day, with processes to extract significant amounts of lithium, cobalt, nickel and other metals (TES, 2021). India's Attero plans to open a recycling facility in Indonesia by 2024 (Saxena, 2022), while ACE Green Recycling announced the creation of a recycling factory with an annual capacity of 10,000 tonnes by 2023 (Mathy, 2022). While recycling will play fundamental roles in secondary supply, Benchmark asserts that in the battery recycling value chain, scrap will be the main source of recyclable material in the coming decade, as EVs coming to the market today are only expected to be recycled in the 2030s (Benchmark Source, 2022a). Scaling up li-ion battery recycling in the region could also lead to benefits like the recovery of minerals that are not greatly produced in the region, most notably lithium, which is currently not produced in commercial quantities and faces a significantly constrained global market supply.

While still an emerging topic, re-mining or secondary supply from mine tailings could, in some places, eventually prove to be economically beneficial, given rising metal prices and increased demand (IEA, 2022d). The global volume of mine tailings is currently estimated at 200 km<sup>3</sup>, implying enormous potential for secondary mining and recovery. Various, mostly individual, studies have already assessed the scientific potential of post-processing tailings in a variety of global locations, including Indonesia (Zglinicki et al., 2021). While these processes are being investigated further, and economic feasibility and global waste regulations need to be assessed, the high number of tailings produced from ASEAN mining operations warrants further consideration and investigation.



## 5.0 Overarching Dynamics

As demonstrated, the ASEAN critical mineral sector features globally significant activity at almost every step of the mineral value chain and is due to play a role in downstream product value chains in the short to mid-term. The potential and outlook for the various stages of the mineral value chain differ substantially between the countries, but ASEAN mineral value chains are significantly impacted by broader domestic, regional, and global dynamics. The following section provides an overview of business and market conditions in key ASEAN countries; the state of sectoral, environmental, and social governance; and, finally, the broader global trends and geopolitics of critical mineral value chains.

### 5.1 ASEAN Market and Trade Conditions

Over the past few decades, ASEAN's economic development and regional integration have spurred highly robust value chains across important industries. The ASEAN Economic Community was formed in 2015 and aims to further integrate the 10 AMS into a single market and production base to boost capacities and expand reach. Along with East Asia, the region has been performing as the “factory of the world,” attracting major investment from both global investors and ASEAN members themselves (Shepherd & Prakash, 2021). The region is seen as highly attractive to investors due to several factors, including (EY, 2022; Foreign, Commonwealth and Development Office, 2021; Meyer et al, 2021).

- Highly globally integrated value chains, including strong trade ties with China, Japan, and South Korea (ASEAN Plus Three), as well as Australia.
- Good geography with strong logistical and shipping access to key end markets.
- A built-up tradition of manufacturing, including increasingly more advanced products.
- A rapidly growing and dynamic domestic end market spurred by a growing population and higher income levels and socio-economic development.
- Multiple free trade agreements, including the Regional Comprehensive Economic Partnership.
- Strong manufacturing initiatives (e.g., the Southeast Asia Manufacturing Alliance).



- Continuous reform of legal and trade frameworks to improve the ease of doing business.
- Potential location for the diversification of production and global value chain concentration.<sup>24</sup>

The emerging consensus is that the ASEAN region is well placed to capture additional value and increase its manufacturing industries with the introduction of Industry 4.0 technologies and with changing global consumption patterns (e.g., the switch to EVs) providing a unique opportunity for the region and its wider socio-techno-economic development prospects.

Overall, the region benefits from several important multilateral and bilateral free trade agreements, including with China, India, Japan, South Korea, Australia, and New Zealand. For instance, the most recently signed Regional Comprehensive Economic Partnership created the largest trade bloc in global history, which could further catalyze AMS' product and manufacturing trade.

Trade has helped to successfully integrate ASEAN economies into the markets of regional powerhouses, such as China, Japan, and South Korea. Starting in 1997, the ASEAN Plus Three initiative has seen broad-based cooperation between the 10 AMS and China, Japan, and South Korea, which accounted for 31.6% of ASEAN's merchandise trade in 2019 and almost 20% of all inward FDI (ASEAN, 2022). While the initiative and broadening of relations have significantly contributed to economic and industrial growth, areas of cooperation have now also included, among other aspects, tourism; energy; security; the promotion of micro, small and medium-sized enterprises; and mineral cooperation. Under the ASEAN Plus Three Cooperation Work Plan for 2023–2027, minerals are also covered, with a focus on a) investment promotion and information sharing, b) sustainable mining principles, c) human capital and capacity building, d) data availability, and e) support for AMCAP (ASEAN, 2022b). Within the ASEAN Minerals Cooperation platform, a dedicated ASEAN Plus Three component also exists (ASEAN, 2022a). As significant mineral consumers and high-tech powerhouses, ASEAN's further integration with the "Plus Three" countries can lead to significant economic spillovers, development of linkages, and technological transfers.

Nonetheless, ASEAN members have also increasingly expanded trading with other global partners. Both exports and imports have grown since the early 2010s, driven by boosted trade with a variety of global partners. Exports to the United States grew by over 143% between 2011 and 2021 and by 82% to China and Hong Kong. Both the United States and European Union account for larger shares of ASEAN exports today than they did in 2010. India and Australia are also highly significant to ASEAN trade and have a number of joint initiatives and work plans, including on the development of ASEAN's mineral industry, trade, and value chains (ASEAN Stats Data Portal, n.d.; author's calculations).

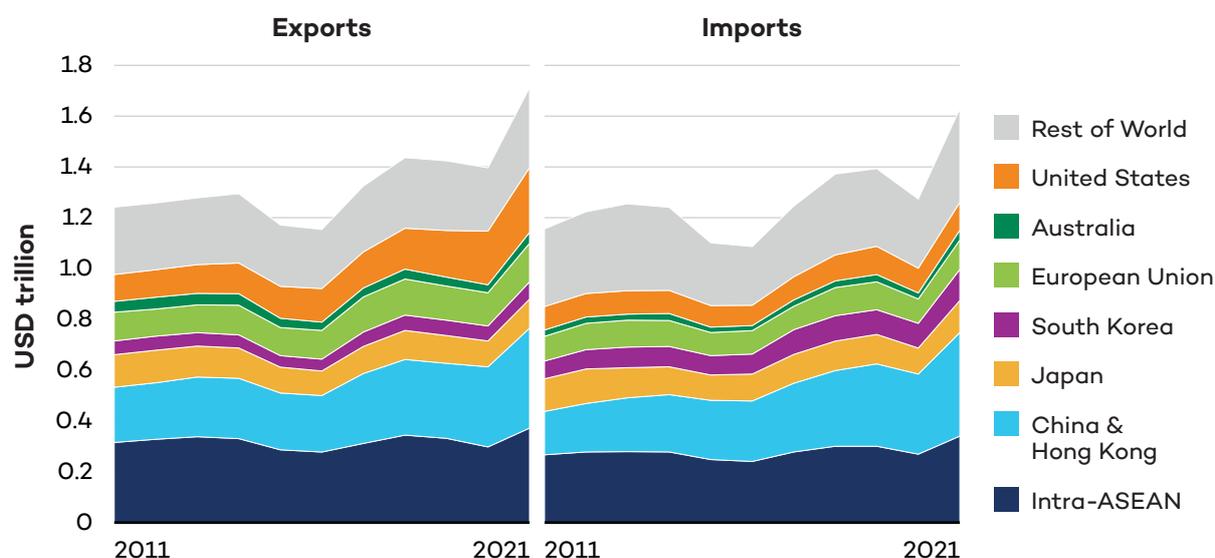
However, during the last decade, the largest trading partner for AMS were other ASEAN countries, highlighting the importance of regional integration (with 24% of total trade being intra-ASEAN) (ASEAN Stats Data Portal, n.d.; author's calculations).

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<sup>24</sup> Economic initiatives and global overreliance on East Asian value chains has seen the launching of the Indo-Pacific Economic Framework for Prosperity, which aims to encourage and incentivize companies to relocate production from China to other regions, including ASEAN countries.



**FIGURE 9. ASEAN exports (left) and imports (right) by main trade partners**



Source: Author's own calculations based on ASEAN Stats Data Portal

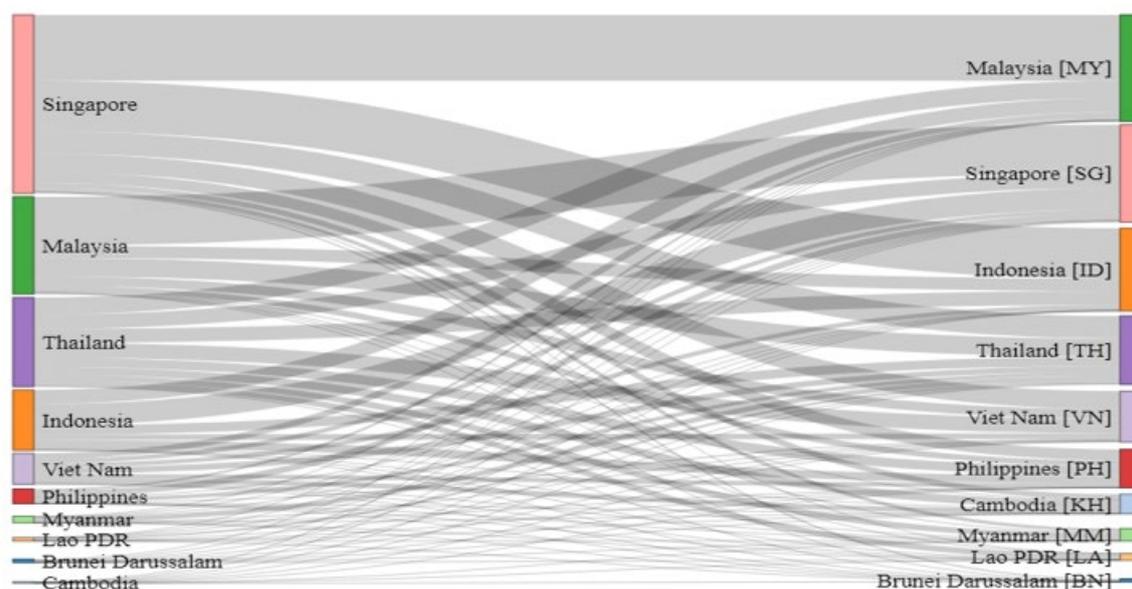
Analysis of ASEAN value chains over the past few decades has shown that there has been increasing regional integration of ASEAN Member State economies, including greater sourcing of regionally made contents and components, which also indicates larger localization of production, suggesting similar development patterns observed previously in China, including increasing evidence of learning-by-doing development (Landa-Arroyo, 2020). While there is significant variation among ASEAN members, the sector has tended toward more integration and localized production. Studies have shown that the intra-ASEAN sourcing of inputs has had beneficial impacts and is comparable to the importance of major external suppliers (e.g., South Korea) (Nguyen, 2020). The largest trade flows between 2011 and 2021 were recorded between Singapore and Malaysia, with Malaysia, Thailand, and Viet Nam composing significant shares of intra-ASEAN exports.

Economic development and the building-up of manufacturing capabilities have been uneven, and strategies such as the establishment of special economic zones have often not yielded benefits due to a lack of up-skilling or technological transfers for smaller ASEAN members (Kuroiwa, 2016). However, the further regionalization of production could have positive spillover effects and FDI inflows if combined with strong policies ensuring knowledge transfers. ASEAN's Economic Community Blueprint 2025 guides the further integration of ASEAN countries and will be fundamental to ensuring the long-term sustainable integration of smaller members.

ASEAN has also seen strong investment activity, with FDI increasing by 65% between 2012 and 2021. Although fluctuating annually, investment has focused on a few core sectors, although differences exist between intra-ASEAN and extra-ASEAN investment patterns. Nonetheless, the manufacturing sector was of fundamental importance, attracting the second-largest share of FDI from investors outside of ASEAN, totalling over USD 250 billion, with a further USD 62 billion from intra-ASEAN investment.



**FIGURE 10.** Intra-ASEAN trade (2011–2021)



Source: Author's own calculations based on ASEAN Stats Data Portal

ASEAN members have also made significant progress in innovation and research. The Global Innovation Index, which measures innovation across seven pillars, shows that five AMS now place within the top 50% of countries globally, with Singapore placing eighth in the world.<sup>25</sup> Crucially, there has been significant improvement in the past decade, with the Philippines moving from 91st in 2012 to 51st and Viet Nam moving from 76th to 44th, now sitting at the highest position in the lower-middle-income country category.

**TABLE 5.** FDI by sector

Sector	Intra-ASEAN	Rest of the world
Manufacturing	27.66%	21.95%
Financial and insurance activities	22.34%	32.23
Real estate activities	13.84%	6.18%
Agriculture, forestry, and fishing	10.32%	0.42%
Wholesale and retail trade; repair of motor vehicles and motorcycles	7.31%	16.41%

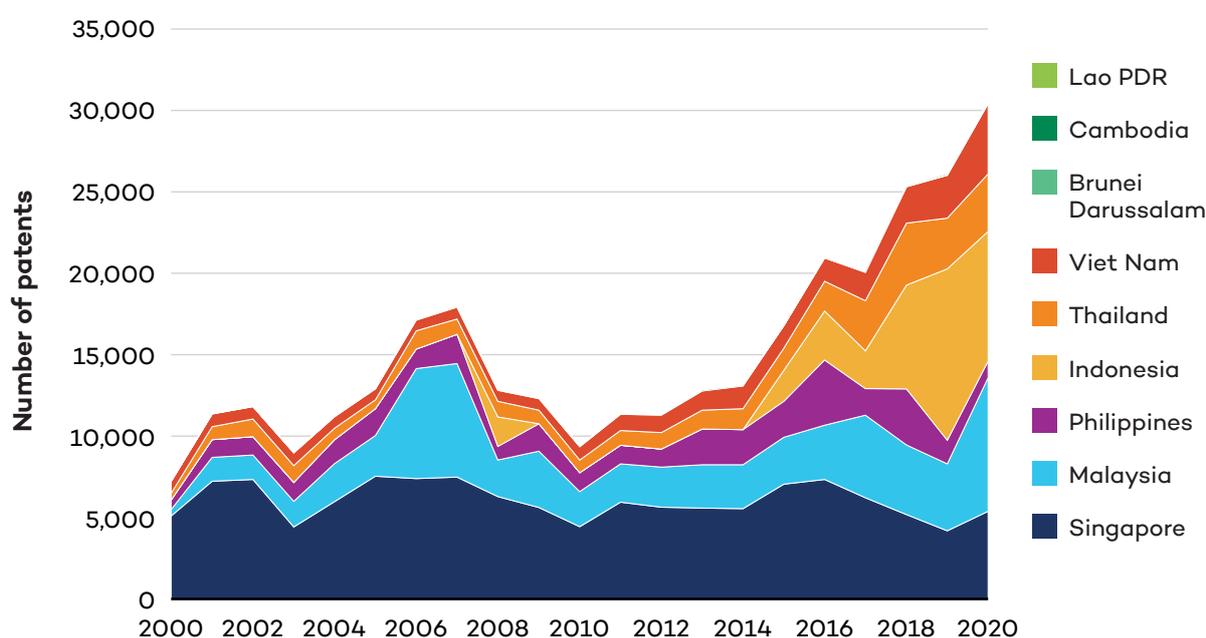
Source: Author's own calculations based on ASEAN Stats Data Portal

<sup>25</sup> The seven pillars are (i) institutions, (ii) human capital and research, (iii) infrastructure, (iv) market sophistication, (v) business sophistication, (vi) knowledge and technology outputs, and (vii) creative outputs (World Intellectual Property Organization, 2021).



This progress has also been reflected in the number of patent applications submitted and patent grants received over the last 2 decades. While in the early 2000s Singapore accounted for the majority of approved patents, other countries, including Indonesia, Malaysia, Thailand, and Viet Nam, have dramatically increased their rates of innovation and patenting. Importantly, R&D and patenting activities have taken place across a number of fields, including, for example, electrical machinery and audiovisual tech (Malaysia and Singapore) and organic chemistry and pharmaceuticals (Malaysia and the Philippines) (WIPO IP Portal, n.d.). Since 2009, ASEAN has also run the Patent Examination Co-operation program, the first regional patent work-sharing program across nine AMS, which aims to speed up the rate of patent approvals.<sup>26</sup>

**FIGURE 11.** Annual number of granted patents by AMS



Source: Author's own calculation based on WIPO IP Portal, n.d.

While AMS have significantly increased their activity in R&D, innovation, and financing, the role and importance of Singapore for the ASEAN region cannot be understated. As a highly advanced economy with significant R&D, innovation, and human capital, Singapore accounts for vast sums of inward FDI and is the region's finance centre and regional hub for multinational corporations, with extremely advanced high-tech manufacturing. Singapore was the first ASEAN nation the EU signed a free trade agreement with (EU–Singapore Free Trade Agreement). It also has agreements with other countries, including through the Comprehensive and Progressive Agreement for Trans-Pacific Partnership and technology and innovation partnerships with other significant global critical mineral producers, including Australia. Singapore will undoubtedly play a fundamental role in R&D, innovation, and up-skilling regional value chains.

26 For a description of the ASEAN Patent Examination Co-operation program see <https://www.aseanip.org/Services/ASEAN-Patent-Examination-Co-operation-ASPEC/What-is-ASPEC>



## 5.2 Regulatory, Environmental, Social, and Governance Aspects

Consumers and investors globally are increasingly more conscious of the track record of the companies or countries where they purchase their goods or that they invest in. The increasing prominence of environmental, social, and governance (ESG) practices in global business is the result of decades of civil society activism and international initiatives to reform historically opaque and often harmful practices in the mining sector and ensure their contribution to sustainable socio-economic development.

Transparency and accountability have become almost non-negotiable conditions for investors and are now considered global standards of governance. This is reinforced by the ability of consumers to gain access to corporate details thanks to the Internet and more accessible information. As a result, producer countries are required to ensure their mining and manufacturing sectors adhere to higher ethical, social, and environmental standards, as documented evidence from several countries has displayed the potential risks that the mismanagement of natural resources might generate (IEA, 2022a).

While ESG considerations should always form the bedrock of mining and industrial development, from a pragmatic point of view, ESG considerations will have significant economic implications for mineral-rich countries. Research and industry surveys have shown that low attainment of ESG metrics and perceptions of risk limit investment in the mining industry (Jacobs, 2022). In addition, failure to mitigate environmental and social ills often makes it difficult to obtain a social licence to operate, leading to project disruptions or shutdowns (Michaels et al., 2022). As AMS develop their wider mineral value chains, civil society organizations need to be involved in (i) decision making, including strengthening their ability to work with government and state-owned enterprise operations, (ii) contracts signed with mining companies, and (iii) upholding environmental and social standards to prevent a “race to the bottom.”

Environmental aspects also factor heavily into the concept of a circular economy. ASEAN adopted the Framework for Circular Economy for the ASEAN Economic Community in 2021, with a focus on five key strategic priorities, including energy and resource efficiency, the enhanced role of innovation, digitalization and emerging green technologies, and the harmonization of policies and standards (ASEAN, 2021a). Importantly, the increased extraction and utilization of minerals in AMS (and globally) will necessitate firm commitments to ensure waste is limited and efficient recycling and reuse can decrease emissions and lessen the burden on the planet.

From a longer-term perspective, the inability to deal with environmental issues can have direct effects on extractive operations due to high exposure to climate risks and the adoption of environmental and emissions trade regulations, such as the Carbon Border Adjustment Mechanism in the EU. Likewise, the progressive application of carbon taxation in key end markets will make it necessary for ASEAN industries to contain emissions and environmental damage to ensure the competitiveness of their export industries. As an example, a ramp-up in the usage of the HPAL technique for nickel processing in Indonesia and the Philippines imposes additional environmental stress due to high water intensity and increased emissions. One kilogram of nickel produced through HPAL consumes over 1,700 litres of water, which represents five times the amount required for “normal” nickel processing and twice as many GHG emissions (IEA, 2022c). Waste from nickel mining and smelting has had significant



impacts on coastal waters, affecting the health and livelihoods of local communities, as well as local flora and fauna (Sawal, 2022). Toxicity in the mining and refining of rare-earth elements globally is well documented and poses issues for both Myanmar and Malaysia. While Scope 1 and 2 emissions are important, industry surveys also found that investors are increasingly worried about Scope 3 investments, that is to say, those created by the buyer of mining products (Jacobs, 2022). AMS should keep emissions and environmental aspects in mind across the broader mineral and industrial value chains to ensure long-term industrial competitiveness.

The critical mineral rush has also spurred an increasing number of international initiatives tackling ESG within critical mineral value chains. Several organizations have been focused on the 3TG and broader mineral segments,<sup>27</sup> while the Extractives Industries Transparency Initiative, International Council on Metals and Mining, Resource Governance Institute, Publish What you Pay, and other organizations have been increasingly active in the critical mineral space. Consuming countries and manufacturers have also been active in ensuring that the minerals sourced for their operations adhere to the highest standards. Just to name a few, the Organisation for Economic Co-operation and Development Due Diligence Framework, United Nations Global Compact Principles, Global Battery Alliance's Battery Passport, Initiative for Responsible Mining Assurance, Responsible Minerals Initiative, and the London Metal Exchange Responsible Sourcing Requirements all contribute to cleaner and more resilient supply chains.

## 5.3 Global Trends and Geopolitics Across Mineral Value Chains

The ASEAN countries are located in a highly globally strategic region, with significant influence and competition between global economic and geopolitical giants. While this strategic location has contributed to the development and economic growth of AMS, it also imposes significant constraints and possible risks.

As discussed in previous sections, major mineral-consuming and some resource-producing countries have instituted national or supra-national strategies tackling the issues of critical mineral supply chain resilience. In addition to diplomacy, trade, and foreign investments, more governments are also actively pursuing policies to increase the domestic production of critical minerals to minimize the uncertainty of foreign supply.

For instance, in March 2022, the U.S. government invoked the Defense Production Act, which included the boosting of U.S. production of various EV and battery minerals. Likewise, the Australian government has made USD 2 billion available to further encourage the development of critical mineral industries, and the Canadian government promised funding of USD 3 billion to develop critical mineral value chains (IEA, 2022d). And as recently as mid-September, European Commission President von der Leyen stressed the need to speed up the ratification of trade agreements already negotiated with major mining countries such as Chile and Mexico, with a view to negotiating agreements with others, including Australia (Blenkinsop, 2022). The European Commission Proposal for a Critical Raw Materials Act of March 2023 focuses on strategic responses to mitigate the risks of supply chain disruption

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<sup>27</sup> See, for example, the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas, <https://www.oecd.org/corporate/mne/mining.html>.



to secure more robust and resilient supply chains in the EU. Once adopted, it will set clear priorities for actions, notably by mitigating supply risks; supporting domestic localization of both mining and refining capacity in the EU; investing in research, innovation, and skills; fostering the circularity and sustainability of critical raw materials; and enhancing partnerships with global suppliers (European Commission, 2023). These strategies open the possibility of larger ASEAN mineral and refined metal exports but also mean that sourcing metals not produced in the region (e.g., lithium) will be more competitive—and hence more difficult—to access.

Re-localizing or reopening domestic mineral production to increase and secure supply has also been a strategy either proposed or already implemented in various countries, despite often significant opposition from environmental and societal groups. The United States has recently reopened the Mountain Pass rare-earth mine, and the EU's Critical Raw Minerals and Horizon programs have been assessing innovation within mining and examining new and old mines for potential, although investment has so far remained low (Keating, 2020).

China's role in critical mineral value chains and the region must be mentioned. China is the world's leading producer of several critical minerals, as well as the undisputed global giant in the refining and manufacturing of many mineral-intensive products. For instance, in the battery segment, China refines 68% of global nickel, 40% of copper, 59% of lithium, and 73% of cobalt; it also produces 70% of cathodes, 85% of anodes, 66% of separators, and 62% of electrolytes (Castillo & Purdy, 2022). The country hosts the highest number of battery gigafactories and leads in EV manufacturing. Chinese companies especially, although not exclusively, have been active in securing long-term supply guarantees by investing in either major existing mines or smaller companies with prospective deposits or by simply buying equity in already existing mines. A significant number of off-take agreements have been signed in African countries, with a focus on battery minerals, including cobalt, copper, lithium, graphite, and others. Chinese companies have been actively supported by their government and state-owned banks to invest in assets, often being viewed as both securing mineral access for refiners back in China and acting as a geopolitical instrument to extend influence in producer countries (Searcey et al., 2021). This has been further reinforced by China's practice of providing resource-backed loans, where loans are either repaid through mineral exports or where natural resources serve as collateral (IEA, 2022d; Mihalyi et al., 2020).

As the EV revolution gathers steam, major global automotive original equipment manufacturers (OEMs) and battery producers have also been signing long-term supply agreements directly with mining companies to ensure the stability of supply. Just to list a few examples, Tesla and GM signed a major contract with Glencore in the Democratic Republic of the Congo, and BMW and Renault concluded agreements with Managem in Morocco (Dunn, 2022; Global Mining Review, 2022). The industry is also witnessing increasing vertical integration between OEMs and miners or battery companies. Volkswagen Group is planning to build at least six battery factories by 2030 to enter the battery segment, but it also plans to begin cobalt and nickel refining in China. Finally, Tesla plans to build a refining plant in Texas, while a joint venture between Toyota and Panasonic has signed strategic agreements with BHP for the future nickel supply (Leggett, 2022).

Many countries and regional blocs are also more actively tackling issues of import dependence in not only mineral and processed metal value chains, but also in final end-use products, especially within the field of energy, technology, and defence. This coincides with the broader trend of policy-makers arguing for the nearshoring of key manufacturing sectors,



despite decades of offshoring and deindustrialization. As such, countries and regional blocs are more firmly adopting industrial policy approaches to ensure the domestic localization/return of key industries of the future. The historical use of industrial policy approaches in various mineral value chains has been well documented, with countries such as China instituting policies for the development of broader value chains from raw ores all the way to finished high-tech end products (see Box 2).

## BOX 2. CHINA'S RARE-EARTH INDUSTRY

The Chinese government has relied on state-led industrial policy in a wide range of sectors. While China holds about one third of global rare-earth reserves, in 2019 it accounted for 60% of global primary production and 87% of global refining. After exporting rare-earth element concentrates in the 1970s, there was a progressive value-addition process to magnets, phosphors, and powders by the late 1990s. By the 2000s, they produced higher-value-added goods, such as electric motors, cell phones, computers, and batteries, and by the early 2010s, when China held a monopoly across the rare-earth element value chain, a total export ban, after a dispute with Japan, sent prices skyrocketing and countries fearing for future supply. China's rare-earth sector benefited from interventions in the form of export quotas, export duties, strategic acquisition of technology, and public funding for R&D. Authorities banned foreign involvement in rare-earth mining but allowed FDI in downstream activities under conditional joint ventures. China developed the downstream industries by also stimulating other industries that required rare-earth elements as inputs and allowing major multinational corporations to relocate to China to gain access.

*Source: Medeiros & Trebat, 2017.*

This understanding of supply security also led to the proliferation of much larger industrial policy packages in 2022, notably in the United States and the EU. In the realm of digital technologies, the United States passed the CHIPS and Science Act to encourage the domestic localization of the semiconductor industry, and the European Commission unveiled the EU Chips Act, which merges political, industrial, and financial support, including, to some extent, encouraging members states to use strategic subsidies to encourage the localization of the semiconductor industry in the EU (Timmers, 2022). The United States has traditionally used industrial policy in a number of sectors, including R&D by government institutions, restrictive government procurement techniques, strategic subsidies, investment, and many other means. For the EU, the introduction of these types of policies shows an understanding of the need to use industrial policy approaches to ensure competitiveness and the localization of industry.

In August 2022, the U.S. Congress passed The Inflation Reduction Act, the largest-ever federal bill in history to tackle climate change and energy supply chains. The act dedicates a significant component to building up renewable and EV value chains and revitalizing the domestic manufacturing economy in the United States (The White House, 2022; U.S. Department of Energy). The total expenditure envisioned for energy and climate areas is USD 369 billion, with an industrial component, which includes:

- Credits for the producers of critical mineral producers and refiners.
- Loans and grants to increase the domestic production of wind turbines, solar panels, batteries, and other energy production and storage units.



- Support for the creation of jobs within the renewable energy sector.
- The continuation of production tax credits (USD 30 billion) and investment tax credits (USD 10 billion) for clean energy manufacturing, including solar, wind, and energy storage.
- EV local content incentivization, including rules on the source of batteries and critical minerals.
- USD 250 billion in tax credits, grants, and other direct spending to drive demand for advanced energy technologies.

As countries around the world either near-shore or localize advanced technology and renewable value chains, ASEAN country governments will need to ensure the provision of sufficient incentives for manufacturers, the bolstering of domestic demand, and the prevention of a global race to the bottom in terms of the environmental and social aspects of critical mineral value chains and downstream production.



## 6.0 Examples of Possible Value Chain Options and Relevant Policy Considerations

AMS—and ASEAN as a regional grouping—are well positioned to capture value and spur development from critical minerals and downstream mineral-based manufacturing supply chains. Acknowledging the varying levels of economic maturity and stages within each country and their strategies for critical minerals, the creation and regional integration of downstream value chains will require significant planning and coordination to ensure that benefits are evenly distributed. Based on the minerals present in the region, as well as the ongoing economic development of various value chains, AMS can pursue a wide range of possible use and industrial strategies. While the in-depth analysis of all possible supply chains is beyond the scope of this report, the following section presents case studies and provides a rationale and policy considerations, as well as an initial assessment of prospective areas for ASEAN to be developed in a regional and holistic way, ordered based on the possibility and technological frontier of ASEAN countries today.

First, the further development of the vertically integrated EV value chain shows how ASEAN economies can work together to create a globally significant industry. Second, the large increases in consumption will result in ever-increasing amounts of industrial and electronic waste. Such growth, coupled with already significant mining sectors, might lead to the development of a mineral recycling industry, which could ease the burden on primary production. The third and final example explores the transition to high-value industrial electronics—namely robotics and additive manufacturing—with local manufacturing capabilities and world-leading R&D contributing to the development of a prominent sector that could further drive advancements in not only the ASEAN region but the world as well.

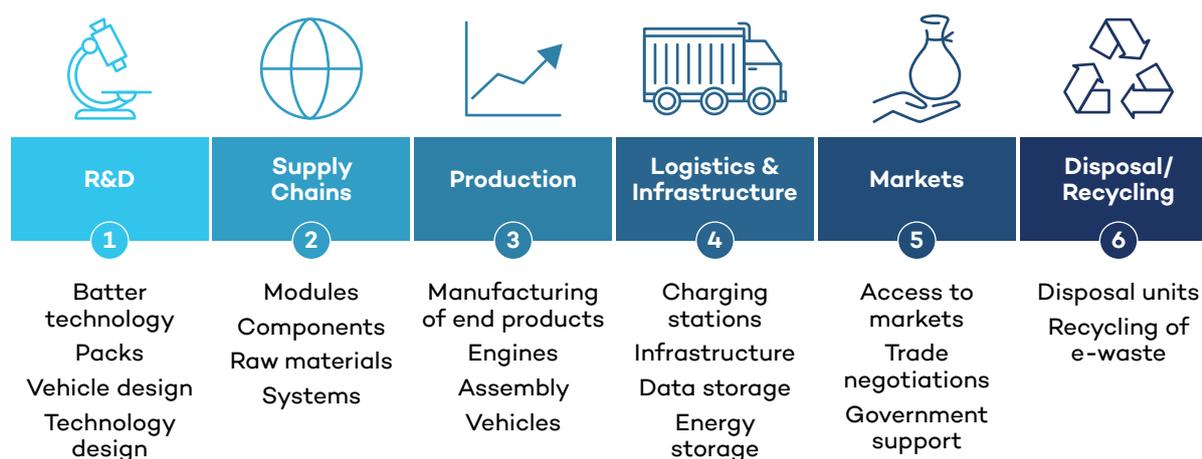
### 6.1 Regionally Integrated Electric Battery and EV Value Chains

Several ASEAN members have announced concrete, investment-backed plans to pursue EV manufacturing, with Indonesia building a vertically integrated value chain from ores to electric batteries to EVs. The li-ion batteries, EVs, and green technologies needed for the age



of the energy transition are all much more mineral-intensive than their predecessors, and the ASEAN countries hold a strong position due to their significant advantage in producing and refining many of the critical minerals needed. The region already boasts at least one globally competitive automotive manufacturer (Thailand), and a number of smaller automotive industries have automotive supply chains that are highly integrated with the other East Asian and global economies.

**FIGURE 12.** Integrated battery supply chain



Source: Author's own illustration

As both regional and global demand for electric batteries and EVs accelerate in the coming years and decades, ASEAN can foster wider regional cooperation to build a truly integrated, globally competitive EV value chain, including two- and three-wheelers or electric buses and trucks. Developing this sector would significantly enhance the value of the region's natural resources, spur innovation and productivity, and contribute to job creation and socio-economic development more broadly. Significant benefits would also be derived from the domestic deployment of electromobility.

While building a strong export-led sector, ASEAN and regional governments must, however, also balance demand- and supply-side policies to ensure uptake and consumption at home and should simultaneously address both channels. Many ASEAN countries have already started this process with key policies and incentives across the entire EV value chain (see Section 5.4), including, for example, Singapore's Green Plan 2030, which covers transportation, Indonesia's EV adoption incentives, Bali's electric bus system, and Thailand's clean mobility program. Nonetheless, ASEAN must ensure these processes are pursued holistically across the region.

On the demand side, ASEAN and AMS should target key areas, including

- **Research and market overview:**
  - Develop comprehensive analyses of regional and global trends regarding EV adoption, capturing local demand variations and potential for deployment with a focus on lower- to mid-tier segments, including two- and three-wheelers and public transport.



- **Infrastructure and an overhaul of the current energy mix and system:**
  - Spur policies to ensure the development of charging infrastructure in both urban zones and more rural areas.
  - Harmonize charging infrastructure to facilitate regional EV uptake across different countries and technologies.
  - Ensure EV roll-out is compatible with current city designs and promote best practices in smarter city development.
- **Wider electrification policies:**
  - Propose comprehensive policies for the green electrification of public transport in major cities.
  - Speed up the adoption of renewable technologies to ensure zero-carbon electricity supply for EVs.
  - Promote prosumers and self-consumption of small-scale renewable generation for EV home-charging.
- **Targets and incentives:**
  - Push for the adoption of binding EV adoption targets at the national and regional levels.
  - Promote awareness and financial incentives for first-time buyers and consumers looking to switch to EVs. Incentive schemes could include tax rebates and direct subsidies to EV buyers, such as purchase premiums.

On the manufacturing side, ASEAN members can propel the development and regionalization of the battery sector and EV sector through

- **Regulation:**
  - Harmonize and streamline transparent and consistent regulations regarding the mining, battery, and EV segments to reduce investor risk perception.
  - Attract additional investment into mining and refining capabilities while ensuring the strictest ESG standards are followed.
  - Develop policies to manage the disposal of—and foster recycling of—used batteries and conventional vehicles. Put in place policies and incentives for the disposal of future batteries and EVs.
- **Suppliers:**
  - Encourage and finance the domestication of component manufacturing and support the repurposing or upgrading of existing suppliers to ICE value chains.
  - Ensure harmonization of quality standards and procurement processes to allow local suppliers to provide components to multiple OEMs.
  - Formulate regional strategies to source critical minerals that are not present in the region from global markets.



- **Research, development, and innovation:**
  - Create regional and global knowledge-sharing networks in battery and EV manufacturing, including through partnerships between universities, the private sector, EV associations, and other key stakeholders.
  - Work with universities and training institutes to adapt their offerings to cater to the technical needs of the integrated EV value chains.
  - Ensure that inward FDI includes provisions for local content, both in terms of component source and employment, to encourage up-skilling and learning-by-doing approaches.
- **Environmental and social considerations:**
  - Conduct rigorous and comprehensive environmental and social impact assessments on the impacts of the industry and a discussion of findings with local stakeholders and civil society.
  - Create harmonized common frameworks for the environmental and social impacts of manufacturing value chains for the region, including robust emissions and life-cycle assessments of the industries.
  - Support companies in cost-saving measures and encourage design and production decisions that maximize the possibility of secondary metal production.

## 6.2 Recycling and Circular Economy Value Chains

Recycling and circular approaches to metals and minerals will play a fundamental role in decreasing the pressure on primary production and improving environmental sustainability in the coming decades. ASEAN currently lags behind other regions in the recycling of bulk metals, including copper, steel, and aluminum, but increasing consumption rates of electronics and manufactured products in the coming years, paired with the rapid deployment of the EV sector, may hold significant promise for secondary metals recovery. Time lags between technology product sales and end-of-life vary significantly by product segment but may provide ASEAN with a good opportunity to use the next decade to develop advanced recycling capacity.

A close alignment between ASEAN members and significant policy efforts will be required to build out an efficient and economically sustainable recycling ecosystem, which can lead to closer regional integration.

- **Regional scoping:**
  - Conduct extensive regional and global scoping on the outlook and expectations for e-waste, industrial waste, and mineral-containing goods.
  - Connect mining companies with scientists and experts for first assessments of potential mineral recovery from existing mining tailings and waste.
  - Investigate the potential reuse applications in ASEAN based on production and demand profiles.
  - Assess recycling economies of scale and comparative advantages for all AMS.



- **National policies:**
  - Support existing recycling infrastructure and enable data sharing across recyclers at a regional level.
  - Provide support for the creation of national and regional strategies and standards on metal recycling.
  - Ensure the codification and harmonization of ASEAN members' policies, ensuring coherence and compatibility.
- **Regulations:**
  - Develop robust regional policies tackling material flows, incorporating risk and hazard assessments of, for example, chemical leakages, managing toxic wastes, etc.
  - Liaise with global actors to adopt best practices in ensuring cohesive and seamless integration across all AMS.
- **Established segments:**
  - Set up schemes incentivizing the collection of commonly used bulk metals from consumer and industrial segments.
  - Incentivize and support already well-researched and commercialized recycling capabilities for bulk metals.
  - Assess the desirability and feasibility of processing and recycling metals and products from outside the ASEAN region.
- **Research:**
  - Form partnerships with regional and global research institutes and universities to keep up to date on state-of-the-art advances in metal recycling and recovery.
  - Ensure that global knowledge is adapted to local contexts, including for the reuse of manufactured products.
- **Feedback loops:**
  - Periodically coordinate with industrial players to assess developing trends and patterns in metal and mineral consumption.
  - Work with manufacturers to ensure that “design for recycling” decisions are made during planning and design to ease recycling processes.
  - Locate recycling facilities closer to industrial battery and EV production sites, as well as closer to consumer end markets, to increase metal inputs in the recycling process.

## 6.3 Advanced Manufacturing, 3D Printing, and Robotics Value Chains

While still a new frontier segment for many ASEAN nations, the ambitious plans to expand regional manufacturing value chains and enter more highly specialized and complex industries



(such as the li-ion and the EV industries) will create significant opportunities for the adoption of Industry 4.0 technologies. Singapore and Thailand are already early adopters of advanced robotics in production processes, and additive manufacturing (3D printing) is utilized in Malaysia, Thailand, and Singapore (Singhal et al., 2021).

Many Industry 4.0 technologies, including robotics and 3D printing, are highly mineral-intensive, featuring many of the metals already produced and refined by ASEAN members. Furthermore, the proliferation of smart factories, expansion of Internet of Things technologies, and progressive switch to cloud computing will require significant rollouts of infrastructure requiring significant mineral inputs, including data warehousing and interconnections. As Industry 4.0 technologies are implemented globally, there could be potential for ASEAN members to enter the production of these value chains, given existing manufacturing capabilities, Singapore's role as a finance and innovation hub, and strong domestic implementation and export potential.

As ASEAN members adopt advanced production technologies, the manufacturing of Industry 4.0 technologies will require broad policy support, including

- **Market scoping:**
  - Develop a more robust understanding of the upcoming trends in Industry 4.0 technologies, as well as their applicability and potential in the ASEAN region and globally.
  - Liaise with early adopters from the region to understand their technological needs, mapping this to existing capacities, R&D, and minerals produced in the region.
  - Assess implementation possibilities across all ASEAN members, as well as which functions, if any, could be localized in smaller Member States.
  - Assess existing linkages, if any, to the production of Industry 4.0 technologies.
- **Capacity development:**
  - Create and encourage knowledge sharing between global and regional industry leaders, academia, and innovation institutes.
  - Gear initial local skills development to the operation of Industry 4.0 technology, but also to advanced engineering, by creating partnerships with world-leading universities.
- **Research and innovation:**
  - Utilize Singapore's unique innovation and high-tech ecosystem to attract research functions in Industry 4.0 technology manufacturing to the region.
  - Overcoming the lack of patents or regional knowledge in Industry 4.0 tech will require strong industry partnerships, which can be stimulated through incentives to localize production by internationally established companies.



## 7.0 Conclusions and Policy Recommendations

Critical and strategic minerals present a significant opportunity for ASEAN. Regional mineral and manufacturing value chains have seen strong growth in the last decade, with increasingly ambitious goals of adding value to the region's natural resources and moving up the value chain to advanced products, including those crucial to the energy and digital transformations. Many AMS have robust existing production capacities and have successfully entered both regional and global markets for these advanced products. With world-leading mineral production, strong regional interconnectivity, and investment inflows, ASEAN as a region can take advantage of critical minerals to further enhance its own industrial production and export baskets while further integrating smaller AMS into regional value chains. At a regional level, these activities can contribute to the higher adoption of energy and digital technologies; the creation of new, higher-skilled jobs; and increases in R&D, which can have positive spillovers into other sectors. In the long term, approaches to and policies developed for the region's critical minerals and mineral-based value chains may not only further spur sustained socio-economic development but also transitions to more sustainable modes of production and circular economies.

However, any value chain selected for prospective regional development must incorporate not only existing producers and capabilities but also emerging countries that are still developing their mineral and manufacturing sectors and skills. Within ASEAN, this represents a significant opportunity, given not only the region's endowments and strengths but also the existing synergies and strengths between Member States. To truly conceptualize a robust, holistic, and overarching strategy for mineral-based value chain development, policies will have to be adopted and implemented at both the country and regional levels. Below are key recommendations for AMS, ASEAN as a region, and the ASEAN Secretariat (ASEC) on possible pathways forward and key considerations.

### 7.1 ASEAN Member States

Each ASEAN Member State possesses unique characteristics and varying levels of development regarding its mineral and downstream manufacturing sectors. When approaching the topic of critical minerals, each Member State must assess its own mineral



base and industrial plans holistically to determine the best course of action. Across the region, all countries and their governments should

- **Define what critical or strategic minerals mean:** This includes not only creating lists or strategies of which minerals are strategic for the local economy, industries, or export, but it may also involve commissioning further exploration activity, production, or refining capacity additions, as well as assessing which minerals are crucial for present and futures industries.
- **Encourage cross-departmental planning and holistic, strategic thinking:** The success of robust critical mineral-based strategies requires inputs, planning, and programming at the country level. This means aligning plans, policies, and regulations across multiple ministries and governmental bodies, including but not limited to ministries of mining, economy, finance, trade and investment, environment, and others. This also means taking a more active role in defining possible projects through sound economic and investment assessments and derisking projects to mitigate adverse impacts on countries and communities. Buy-in from all stakeholder groups and alignment is fundamental to any successful long-term policy.
- **Assess partnerships and opportunities, learning from best practice:** To pursue successful mineral-based value chain development, a myriad of factors is necessary, including securing investment and obtaining and scaling up domestic technological knowledge and up-skilling. Ensuring technology transfers; adopting best practices from international partners, research institutes, and universities; and utilizing learning-by-doing approaches can lead to significant long-term benefits and economic spillovers.
- **Help coordination between businesses across the value chain:** Coordination failures are common, and strategic interventions and dialogue with businesses are necessary to ensure that miners and manufacturing producers are securing the mineral supplies needed for production. Keeping channels and feedback loops open will also enable assessments of which minerals may be lacking, thereafter helping ensure a consistent supply. It will also be necessary to actively help match up local talent with producers and ensure the continuous creation of good jobs.
- **Focus on integrating ESG and circular economy approaches:** Any project or value chain must ensure environmental sustainability, social considerations, and the involvement of civil society in all key processes. National governments have a primary role to play in setting policies and regulations and providing the right incentives to producers to ensure adherence to sustainability and to consumers and society at large to conserve, recycle, and reuse resources.

## 7.2 ASEAN as a Region

At the broader regional level, extensive coordination and cooperation among the AMS will be required to ensure robust and resilient mineral and industrial supply chains. The different AMS greatly complement each other, with significant strengths and synergies developed over decades of increasing regional integration. As such, any prospective regional value chains should aim to take advantage of various ASEAN members' skills and competitive advantages. To take advantage of these, all stakeholders should



- **Identify and tap into regional synergies and make regional cooperation a priority:** While regional integration has been steadily increasing, more can be done to further integrate smaller members into planned mineral-based value chains. Successful industrial development requires significant inputs besides minerals and productive capabilities that include finance, R&D, services, IT, logistics, design, marketing, and other key components. Strengths and opportunities should be identified at the regional level by governments and businesses, with ASEC and other stakeholders playing key roles as convenors and facilitators. Value chains should be spread across all Member States, and incentive structures must be well designed to enable localization, which should contribute to local economic benefits, up-skilling, and technological advancement. This also includes the longer-term development of logistical capabilities and transportation cost reductions in the region to encourage increased flows.
- **Increase the rate of interaction, information sharing, and exposure:** Stronger cooperation can stem from greater rates of information and knowledge sharing, as well as interaction between stakeholders. More frequent and targeted exchanges between regional governments, businesses, and research bodies should be promoted, with systems set up to better connect actors within mineral-based value chains. Organizing more expos, events, and strategic dialogues, as well as a regional match-up system for smaller businesses and suppliers, can further accelerate regional integration.
- **Collaborate with other countries/regional blocs:** Together, the AMS form a globally significant economic bloc, with strength stemming from the collective capabilities of all 10 members. Highlighting ASEAN as a region can be more powerful in attracting localization and further investment. Exploring further partnerships with countries where ASEAN already has established relations or active work plans and promoting opportunities in the region collectively can improve the adoption of new technologies and best practices. This approach should also be complemented with further intergovernmental partnership development.

## 7.3 ASEAN Secretariat

ASEC and various ASEAN-led, mineral-focused programs and initiatives are fundamental to developing robust and sustainable critical mineral and downstream manufacturing sectors. As the organizing body, ASEC can further enhance and bolster the efforts of AMS and should

- **Define what regional critical or strategic minerals can be:** ASEC should play a dual role in terms of the definitions and strategies for critical minerals. First, it should assist AMS with the creation of their own strategies and visions through the convening of meetings, dialogues, and studies to encourage thinking and the adoption of best practices. In this capacity development role, ASEC should act as the chief convenor and organizer to enable AMS to solidify their views on critical minerals. Second, ASEC should actively work with AMS to create a regional definition and vision of what critical minerals mean and how to ensure everyone's views are taken into consideration. This should be an ongoing, iterative process that ensures regional visions and strategies are evolving in line with developments.



- **Act as convener and facilitator among Member States and cross-sectoral bodies:** In line with the cross-departmental approaches recommended at the country level, ASEC should bring together not only AMS but also different ASEAN sectoral bodies and policy/task groups within the ASEAN organization to contribute to critical mineral strategies and value chains. Ensuring representatives focusing on mining, economic, financial, environmental, circular economy, social, and governance topics are present and have input into regional strategies is fundamental to alignment and long-term cohesion.
- **Work with countries to harmonize policies and regulations:** Despite the already high level of integration among AMS, any project relating to critical minerals or downstream value chain development must consider regulatory aspects but also push for longer-term policy harmonization across Member States. Harmonized policies related to, for example, e-mobility or recycling can encourage further regional market integration, including more spread-out localization of production and wider regional benefits, including spillovers and the development of new industries. ASEC can play a key role in working with AMS to harmonize and align these policies and regulations.
- **Provide thought leadership and push for commitments in the ESG fields:** In line with the AMS striving for greener and more sustainable extractive sectors and economies, ASEC should promote ESG and circular economy approaches and work with stakeholders and thought leaders, both within the region and globally, to help set the highest standards on the path to greater sustainability.
- **Liaise strategically with businesses and international partners:** Given its coordinating and steering role, ASEC should seek to form international partnerships with like-minded organizations and leaders from business, research, and academia to keep up to date on trends and best practices in the critical mineral space. In parallel, through regional partner organizations, ASEC should continue to seek to further promote trade and investment in AMS while ensuring sustainability and equitable development.
- **Spur innovative, long-term, and strategic thinking:** In line with previous recommendations, ASEC should ensure that AMS and collective regional thinking and understanding of the trends and developments in critical minerals and advanced technologies are constantly being kept up to date. This also means providing the necessary knowledge and support to enable countries and the region to have the foresight and necessary technical ability to make long-term, data-driven, and financially robust strategic decisions in their future value chain development strategies.



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## Appendix A.

**TABLE A1.** List of critical minerals in the European Union, the United Kingdom, the United States, Canada, and Australia

	European Union critical raw materials, 2023	United States critical minerals, 2021	Canada critical minerals, 2021	Australia critical minerals, 2020	United Kingdom critical minerals, 2022	Minerals produced in the ASEAN region
Aluminum	✓	✓	✓			
Antimony	✓	✓	✓	✓	✓	
Arsenic	✓	✓				
Baryte	✓	✓				
Bauxite	✓					
Beryllium	✓	✓		✓		
Bismuth	✓	✓	✓	✓	✓	
Borates	✓					
Cerium		✓	✓			
Chromium		✓	✓	✓		
Cobalt	✓	✓	✓	✓	✓	
Coking coal	✓					
Copper	✓		✓			
Fluorspar	✓	✓	✓			
Gallium	✓	✓	✓	✓	✓	
Germanium	✓	✓	✓	✓		
Graphite	✓	✓	✓	✓	✓	
Hafnium	✓	✓		✓		
Helium	✓		✓	✓		
Indium		✓	✓	✓	✓	
Lithium	✓	✓	✓	✓	✓	
Magnesium	✓	✓	✓	✓	✓	



	European Union critical raw materials, 2023	United States critical minerals, 2021	Canada critical minerals, 2021	Australia critical minerals, 2020	United Kingdom critical minerals, 2022	Minerals produced in the ASEAN region
Manganese	✓	✓	✓	✓	i	
Natural rubber						
Molybdenum			✓			
Nickel	✓	✓	✓		i	
Niobium	✓	✓	✓	✓	✓	
Phosphate rocks	✓					
Phosphorus	✓				i	
Potash			✓			
Rare-earth elements	✓	✓	✓	✓	✓	
Rhenium				✓		
Silicon metal	✓				✓	
Tantalum	✓	✓	✓	✓	✓	
Strontium	✓					
Tellurium		✓	✓		✓	
Rubidium		✓				
Tin		✓	✓		✓	
Titanium	✓	✓	✓	✓		
Tungsten	✓	✓	✓	✓	✓	
Vanadium	✓	✓	✓	✓	✓	
Uranium			✓			
Zinc		✓	✓			
Zirconium		✓		✓		



	European Union critical raw materials, 2023	United States critical minerals, 2021	Canada critical minerals, 2021	Australia critical minerals, 2020	United Kingdom critical minerals, 2022	Minerals produced in the ASEAN region
<b>Platinum Group Metals (PGMs) - 6 metals</b>						
Ruthenium	✓	✓	✓	✓	i	
Rhodium	✓	✓	✓	✓		
Palladium	✓	✓	✓	✓	✓	
Osmium	✓	✓	✓	✓		
Iridium	✓	✓	✓	✓	i	
Platinum	✓	✓	✓	✓	✓	

Note:

✓ The mineral or metal is included in the official list of critical minerals of the country and/or region.

i UK watch list.

■ The mineral or metal is produced in ASEAN region.



## Appendix B.

**TABLE B1.** ASEAN mineral production shares: 5-year regional and global trend

Mineral	Unit	2015 ASEAN as % of world	2020 ASEAN as % of world	ASEAN absolute production trend (2015–2020)	Global production trend (2015–2020)
Nickel	tonnes	28.11%	46.84%	137.00%	-10.64%
Tin	tonnes	42.26%	34.84%	-6.06%	-3.72%
Steam coal	tonnes	8.87%	10.90%	29.06%	-1.22%
Bismuth	tonnes	25.67%	10.44%	-54.45%	-1.94%
Tungsten (W)	tonnes	4.94%	9.37%	-5.19%	-5.22%
Rare earths (REO)	tonnes	0.64%	9.35%	344.82%	64.81%
Bauxite	tonnes	10.13%	7.93%	140.81%	31.90%
Gypsum and anhydrite	tonnes	9.11%	6.34%	-14.20%	14.87%
Zircon	tonnes	2.61%	6.09%	79.09%	-21.84%
Antimony	tonnes	2.93%	5.46%	110.30%	-16.88%
Feldspar	tonnes	10.74%	5.44%	-32.86%	16.49%
Natural gas	Mio m <sup>3</sup>	6.27%	5.03%	-3.53%	11.88%
Kaolin (China- Clay)	tonnes	3.09%	5.02%	151.97%	8.52%
Lignite	tonnes	2.40%	4.47%	-0.60%	-24.15%
Copper	tonnes	4.82%	4.30%	-25.87%	8.00%
Manganese	tonnes	2.03%	3.95%	96.39%	18.07%
Cobalt	tonnes	3.08%	3.06%	2.91%	-12.17%
Fluorspar	tonnes	3.64%	3.03%	8.90%	20.97%
Selenium	tonnes	2.14%	3.00%	11.11%	0.90%
Gold	kg	4.17%	2.90%	7.13%	4.33%



Mineral	Unit	2015 ASEAN as % of world	2020 ASEAN as % of world	ASEAN absolute production trend (2015–2020)	Global production trend (2015–2020)
Baryte	tonnes	3.57%	2.14%	-59.38%	-15.71%
Petroleum	tonnes	2.56%	2.14%	-11.97%	-3.13%
Phosphate rock (P <sub>2</sub> O <sub>5</sub> )	tonnes	1.07%	1.88%	41.58%	-16.17%
Aluminum	tonnes	1.20%	1.84%	14.79%	12.23%
Sulphur (elemental & industrial)	tonnes	2.04%	1.74%	-7.43%	2.11%
Salt (rock, brines, marine)	tonnes	2.03%	1.68%	40.24%	-7.97%
Titanium (TiO <sub>2</sub> )	tonnes	1.94%	1.51%	3.52%	28.78%
Silver	kg	1.08%	1.48%	57.44%	-7.61%
Lead	tonnes	0.42%	1.03%	108.09%	-5.37%
Potash (K <sub>2</sub> O)	tonnes	0.63%	0.98%	44.46%	11.43%
Iron (Fe)	tonnes	0.34%	0.61%	46.84%	4.40%
Coking coal	tonnes	0.20%	0.53%	72.22%	-5.69%
Talc, steatite & pyrophyllite	tonnes	0.70%	0.50%	-85.99%	2.10%
Graphite	tonnes	0.00%	0.39%		-16.85%
Zinc	tonnes	0.58%	0.34%	-22.20%	-5.30%
Tantalum (Ta <sub>2</sub> O <sub>5</sub> )	tonnes	0.51%	0.12%	-75.00%	-3.50%
Chromium (Cr <sub>2</sub> O <sub>3</sub> )	tonnes	0.05%	0.12%	41.46%	-9.74%
Perlite	tonnes	2.07%	0.12%	-60.30%	20.58%
Bentonite	tonnes	0.02%	0.03%	240.73%	14.69%
Magnesite	tonnes	0.03%	0.00%	-99.61%	-0.17%



## Appendix C.

**TABLE C1.** Relevant country-level policies and regulations

Country	Key instrument	Relevant instruments for large-scale mining
Brunei	Relevant legislation	Mining Act revised edition 1984
Cambodia	Policy statements	National Environment Strategy and Action Plan 2016-2023
	Relevant legislation	Law on Mineral Resource Management and Exploitation 2001
	Relevant legislation	Law on Forestry 2002
	Relevant legislation	Land Law 2001
	Relevant legislation	Sub-Decree No. 72, The Management of Mineral Resource Exploration License and Industrial Mining License
	Relevant legislation	Circular No. 360, Guideline for Granting Mineral Exploration License
Indonesia	Policy statements	The National Medium-Term Development Plan for 2020-2024
	Policy statements	Low Carbon Development Report: A paradigm shift towards a green economy in Indonesia
	Relevant legislation	Law No. 4 of 2009 on Mineral and Coal Mining
	Relevant legislation	Presidential Regulation No. 55/2019
	Relevant legislation	Law No. 11 of 2020 on Job Creation
	Relevant legislation	Law No. 32 of 2009 on Environmental Protection
	Relevant legislation	Law No. 3 of 2020 on the Amendment to Law No. 4 of 2009 on Mineral and Coal Mining
	Relevant legislation	Law No. 5 of 1960 of the Basic Agrarian Principles
	Relevant legislation	GR 23/2010 on the implementation of Coal and Mineral Mining Business Activities amended by GR 24/2012, GR 1/2012, GR 77/2014, GR 1/2017, GR 8/2018



Country	Key instrument	Relevant instruments for large-scale mining
Indonesia (continued)	Relevant legislation	GR 55/2010 on the Development and Monitoring of the Implementation of Coal and Mineral Mining Business Activities
	Relevant legislation	GR 78/2010 on Reclamation and Post-Mining Activities
	Relevant legislation	GR 81/2019 on the Types and Tariffs for Non-Tax State Revenues Applicable to the Ministry of Energy and Mineral Resources
	Relevant legislation	GR 5/2021 on Risk-Based Business Licensing
	Relevant legislation	GR 25/2021 on the Organization of the Energy and Mineral Resources Sector
	Relevant legislation	MEMR Regulation 43/2015 on the Procedure for the Evaluation of the Issuance of Coal and Mineral Business Licenses
	Relevant legislation	MEMR Regulation 7/2017 on the Procedure for Determining Coal and Mineral Benchmark prices as amended by MEMR Regulation 44/2017, MEMR Regulation 19/2018 and MEMR Regulation 11/2020
	Relevant legislation	MEMR Regulation 9/2017 on the Divestment Procedure and Price Determination Mechanism for the Divestment of Shares in Coal and Mineral Mining Businesses as amended by MEMR Regulation 43/2018
	Relevant legislation	MEMR Regulation 48/2017 on the Supervision of Business Activities in the Energy and Mineral Resources Sector as amended by MEMR Regulation 7/2020
	Relevant legislation	MEMR Regulation 25/2018 on Coal and Mineral Mining Business as amended by MEMR Regulation 17/2020



Country	Key instrument	Relevant instruments for large-scale mining
Indonesia (continued)	Relevant legislation	MEMR Regulation 26/2018 on the Implementation of Good Mining Principles and the Supervision of Coal and Mineral Mining
	Relevant legislation	MEMR Regulation 7/2020 on Procedures for the Granting of Areas, Licensing and Reporting of Coal and Mineral Mining Business
Lao PDR	Policy statements	National Green Growth Strategy of the Lao PDR till 2030
	Relevant legislation	Law on Minerals (Law No. 291 of 2017)
	Relevant legislation	Presidential Edict No. 001/P dated 15 December 2015 (“the Edict”) regarding the royalty rate for natural resources
Malaysia	Policy statements	National Mineral Industry Transformation Plan 2020–2030
	Relevant legislation	The Mineral Development Act 1994
	Relevant legislation	National Mineral Policy
	Relevant legislation	Mineral Development (Operational Mining Scheme, Plans and Record Books) Regulations 2007
	Relevant legislation	Mineral Development (Blasting) Regulations 2013
	Relevant legislation	Mineral Development (Safety in Exploration and Surface Mining) Regulations 2014
	Relevant legislation	Mineral Development (Licensing) Regulations 2016
	Relevant legislation	Mineral Development (Effluent) Regulations 2016
	Relevant legislation	Mineral Development (Statistical Return) Regulations 2019
	Relevant legislation	Mineral Development (Compounding of Offences) Regulations 2019
Relevant legislation	Environmental Quality Act 1974	



Country	Key instrument	Relevant instruments for large-scale mining
Myanmar	Policy statements	Myanmar Sustainable Development Plan (2018 – 2030)
	Relevant legislation	Amendment to the Myanmar Mines Law, 2015
	Relevant legislation	Myanmar Mines Law 1994
	Relevant legislation	Myanmar Mines Rules 2018
	Relevant legislation	Myanmar Investment Rules 2017
	Relevant legislation	Environmental Conservation Law 2012
	Relevant legislation	MIC Notification No. 10/2017(Designation of Development Zones)
	Relevant legislation	MIC Notification No. 11/2017 (prescribed Investment Capital Amendments)
	Relevant legislation	MIC Notification No. 13/2017 (Classification of Promoted Sectors)
	Relevant legislation	MIC Notification No. 15/2017 (List of Restricted Investment Activities)
	Relevant legislation	State-Owned Economic Enterprises Law 1989
Philippines	Policy statements	Philippine strategy for sustainable development
	Relevant legislation	Republic Act No. 7942 (the “Philippine Mining Act”)
	Relevant legislation	Executive order No. 79, s. 2012 (Institutionalising and Implementing Reforms in the Philippine Mining Sector, Providing Policies and Guidelines to Ensure Environmental Protection and Responsible Mining in the Utilisation of Mineral Resources)
	Relevant legislation	Executive order No. 130, s. 2021
	Relevant legislation	The Constitution of the Republic of the Philippines
	Relevant legislation	Republic Act No. 7076 (the “People’s Small Scale Mining Act of 1991)



Country	Key instrument	Relevant instruments for large-scale mining
Philippines (continued)	Relevant legislation	Republic Act No. 8749 (the “Clean Air Act”)
	Relevant legislation	Republic Act No. 9003 (the “Ecological Solid Waste Management Act”)
	Relevant legislation	Republic Act No. 8371 (the “Indigenous Peoples’ Rights Act”)
Thailand	Policy statements	The 20-Year National Strategy Framework (2017–2036)
	Relevant legislation	Minerals Act, B.E. 2560 (A.D. 2017)
	Relevant legislation	Foreign Business Act, B.E. 2542 (A.D. 1999)
	Relevant legislation	Constitution of the Kingdom of Thailand
	Relevant legislation	National Environmental Quality Act, B.E. 2535 (A.D. 1992)
	Relevant legislation	MR BE 2561 (2018)
Viet Nam	Policy statements	Mineral resources strategy to 2020, with a vision toward 2030
	Policy statements	Viet Nam Green Growth Strategy
	Relevant legislation	Law on Minerals
	Relevant legislation	The Constitution of Viet Nam
	Relevant legislation	Directive No. 2/CT-TTg of January 2012
	Relevant legislation	Decree No. 15/2015/ND-CP
	Relevant legislation	Circular No. 158/2011/TT-BTC
	Relevant legislation	Decree No. 203/2013/ND-CP
	Relevant legislation	Resolution No. 712/2013/UBTVQH13
	Relevant legislation	Decree No. 122/ND-CP
	Relevant legislation	Decree No. 124/2008/ND-CP
	Relevant legislation	Law on Enterprise Income Tax No. 14/2008/QH12



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