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BUSINESS MODEL FOR THE DEVELOPMENT OF ION-ADSORPTION CLAY RARE EARTHS INDUSTRY IN MALAYSIA

MINISTRY OF NATURAL RESOURCES AND
ENVIRONMENTAL SUSTAINABILITY

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ASM	Academy of Sciences Malaysia
BMP	Best Management Practices
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CEPA	Communication, Education and Public Awareness
CERRM	Centre of Earth Resources Research and Management
CoE	Centre of Excellence
CRIRSCO	Committee for Mineral Reserves International Reporting Standards
CRM	Certified Reference Material
CSR	Corporate Social Responsibility
DOE	Department of Environment
DOSM	Department of Statistics Malaysia
EITI	Extractive Industries Transparency Initiative
EKM	Electrokinetic Mining
EL	Exploration License
ESA	Environmental Sensitive Area
ESG	Environmental, Social and Governance
EV	Electric Vehicle
FDI	Foreign Direct Investments
FESEM	Field Emission Scanning Electron Microscopy
FGD	Focus Group Discussion
GHG	Green House Gases
GLC	Government-Linked Companies
GRI	Global Reporting Initiative
GRPS	Global Risks Perception Survey
HREE	Heavy Rare Earth Elements
IAC	Ion Adsorption Clay
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ICP-OES	Inductively Coupled Plasma-Optical Emission Spectroscopy
IIRC	International Integrated Reporting Council
ISCC	International Sustainability Carbon Certification

LIST OF ACRONYMS

ISL	In-situ Leaching
ITA	Investment Tax Allowance
ITSCI	International Tin Supply Chain Initiative
IX	Ion Extraction
JMG	Department of Mineral and Geoscience Malaysia
JORC	Australasian Joint Ore Reserves Committee
JV	Joint Venture
KASA	Ministry of Environment and Water
KeTSA	Ministry of Energy and Natural Resources
LA-ICP-MS	Laser Ablation Inductively Coupled Plasma Mass Spectrometry
LAMP	Lynas Advanced Material Plant
LOV	Loss of Value
LREE	Light Rare Earth Elements
MCOM	Malaysian Chamber of Mines
MIDA	Malaysian Investment Development Authority
MITI	Ministry of Investment, Trade and Industry
ML	Mining Lease
MMRC	Malaysian Mineral Resource and Reserve Reporting Code
MOF	Ministry of Finance
MOHR	Ministry of Human Resources
MOSTI	Ministry of Science, Technology and Innovation
MoU	Memorandum of Understanding
MRTP	Malaysia Rare Earths Technology Park
NCER	Northern Corridor Economic Region
NGOs	Non-Governmental Organizations
NMC	National Mineral Council
NMP2	National Mineral Policy 2
NPI	Net Positive Impact
NRE	Ministry of Natural Resources and Environment
NRECC	Ministry of Natural Resources, Environment and Climate Change
NRES	Ministry of Natural Resources and Environmental Sustainability
NR-REE	Non-Radioactive Rare Earth Elements
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturing
OMS	Operational Mining Scheme
OPEX	Operating Expenditure
PL	Prospecting Licence

PML	Proprietary Mining Licence
PPM	Mineral Research Centre
PFR	Permanent Forest Reserves
PTG	Office of The Director of Land and Mines
REC	Rare Earth Carbonates
REE	Rare Earth Elements
RFID	Radio-frequency Identification
REO	Rare Earth Oxides
REPP	Rare Earths Processing Plant
RERC	Rare Earth Research Centre
11MP	11th Malaysia Plan
12MP	12th Malaysia Plan
ROV	Return on Value
SASB	Sustainability Accounting Standards Board
SDG	Sustainable Development Goals
SIA	Social Impact Assessment
SME	State Mineral Enactment
SMEs	Small and Medium Enterprises
SMRC	State Mineral Resources Committee
SOP	Standard Operating Procedure
SSM	Companies Commission of Malaysia
SWOT	Strengths Weakness Opportunities Threats
SX	Solvent Extraction
TIM 2021-2030	Transformasi Industri Mineral 2021-2030
TOR	Terms of Reference
TREE	Total Rare Earth Elements
TREO	Total Rare Earth Oxide
TVET	Technical and Vocational Education Training
UAV	Unmanned Aerial Vehicles
UKK	Unit Komunikasi Korporat
UMK	Universiti Malaysia Kelantan
UMPSA	Universiti Malaysia Pahang Al-Sultan Abdullah
UTP	Universiti Teknologi Petronas
UNFCCC	United Nations Framework Convention Climate Change
XRD	X-Ray Diffraction Analysis
XRF	X-Ray Fluorescence

LIST OF APPENDICES

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NGO

Malaysia Nature Society	Sahabat Alam Malaysia	Treat Every Environment Special
World Wildlife Fund for Nature	EcoKnights	Sustainable Development Network Malaysia

FOREWORD

Considering the forward march of the modern age, contemporary life is greatly reliant on the advancement of technology. Nevertheless, as we eagerly embrace this modern era, it is crucial to synchronize the use of advanced technology with environmental sustainability to ensure it enhances the well-being of all communities.

To sustain this equilibrium, the government has delved into the potential of a new mineral resource called Ion-Adsorption Clay Rare-Earth Elements (IAC-REE). These resources present immense possibilities for fuelling technological progress today, given their wide-ranging applications, spanning from the manufacture of high-tech gadgets like smartphones, laptops, and TVs, to military assets, and even to the production of renewable and environmentally friendly energy sources like wind turbines and solar panels, among others.

Given the nation's reserves of IAC-REE, it's imperative to ensure their efficient utilization through responsible and sustainable production practices. Following this principle, the ministry aims to align Malaysia's IAC-REE industry development with Environmental, Social, and Governance (ESG) standards to meet the objectives outlined in the Sustainable Development Goals 2030 (SDG 2030).

With the publication of this document, it is hoped that it will serve as a reference for all stakeholders interested in developing the IAC-REE industry in Malaysia.

YB TUAN NIK NAZMI BIN NIK AHMAD
Ministry of Natural Resources and Environmental Sustainability

PREFACE

In the fast-evolving high-technology industries, the need and demand for Ion-Adsorption Clay rare earth elements (IAC-REE) and their products, are rapidly increasing, especially in the electronics, transport, energy, and defence sectors. To develop a sustainable value chain in the IAC-REE industry, it is important to develop the mining, processing and manufacturing of rare earth-based products responsibly to harvest its socioeconomic value. It is timely for the Malaysian Government to develop the IAC-REE industry on the right footing, where its activities should prioritise sustainability and well-being of the people. That's where the Environment, Sustainability, and Governance (ESG) standards come into play, guiding the industry toward a greener future.

Currently, global demand for REE is out-stripping supply, and, if net zero carbon is to be achieved by 2050. The abundance of IAC-REE resources in Malaysia give us the strength to become a global player in this industry. NRES envisions Malaysia becoming the next regional hub for rare earth-based products manufactured. Essentially, this would translate as vertical integration of a critical mineral commodity from mine to finished mass-produced products ready for end-user product fabrication. The raw materials of IAC-REE need to be mined responsibly, processed in locally established rare earth processing plants, metals and alloys plants, then go into downstream manufacturing plants for super-magnet and electric motors production.

To unlock the full economic potential of domestic IAC-REE resources towards achieving Net Zero Carbon Emissions goal by 2050, a business model for the entire rare earths ecosystem has been formulated. The study comprised the whole value chain – upstream, midstream, downstream, ESG, and the integrated business model which would serve as a guide for government agencies, both at the Federal and State levels, as well as industry players to develop respective holistic action-oriented plans.

YBHG. DATUK DR. CHING THOO A/L KIM
Secretary General
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EXECUTIVE SUMMARY

What are rare earths? Rare earths are a group of 15 elements (REE) of the lanthanide series, as well as scandium and yttrium, which make up 17 critical elements of great demand. Rare earths, which are also known as technology metals, are among the most resource-critical raw materials. They are of the highest economic importance and, at the same time, feature high supply risk considering that the supply chain is dominated by China, especially with the production of powerful rare earth magnets used in electric vehicles, wind turbines, consumer electronics, and military hardware. The COVID-19 pandemic has disrupted the global rare earths supply chains. In fact, the European Commission in 2022 stated that, "Lithium and rare earths will soon be more important than oil and gas. Our demand for rare earths alone will increase fivefold by 2030".

With the start of Lynas Malaysia in 2013, Vietnam used all the products produced by Lynas[1] in Malaysia and successfully developed the third-largest magnets manufacturing base in the world (behind China and Japan). It is regretful that Malaysia did not capitalise on this opportunity back then. Since then, Malaysia has identified large amounts of REE in ion adsorption clays. The first pilot project in Kenering, Perak, was audited up to the end of 2022 to ensure no adverse environmental impact from the practised in-situ leaching of REE. With the approval of the Standard Operating Procedure (SOP) of Non-Radioactive Rare Earth Elements (NR-REE)[2] Mining in Perak (SOP NR-REE Perak), other states in Malaysia will be ready to move into the extraction of REE from ion adsorption clays. It is anticipated that, with the extraction of IAC-REE, Malaysia can establish a full rare earths value chain from the upstream and midstream sectors to the downstream sector.

Value proposition and key strategies for each sector, as well as an integrated business model will be introduced in this report.

1. Upstream sector

(i) If 5% of the Inferred Resource of 16 million tonnes of total rare earth elements (TREE), which is equivalent to 19 million tonnes of total rare earth oxide (TREO), can be upgraded to Measured Resource, and if 75% of the Measured Resource[3] can be upgraded to Probable or Proved (mineable) Reserve (after feasibility studies by the private sector), then Malaysia will have the potential to produce 600,000 tonnes of TREE or 710,000 tonnes of TREO. With the target of producing 30,000 tonnes of TREO annually, 710,000 tonnes of mineable reserves should be able to sustain the production of IAC-REE for 23 years. It is strongly believed that IAC-REE mines can produce 7,000 tonnes of rare earth carbonate (REC), containing about 3,000 tonnes of TREO per year per mine. The footprint of mining is small as in-situ leaching (ISL) involves minimum removal of vegetation and no removal of topsoil. Upon completion of mining, the mine rehabilitation of ISL mining is easier than that of a typical open-cast mine because ISL mining involves less removal of vegetation and overburden. The involved area is also smaller, and therefore, requires shorter time to rehabilitate, as compared to open-cast mining.

(ii) With the target production of 30,000 tonnes of TREO per year, there will be opportunities for the employment of at least 3,000 employees, including local and foreign talents.

(iii) In terms of valuation, the potential (in-situ) value of the estimated 710,000 tonnes of TREO (equivalent to 1,650,000 tonnes of REC) will be RM 49 billion[4].

(iv) It is estimated that the total revenue from the 30,000 tonnes of TREO would amount to RM 2.1 billion per year (estimation based on the 2022-2023 Shanghai Metal Market REC prices).

(v) The combined royalty due to the States will amount to RM 252 million annually based on the 12% royalty ad valorem rate. Landowners will receive 3% tribute if all mining and on-site processing are to be carried out in alienated land. The total amount due to the landowners will be RM 63 million annually.

(vi) In terms of the cost for each mine, the capital expenditure (CAPEX) is estimated at RM 16 million, and the operational expenditure (OPEX) is estimated at RM 10 million.

---

1 Lynas Malaysia has the capability and capacity to produce mainly light rare earth oxides of up to 22,000 tonnes per annum of separated REO products, such as praseodymium/neodymium.

2 the use of NR-REE is officially replaced by IAC-REE to reflect the scientific nature of the type of rare earth elements found in Malaysia.

3 Assuming that if 5% of the Inferred Resource can be converted to Measured Resource, then some 950,000 tonnes of TREO covering 650 km^2 will be available for the private sector to undertake feasibility studies.

4 As of March 2023, the REC price of about USD 6,892 (RM 30,000) per tonne, containing 43% of TREO.

2. Midstream sector

(i) The establishment of Malaysia Rare Earths Technology Park (MRTP) consisting of a rare earth processing plant (REPP), with an annual processing capacity of 70,000 tonnes of REC (equivalent to approximately 30,000 tonnes of TREO).

(ii) The MRTP should also include the metal refining plant and alloys manufacturing plant. The remaining land area would be reserved for super-magnets manufacturing, components modules, electric vehicles (EVs), and end-user products manufacturing.

(iii) The REPP would be able to separate 30,000 tonnes of TREO per year and produce 10,000 tonnes of Nd/Pr oxides, with HREE being produced as by-products.

(iv) Employment of about 1,300 local employees is expected to be offered.

(v) Capital costs to set up a REPP with 70,000 tonnes of REC (30,000 tonnes of TREO) per year is estimated at RM 1.76 billion. The costs of metals and alloys plants would be an additional of RM 378.4 million.

(vi) Revenues for the separated TREOs is expected to amount to RM7.26 billion[5] by 2030.

(vii) Revenues for the NdPr alloys manufacturing plant and the plant producing 10,000 tonnes of NdPr alloys per year by 2030, when fully operational (alloys currently selling at RM 415,000 per tonne[6]), is expected to amount to RM 4.15 billion.

3. Downstream sector

Manufacturing plants to be sited in the proposed MRTP

(i) With an estimated investment of RM 3.5 billion, the manufacture of NdFeB super-magnets at production capacity of 35,000 tonnes per year would provide employment for 10,500 direct employees by 2030.

(ii) With an estimated investment of RM 3 billion, the manufacture of electric motors at production capacity of 5 million units would provide employment for 10,000 direct employees and 10% of increase in demand by 2030.

(iii) The potential revenue in 2030 from the manufacture of super-magnets is RM 8.27 billion, while that of electric motors is expected to be RM 5.32 billion.

(iv) Plants for recycling and repurposing of super-magnets and other rare earths residues are proposed to be established in line with 12MP's Circular Economy.

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[5] Based on prices of NdPr on March 2023

[6] The selling price of NdPr basic alloy on 4th April 2023 was RMB 648,000 (RM 415,000) per tonne.

4. Environment, social, and governance

An Environment, Social and Governance (ESG) materiality model is proposed. It is applicable to the rare earth industry, covering the aspects of activities/products, lifecycle stages, materiality triggers, stakeholders, and materiality components. It includes the whole ecosystem, from the upstream sector to the downstream sector, and emphasises start-up, operations, rehabilitation, residue management, and recycling.

5. Integrated business model

The upstream, midstream, and downstream sectors are seamlessly integrated to create the network, highlighting the externalities and multiplier effects. With that, it would create better economies of scale, economies of scope, and return on value (ROV) from the rare earth resources this country is blessed with.

Based on the 8R-8i values-based framework, as given in Chapter 2, the key strategies are as follows:

(i) The export of REC from the upstream sector should be allowed until the local processing plant and central buying house are established.
(ii) The midstream sector's products (alloys) are to be sent to the downstream sector's plants for the manufacture of super-magnets and energy-efficient electric motors.
(iii) Any surplus midstream sector's products are to be exported if no additional plants are set up locally.
(iv) The downstream sector's manufacturing is expanded to cater to original equipment manufacturers (OEM).
(v) Existing recycling programmes and facilities are leveraged and improved to increase recycling and repurposing of e-waste and used super-magnets and motors.
(vi) Joint ventures (JVs) and strategic partnerships with foreign partners are encouraged for knowledge and technology transfers, and domestic talent capability building.
(vii) Indigenous research and development (R&D) and innovation across all three sectors in sustainable and advanced technologies and process for REE extraction, processing, and commercial applications are encouraged and incentivised.
(viii) ESG reporting is integrated into the upstream, midstream, and downstream sectors.
(ix) Governance aspects are streamlined across all three sectors.

Timeline for the implementation of IAC-REE study's recommendations

The following timeline is proposed for the operationalisation of the study's recommendations within the timeframe of between 2024 and 2030:

TIMELINE	ACTIVITY
2024	The formation of Committee for the Development of Rare Earth Industry (ComDREI) to facilitate and monitor the implementation of recommendations
	To set up a REC central buying house as a government-linked company (GLC) to purchase and store REC before the plants are ready and operational (to prevent the export of strategic critical commodity)
2024 - 2030	To achieve the annual mine production of 70,000 tonnes of REC, containing 30,000 tonnes of TREO, with each mine producing about 7,000 tonnes of REC, containing 3,000 tonnes of TREO
2024 - 2026	The development of MRTP, including the construction of REPP and plants for metal refining, and manufacture of alloys, super-magnets, and electric motors, as well as recycling/repurposing of used REE-bearing magnets
2027 - 2030	All plants are fully operational

Major recommendations

A total of 14 major recommendations are proposed as follows:

(i) Establish a ComDREI at the federal level, with similar committees at the state level.

(ii) ComDREI to direct NRES and relevant ministries at the federal and state levels to jointly develop a strong communication, education, and public awareness (CEPA) programme.

(iii) Strengthen institutional governance to ensure the development of seamless integration of the IAC-REE (upstream, midstream, and downstream) ecosystems.

(iv) Provide sustainable economic and financial resources to develop an integrated IAC-REE business value chain through a comprehensive incentive system that supports a technology – and knowledge-driven IAC-REE industry, nurtures creative talents, and strengthens the domestic IAC-REE supply chain.

(v) Set up a MRTP, inclusive of a REPP, a metals and alloys manufacturing plant, and a super-magnets and electric motors manufacturing plant, and a reprocessing and repurposing plant for the recycling of used super-magnets and electric motors.

(vi) Set up a REC central buying house.

(vii) Conduct government-to-government (G2G) negotiations to obtain necessary technology and knowledge transfers (e.g., China, Japan, South Korea, Australia, and the USA).

(viii) Ensure that the federal ministries and agencies as well as state governments, in any collaboration/agreement made with foreign investors, insert a condition for local talent development and technology transfer.

(ix) Ensure the appointment of NRES as the lead agency that formulates and manages the incentives for the exploration and mining of strategic critical technology minerals.

(x) Ensure the setup of a cross-ministerial one-stop centre by NRES that contains the latest REE information.

(xi) Introduce science, technology, innovation, and economy (STIE)-driven solutions to foster strong collaborative partnerships among all stakeholders in the IAC-REE ecosystem, putting in place a robust chain of custody anchored on the 10-10MySTIE, as outlined in the 12MP.

(xii) NRES to designate Mineral Research Centre (PPM), under JMG, as the Rare Earths R&D national focal point to coordinate Rare Earths R&D with universities and research institutes under sustainable regular research grants and necessary funding.

(xiii) Collaborations for technical and vocational education and training (TVET), universities, and industries to provide upskilling courses through micro-credential or stackable modular units.

(xiv) Ministry of Higher Education (MOHE) to initiate cooperation between faculties in universities to offer rare earth-related courses in geology, mining, metallurgy, mineral processing, and chemical engineering in order to produce talents knowledgeable about REE resources.

In addition to these 14 major recommendations, a total of 85 sectoral recommendations are also proposed for the strengthening and development of the IAC-REE Industry.

Contributions of the IAC-REE industry to the economy

By 2030, the industry has the potential to create 24,800 jobs and is estimated to contribute RM 8 billion to the country's GDP in 2030, with a cumulative GDP value of RM 28 billion from 2025 to 2030.

Conclusion

In conclusion, this study identified the significant potentials of the country's IAC-REE resources as a new source of economic growth and the vast employment opportunities for skilled and semi-skilled Malaysians in a wide array of technological industries, as well as in the R&D sector. These opportunities would benefit the people, universities, industries, and government agencies.

Malaysia has all the necessary ingredients to become the region's vertically integrated rare earth-based products supplier.

1

CHAPTER

INTRODUCTION

1.1 Background

Malaysia is rich in various mineral resources and rock materials, which make the mining and quarrying sector one of the significant contributors to the country's economic development. These minerals and rock materials are important components that contribute to other sectors of the economy, such as construction, manufacturing, energy, and agriculture.

In the past 15 years, the rapid growth of the East Asian consumer economy has resulted in a dramatic increase in the demand for miniaturised electronic devices used for communications, data processing, and entertainment, as well as lightweight wind turbines (to drive the demand for renewable wind energy). Specific rare earth metals for the manufacturing of miniaturised high-strength super-magnets for use in automobiles have recently shown an exponential increase. In addition, the R&D results showed that the original equipment manufacturing (OEM) automotive industry in the late 1970s began to switch from ferrite-and alnico-based permanent magnet motors and generators to rare earth permanent super-magnet-based devices in the early 1980s. This was driven by the need to minimise the weight of motor vehicles for lower fuel consumption and improved fuel economy without compromising the performance efficiency. Rare earth super-magnets are highly crucial for the EV industry. Accordingly, an average electric car requires about 2.5 kilograms of Nd/Pr of the super-magnets. Furthermore, in 2016, with the signing of the COP 21 Paris Agreement, various governments have begun to lower their country's carbon footprint. Various initiatives have been implemented to develop technologies for renewable energy generation, automotive engineering, and development of unmanned aerial vehicles (UAV), among others; all of which require the use of rare earth metals and alloys.

Rare earths, which are also known as technology metals, are among the most resource-critical raw materials. They are of the highest economic importance and, at the same time, feature high supply risk considering that the supply chain is dominated by China, especially with the production of powerful rare earth magnets used in EVs, wind turbines, consumer electronics, and military hardware. In addition, rare earth metals are used in the aerospace industry, green technology, petroleum refining, and advanced materials. For instance, in consumer electronics, numerous REE are used in the manufacturing of smartphones (Figure 1.1). A snapshot of REE applications is shown in Figure 1.2.

FIGURE 1.1

Figure 1.1: REE as technology metals (Venditti, 2021)

FIGURE 1.2

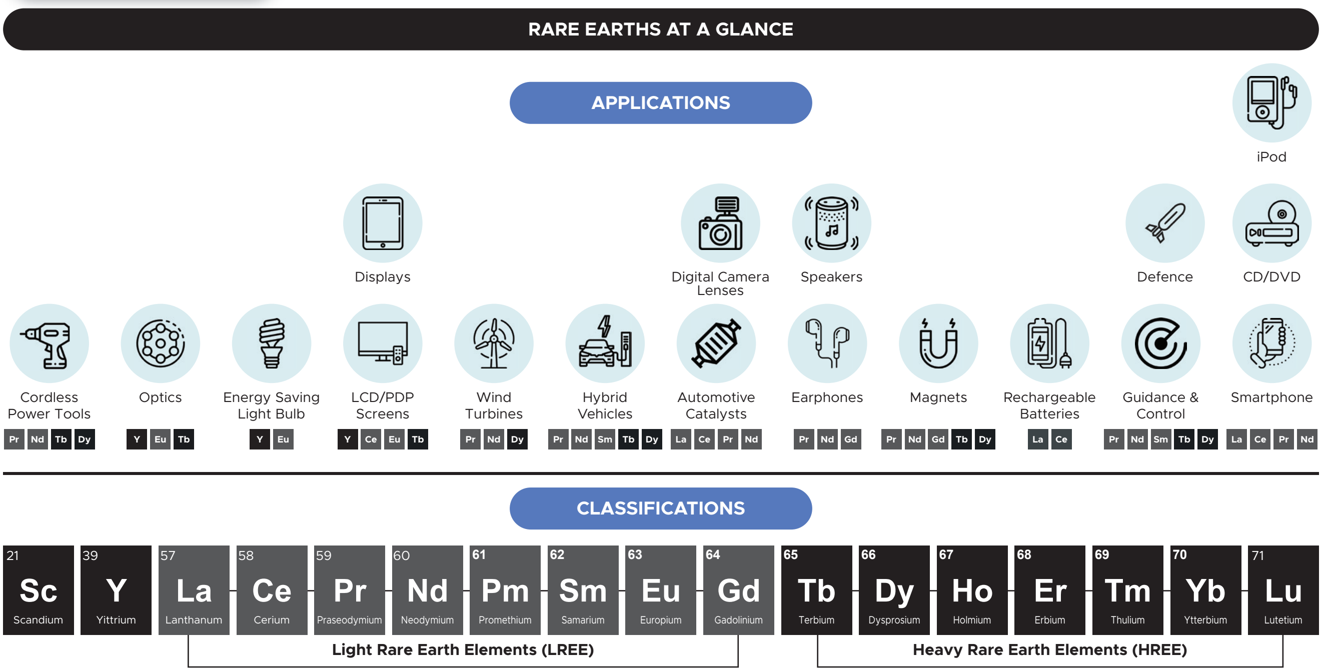

Figure 1.2: Snapshot of REE applications

The COVID-19 pandemic has disrupted the global REE supply chains. The European Commission in 2022 stated: "Lithium and rare earths will soon be more important than oil and gas. Our demand for rare earths alone will increase fivefold by 2030". According to the Information from Wood MacKenzie (2022a, 2022b, 2022c), in Global Rare Earth Strategic Planning Outlook to 2050, and Adamas Intelligence (2019) stated that rare earths mining may need to quadruple by 2030 based on supply constraints versus growing demand. Super-magnets and electric motors make up about 95% of the value of REE, which are mainly used in EVs and hybrid cars, wind turbines, consumer electronics, and defence applications.

With the start of Lynas Malaysia in 2013, Vietnam used all products produced by Lynas[7] in Malaysia and successfully developed the third-largest magnets manufacturing base in the world (behind China and Japan). It is regretful that Malaysia did not capitalise on this opportunity. Malaysia has identified large amounts of REE in ion adsorption clays. The widespread occurrence of ion adsorption clays has offered significant potentials for Malaysia to trigger the development of the IAC-REE industry.

The first pilot project was completed at the end of 2022 without any adverse environmental impact from the in-situ leaching of REE. Following the approval of the SOP NR-REE Perak, other states in Malaysia are ready to move into the extraction of REE from ion adsorption clays. It is anticipated that, with the extraction of IAC-REE, Malaysia can establish full rare earths value chain from the upstream sector to the downstream sector.

Malaysia has been a rare earth minerals producer and exporter for a long time. The country possesses significant sources of monazite and xenotime, which are produced as by-products of tin mining. It also has the capacity to attract specialised refining and fabricating vendors to cover the entire spectrum of rare earth-enabled products.

In 2014, ASM published and launched its publication, entitled "Blueprint for the Establishment of Rare Earths-Based Industries in Malaysia (A Strategic New Source for Economic Growth)". The blueprint outlined in detail how the entire ecosystem, from upstream mining and midstream processing and refining to downstream manufacturing, can be achieved.

On 22nd April 2021, Prime Minister, Tan Sri Dato' Haji Muhyiddin bin Haji Mohd. Yassin, launched *"Kerangka Pelan Transformasi Industri Mineral Negara 2021–2030"* (TIM 2021–2030). TIM 2021–2030 is a comprehensive framework developed by KeTSA[8] as an initiative towards developing a comprehensive national mineral industry that covers the upstream, midstream, and downstream sectors, with the emphasis on five national strategic mineral commodities. The framework aims to ensure a responsible and sustainable development of the country's mineral industry through the efficient management of natural resources, making the mineral industry a new and important national wealth source.

According to TIM 2021–2030, one of the five national strategic mineral commodities is non-radioactive rare earth elements (NR-REE)[9], occurring within ion adsorption clays overlying granitoid bodies throughout the country. REE are considered strategic given their downstream products of high market value.

TIM 2021–2030 also lays the basic principle that the IAC-REE industry implements responsible and sustainable mining, processing, and manufacturing of REE-based products to enhance the economy and ensure no negative impacts on the environment and the societal well-being. Malaysia is envisioned as the next hub producing REE-based products from its own local resources. In essence, this would translate as the vertical integration of a critical mineral commodity from the mine to the finished mass-produced product ready for end-user product fabrication.

In order to realise the potential economic value of domestic REE, NRES has appointed ASM as its strategic partner to develop the business model on IAC-REE in Malaysia, which serves as a guide for government ministries and agencies, whether at the federal or state levels, and industry players to develop their respective holistic and action-oriented plans. The terms of reference and methodology of the study are outlined in Appendix 1.

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7 Lynas Malaysia has the capability and capacity to produce mainly light rare earth oxides of up to 22,000 tonnes per annum of separated REO products, such as praseodymium/neodymium.

8 Following GE 15, KeTSA has been renamed as Ministry of Natural Resources, Environment, and Climate Change (NRECC) and subsequently, Ministry of Natural Resources and Environmental Sustainability (NRES).

9 Internationally, this resource is more commonly known as ion adsorption clay-hosted rare earth elements (IAC-REE). Some global examples of IAC-REE resources are in China, Vietnam, Myanmar, Thailand, Uganda, and Australia. This study report recommends the term "ion adsorption clay rare earth elements" for NRES to use in its papers and publications.

2

CHAPTER

APPROACH AND METHODOLOGY

The country's IAC-REE resources are a valuable commodity to be extracted in a responsible and sustainable manner. There should be a full ecosystem from leach extraction to processing, purification, and metals/alloys production, and finally, the production of REE-based high-value products. Malaysia intends to embark on a venture to be part of the global rare earths value chain. As of now, only China can claim to have the full ecosystem in place.

2.1 Approach

A twin-pronged approach was proposed for the formulation of an IAC-REE Business Model. The detail of each sectoral approach is discussed in Appendix 1.

2.1.1 Business Model Canvas

A business model canvas was considered for the development of a business model in this study (Dasha, 2020). As shown in Figure 2.1, a business model canvas consists of nine elements.

FIGURE 2.1

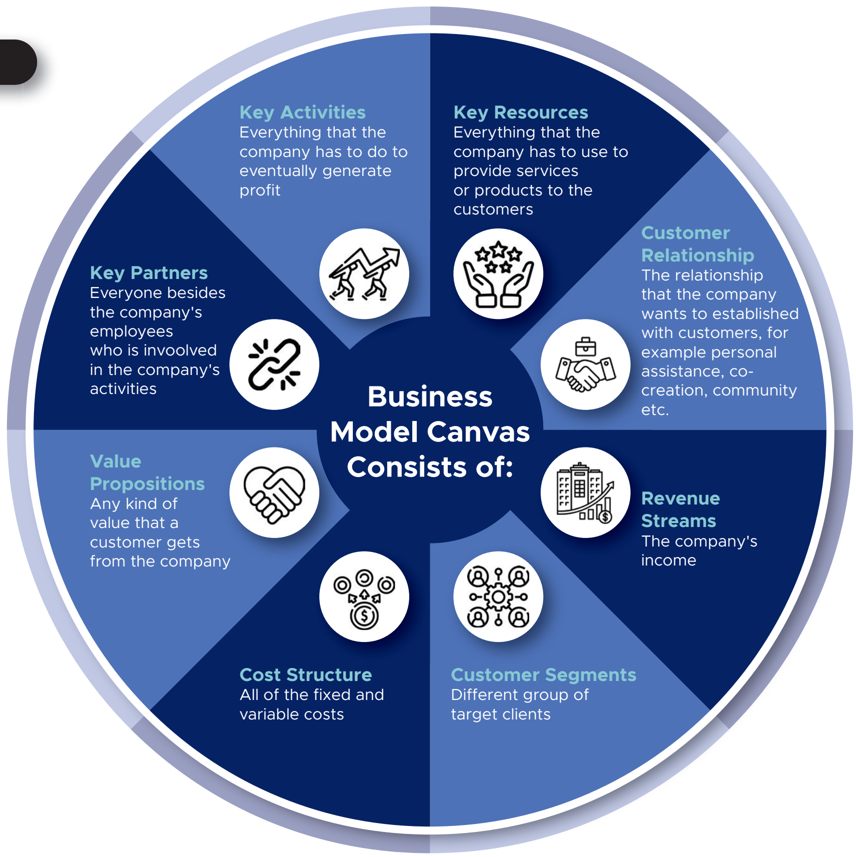


Figure 2.1: Business model canvas

2.1.2 Integrated Business Model Framework

The IAC-REE value chain in Malaysia can be subdivided into three sectors, which include the upstream sector (exploration, in-situ leaching, and on-site processing), midstream sector (separation, purification, and conversion into metals and alloys), and downstream (manufacturing of super-magnets and motors and other REE-based products). The resulting output of the industry has massive spillover impact on Malaysia's other economic sectors, such as green energy, transportation, and consumer electronics. Each sector plays a vital role within the value chain. However, to date, no study has been done to fully capture the current state of the domestic IAC-REE ecosystem and its future economic potentials. It is imperative that an ecosystem approach is used to characterise the entire value chain (from upstream to downstream) and identify the gaps and way-forward for the industry. An approach governed by the 8R-8i values-based framework allows a holistic mapping of both strengths and gaps within the ecosystem of each sector for the development of strategies to strengthen the industry's dynamic capabilities[10] for return on value[11] (ROV). Doing so enables the nation to derive substantial benefits and values from its wealth in rare earth resources, which could potentially serve as strong value-added drivers for the socioeconomic development of Malaysia. This approach will be discussed in the following subsections.

2.2 Methodology

2.2.1 Conceptual Framework to Characterise the IAC-REE Business Value Chain

The IAC-REE industry is characterised by multiple players within the value chain, comprising the upstream, midstream, and downstream sectors. Both tangible and intangible values of the upstream, midstream, and downstream sectors were assessed in this study using an integrated ecosystem approach. Tangible value refers to the economic value, while intangible value refers to investments, developed networks, talent development, job creation, planetary health, and other spillover impacts that contribute to increasing economic value and competitiveness of the IAC-REE industry.

[10] Dynamic capabilities are the ability of firms in the IAC-REE industry to build absorptive, adaptive, and innovative capabilities. Dynamic capabilities can be categorised into three types, namely absorptive capabilities (the ability to identify new external information and knowledge and to use them to create value for the firm and other stakeholders in the ecosystem), adaptive capabilities (the ability to use external knowledge and information to be adaptive in responding to the changing market conditions and external environment quickly), and *innovative capabilities* (the ability to develop innovations and discoveries that can contribute new products, processes, designs, and/or markets). Wang and Ahmed (2007) presented more details on dynamic capabilities.

[11] Return on value (ROV) refers to the value gained by all stakeholders in the economy through the adoption of the best technologies and knowledge systems, aligned to global best practices in the IAC-REE industry. The economic value generated by the industry is in terms of global competitiveness, income potential, and creation of high-value added jobs. Nair et al. (2022) presented more details on the ROV.

The interlinkages and levels of integration of these three sectors were examined via an integrated IAC-REE ecosystem framework, enabling the seamless integration of these three different sectors of the industry (upstream, midstream, and downstream sectors) to value-add one another and to create a more competitive IAC-REE industry. This new framework that characterises the IAC-REE business value chain enables the assessment of the current state of the industry and the identification of key strengths and weaknesses in the enablers of the value chain. This method provides valuable insights for the development of more comprehensive strategies to bridge the identified gaps within the ecosystems; ultimately increasing both tangible and intangible value for the IAC-REE industry and the Malaysian economy.

2.2.2 The Characterisation of an Integrated IAC-REE Business Value Chain Model

This section discusses the building-blocks of the IAC-REE business value chain. In this context, the IAC-REE business value model refers to a model that would enhance the contributions of the rare earth industry for the socioeconomic development of the nation through the efficient, responsible, and sustainable development of its IAC-REE resources and their value-added products, backed by a projected increase in ROV without compromising on ESG and sustainability requirements. In this case, ROV would include, but not limited to, the monetisation of IAC-REE resources, increase in revenue for the federal and state governments, and socioeconomic improvement for the community and society at large.

The IAC-REE business value chain comprises key components, which include eight core values (8Rs) that incorporate both planetary health and ESG considerations across all aspects of the IAC-REE operations in the upstream, midstream, and downstream sectors. The 8R values-based development philosophy would enable the industry to obtain higher value from natural resources and minerals within the ecosystem, which are outlined below (Figure 2.2):

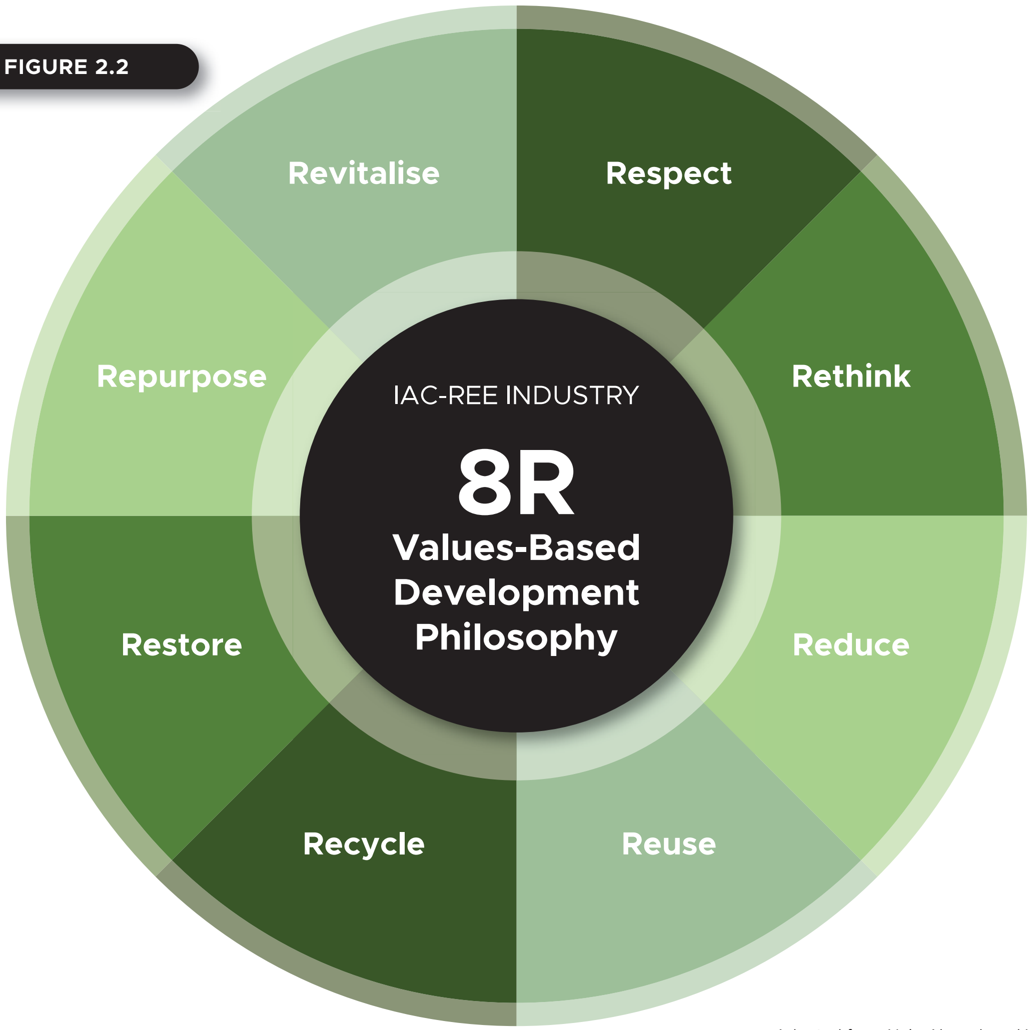
(i) **Respect** terrestrial and aquatic biodiversity and ecosystems, ensuring that all IAC-REE activities do not adversely affect these ecosystems;
(ii) **Rethink** the ROV of land and mineral resources to society, especially key technology-driven industries that would increase the use of cleaner energy sources (solar and battery technologies) and other industries, aligned to planetary health and sustainable development action plans;
(iii) **Reduce** the impact of extractive and manufacturing industries that harm terrestrial and aquatic biodiversity and ecosystems (ensuring that ESG requirements are core to the operations of the IAC-REE industry);
(iv) **Reuse** mineral and land resources in a responsible and sustainable manner (e.g., adopting a circular economy);
(v) **Recycle** residue and waste from IAC-REE activities to prevent the overuse of resources and discharge of harmful effluents into the terrestrial and aquatic ecosystems;

(vi) **Restore** the biodiversity of terrestrial and aquatic ecosystems impacted by IAC-REE activities;

(vii) **Repurpose** IAC-REE by-products to ensure the industry derives a higher ROV – creating a sustainable industrial value chain and high income jobs; and,

(viii) **Revitalise** the IAC-REE industry using advanced environmentally-friendly technologies and circular economic models; so as to minimise the risk of IAC-REE activities that lead to environmental degradation of terrestrial and aquatic ecosystems, and to revitalise these ecosystems for current and future generations (incorporation of ESG requirements at all levels – upstream, midstream, and downstream sectors).

FIGURE 2.2



Adapted from Nair, Ahmed, and Vaithilingam (2022)

Figure 2.2: 8R values-based development philosophy (Nair et al., 2022)

The sustainable IAC-REE business value chain comprises three important components. The first component involves the 8i-ecosystem, which consists of the following eight enablers (Figure 2.3):

(i) ***Infrastructure:*** Refers to the physical infrastructure (separation and processing plants, waste treatment plants, logistics supply chain, transportation, and other critical infrastructure to ensure the competitiveness of the industry) and natural infrastructure (forests, rivers, aquifers, lands, and other natural habitats) that support and are affected by the production and distribution network of the IAC-REE industry. Environmentally friendly advanced technologies are to be used in the IAC-REE industry to mitigate the risks of pollution and contamination of natural habitats; all of which are aligned to global best practices related to the 8R values-based development philosophy and ESG standards.

(ii) ***Infostructure:*** Refers to the state of digital infrastructure and level of use of data-driven technologies within the IAC-REE industry, such as advanced information and communication technologies (ICT), big data analytics, blockchain, and Internet of Things (IoT) for seamless and efficient management, production, and distribution of raw materials, products, and services within and across the upstream, midstream, and downstream sectors.

(iii) ***Intellectual capital:*** Refers to the state of the talent stock (generalised and specialised skillsets) and the quality of knowledge institutions to transform the IAC-REE industry into a technology- and knowledge-driven industry that is aligned to the 8R-values-based development philosophy and ESG requirements. It also involves increasing the public understanding on the operations of the IAC-REE industry and its contributions to the nation through CEPA programmes.

(iv) ***Integrity systems:*** Refers to the state of corporate and public governance systems (at the federal, state, and local levels) that enable seamless implementation of strategic policies and standards, as well as systems that can enable greater transparency, traceability, and accountability to optimise economic value for all stakeholders in the economy. A key feature of a sound integrity system in the industry lies in having a robust and transparent regulatory architecture that promotes the sustainable development of the industry. It also includes ensuring that all operations within the IAC-REE industry adhere to the 8R-8i values-based development philosophy and ESG requirements.

(v) ***Incentives programmes:*** Refers to the availability of fiscal and non-fiscal support systems to enhance the development and competitiveness of the IAC-REE industry in Malaysia. It includes support for R&D, innovation grants, access to cutting-edge research facilities, tax incentives and subsidies, incentives to promote R&D activities, and business-friendly policies. Business-friendly policies include policy consistency, pertaining to the award of licenses for mining and processing of rare earths and valuable minerals and ensuring firms in the industry comply to ESG standards. These incentives are important to reinforce the local industries to move up the global value chain.

(vi) ***Institutions:*** Refers to the availability of quality institutions of governance at all levels of government (federal, state, and local councils), industry associations, community organisations, and educational institutions in managing and moving the IAC-REE industry up the competitiveness value chain through the Whole-of-Government and Whole-of-Society approach. This also involves key players in the industry continuously strengthening the regulatory architecture, business policies, and incentive systems to collectively enhance the global competitiveness of the industry that adheres to the 8R-values-based development philosophy and ESG standards.

(vii) ***Interaction:*** Refers to the depth and quality of cooperation, collaboration, and knowledge sharing among the key stakeholders in the industry to nurture and sustain a dynamic and globally competitive local IAC-REE industry.

(viii) ***Internationalisation:*** Refers to the state of global outreach and international collaboration in the industry that promote technology and knowledge transfer, expansion of market share, and strong participation in global IAC-REE value chains. This includes involvement in formulating global best practices and standards related to mining, processing, and management of REE.

FIGURE 2.3

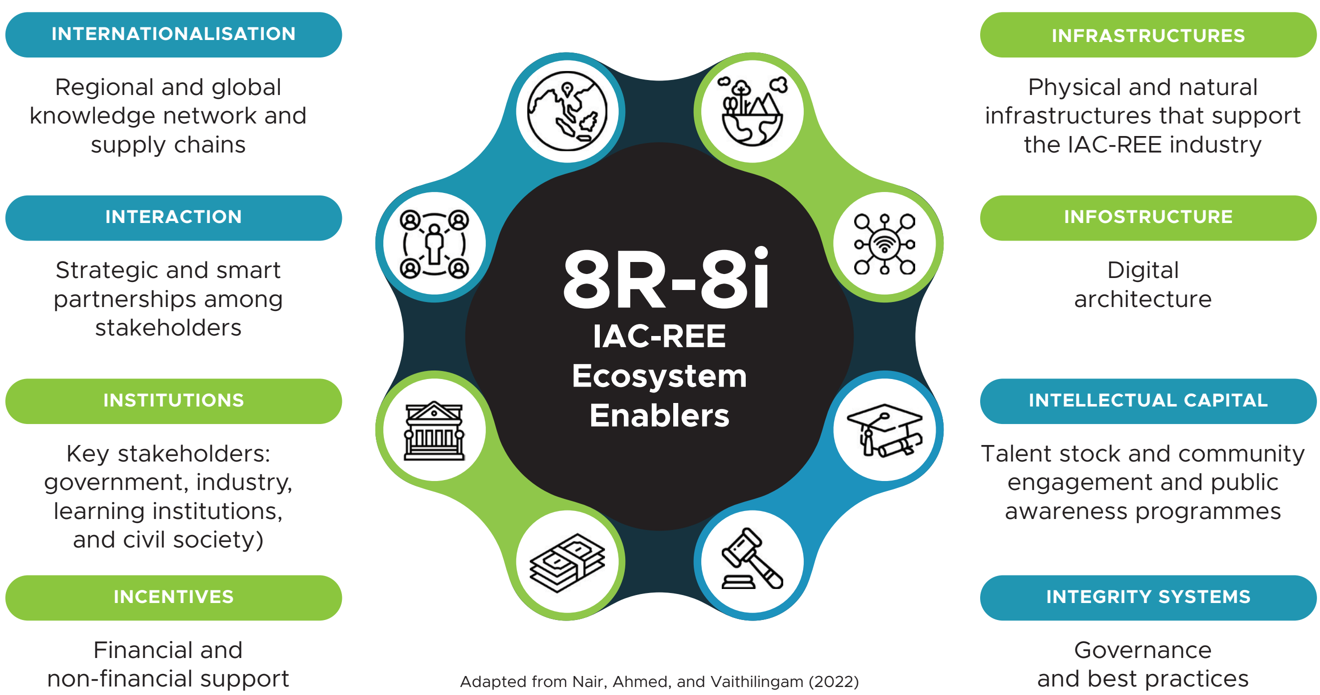


Figure 2.3: Descriptions of the 8i IAC-REE ecosystem enablers (Nair et al., 2022)

The second key component of the IAC-REE business value chain includes the dynamic capabilities of the key players in the industry. There are three key components that entail the dynamic capabilities of firms in the industry (Figure 2.4):

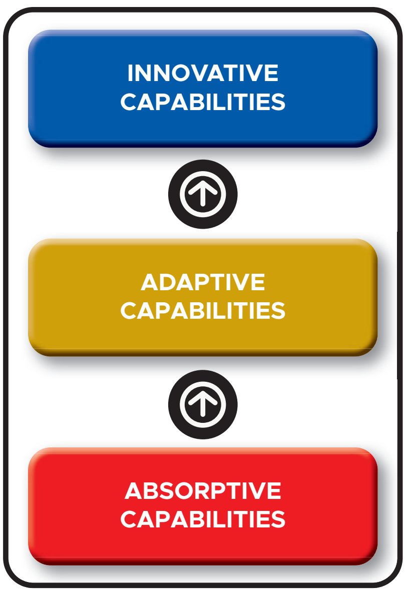
(i) ***Absorptive capabilities:*** Firms in the industry incorporate external knowledge into their business processes and innovation to enhance productivity and efficiency, thereby creating value for their stakeholders.

(ii) ***Adaptive capabilities:*** Firms in the industry undertake process engineering and "recombinant innovation" of external knowledge, contextualising to the needs of firms and their external stakeholders.

(iii) ***Innovative capabilities:*** Firms that invest in R&D that lead to new knowledge and innovations, which initiate spillover impacts on process improvement, product development, and/or business models; thereby increasing value for all stakeholders in the ecosystem.

FIGURE 2.4

Dynamic Capabilities of the IAC-REE Industry



Invest in R&D that can lead to new knowledge and innovations, which can contribute to the spillover impact on process improvement, product development, and/or new business models that can raise the ROV for firms and their stakeholders

e.g., *develop new innovative mining, processing, and product development that have domestic and international market demands – nurture new markets and revenue streams from IAC-REE technology and ecosystem services*

Undertake process re-engineering and "recombinant innovation" of external knowledge, contextualising to the needs of the firms and their external stakeholders

e.g., *ability to adapt responsible and sustainable mining, processing, and product development to the local and regional context*

Incorporate external knowledge into organisational business processes and innovations to enhance productivity and efficiency and to create better ROV for stakeholders

e.g., *ability to learn about responsible and sustainable mining, processing, and product development from leading players in the market (foreign players)*

Adapted from Nair, Ahmed, and Vaithilingam (2022)

Figure 2.4: Dynamic capabilities of firms in the IAC-REE industry (Nair et al., 2022)

Dynamic capabilities suggest that there is a strong relationship between the three components of dynamic capabilities in many advanced industrial markets – strong absorptive capabilities provide strong foundations for nurturing strong adaptive and innovative capabilities[12] .

The third component of the IAC-REE business value chain involves the desired outcome of firms in the industry. In this case, the desired outcome is characterised as ROV to the local IAC-REE ecosystem and to the Malaysian economy. The components of the ROV are as follows (Figure 2.5):

(i) ***Creative talent:*** Nurture creative talents that meet the needs of the industry and enable firms to move up the global innovation value chain.

(ii) ***New knowledge:*** Create new innovations and discoveries in mining, processing, and product development in the local IAC-REE industry – continuously improving productivity, efficiency, cost-competitiveness and enhancing value proposition for all stakeholders in the ecosystem.

(iii) ***Knowledge networks:*** Create knowledge and innovation networks, including strong vertical and horizontal industrial supply chains and consumer channels[13]. These networks provide opportunities for co-creation that can enhance the value proposition for firms in the supply chain and its consumers.

(iv) ***Wealth creation:*** Contribute to revenue streams and firm profitability, create high-income jobs, and ultimately, contribute to the country's GDP.

(v) ***Societal impact:*** IAC-REE is a major contributor of components such as battery technology, solar panels, and a myriad of electrical components; all of which contribute to job creation that lifts many communities out of poverty. Furthermore, minerals serve as important inputs for core technologies that enable the transition towards a more decarbonised global economy – an economy that uses minimal fossil fuels and contributes positively to the health of the planet and people.

(vi) ***Branding and positioning:*** A strong and integrated local IAC-REE supply chain that enables local firms (upstream, midstream, and downstream) to be dominant regional and global players in supplying vital minerals and processing facilities, products, and services; thereby increasing domestic and foreign investments into the industry.

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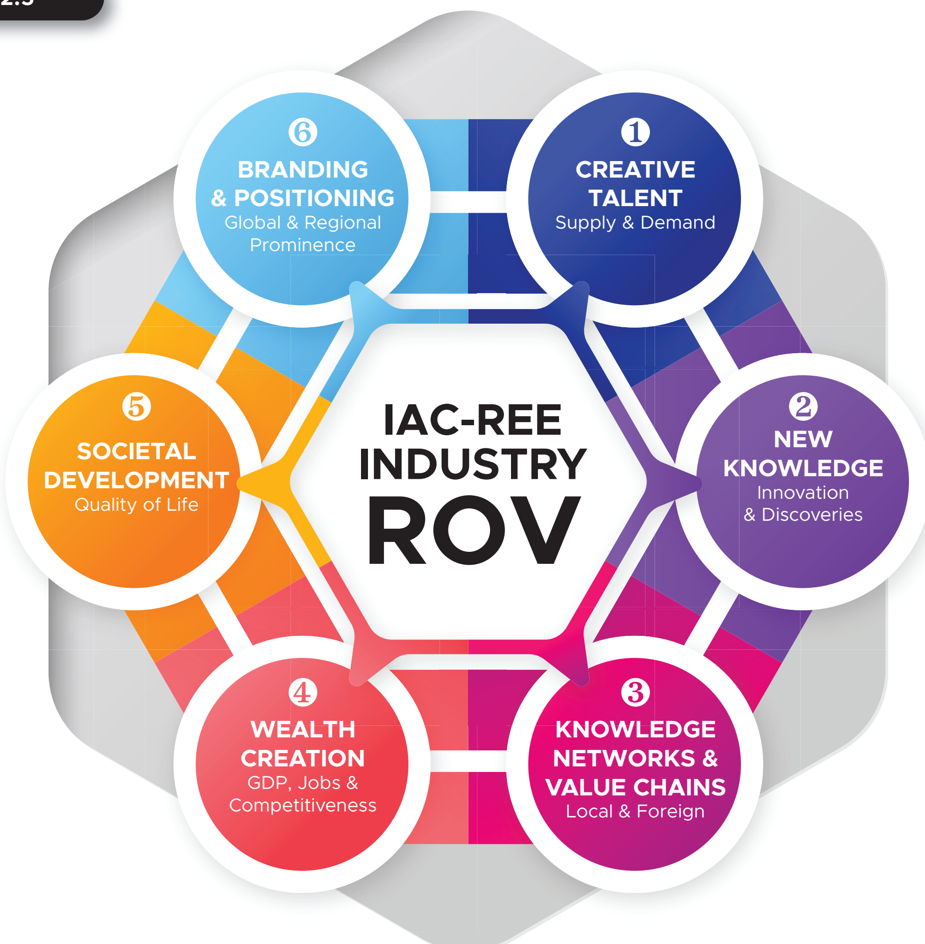
[12] Refer to Wang and Ahmed (2007)

[13] Vertical supply chain includes collaborations, partnerships, and joint ventures within the sectors of the industry (upstream, midstream, and downstream), whereas horizontal supply chain covers partnerships across the different sectors and other industrial sectors in the economy. Similarly, customer channels can be within or across the three sectors of the IAC-REE industry.

The IAC-REE industry ROV suggests that there are strong transmission mechanisms between the components of ROV. Firstly, a strong talent stock will help transform the industry to become more knowledge and innovation-intensive. This enables the formation of deep and wide knowledge networks and value chains within the country and across the globe. These knowledge networks can contribute to the wealth of the industry and socioeconomic development of local IAC-REE ecosystems and the country's GDP. A vibrant and competitive IAC-REE ecosystem helps position the local industry as a key regional and global player; all of which can attract investments that further strengthen the industry and its economic contributions. This virtuous ROV cycle is shown in Figure 2.5.

FIGURE 2.5

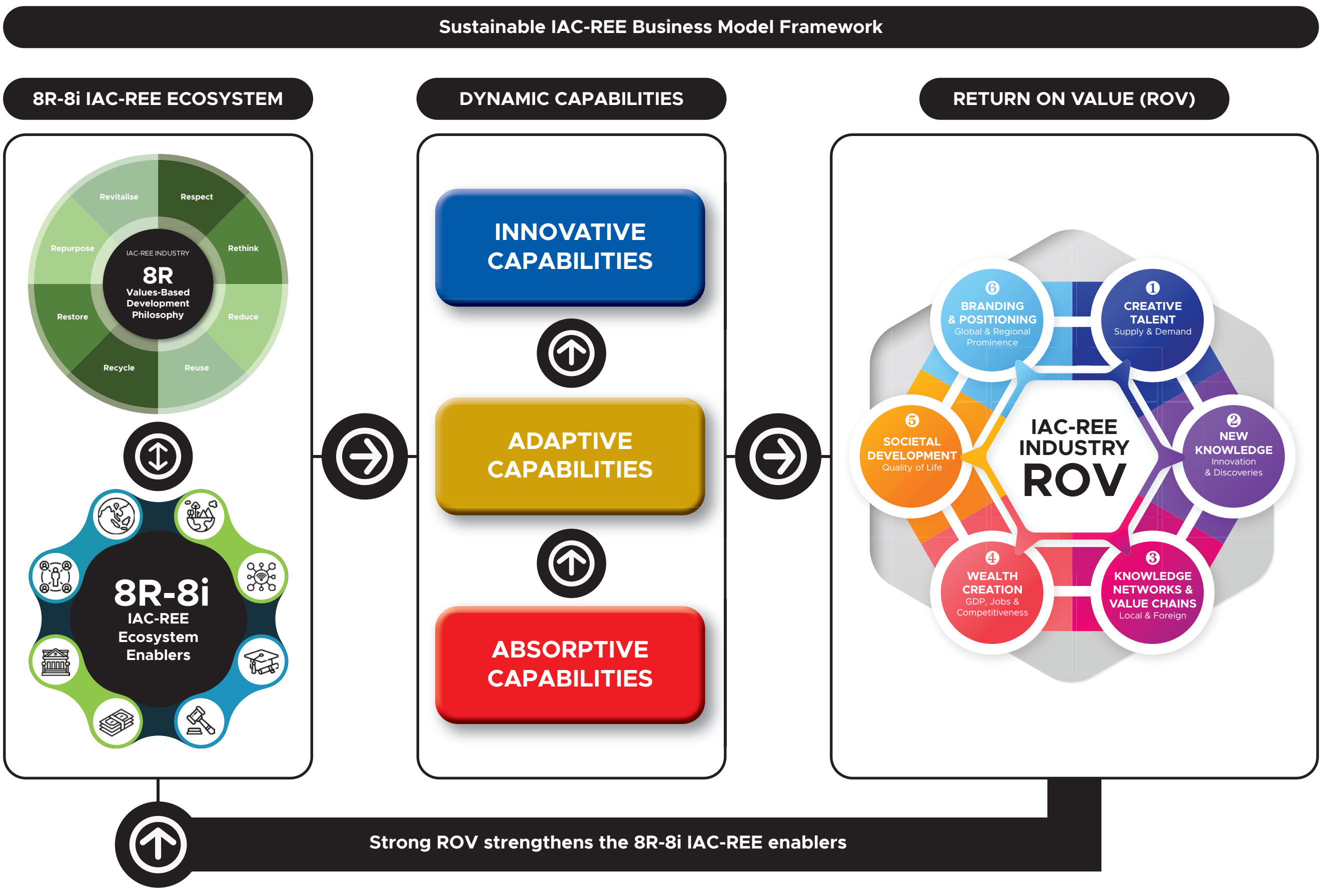


Adapted from Nair, Ahmed, and Vaithilingam (2022)

Figure 2.5: Components of ROV for the IAC-REE industry (Nair et al., 2022)

Figure 2.6 postulates that strong enablers of the IAC-REE ecosystem aligned to the 8R values-based development philosophy (ESG compliance) can enhance the dynamic capabilities of the industry. This would have a "knock-on" impact on the ROV of the industry. In many advanced countries, higher ROV in high-technology industries have resulted in more investments, which strengthen the 8R-8i ecosystem enablers of the industrial ecosystems[14]. This enables the industries to build stronger dynamic capabilities and move up the global innovation and value chain. Any weaknesses in the enablers of the ecosystem would result in firms operating at the lower end of the value chain. Many firms, over time, would lose their competitive advantages to other dominant players in the global market.

FIGURE 2.6



Adapted from Nair, Ahmed, and Vaithilingam (2022)

Figure 2.6: Characterisation of sustainable IAC-REE business value chain (Nair et al., 2022)

[14] Refer to EPU (2016a, 2016b)

3

CHAPTER

GLOBAL SCENARIO AND CURRENT STATUS OF THE RARE EARTH INDUSTRY IN MALAYSIA

3.1 What are Rare Earth Elements?

Rare earths are a group of 15 elements (REE) of the lanthanide series, as well as scandium and yttrium, which make up 17 critical elements of great demand (Figure 3.1). All REE, except promethium (Pm), are not radioactive. However, Pm is extremely rare, with only 0.5–0.6 kg naturally occurring in the Earth's crust at any one time, and is considered non-existent (Royal Society of Chemistry).

REE are divided into light and heavy REE groups: LREE (La, Ce, Pr, Nd, Sm, and Eu) and HREE (Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu). Sc is typically treated as a separate technology metal. REE occur in groups of different percentage constituents in about 160 REE-minerals[15], but most of these minerals generally do not contain economic quantities of REE. Only two minerals, namely bastnasite and monazite, contain economic quantities of REE that can be mined.

FIGURE 3.1

Rare Earth Elements

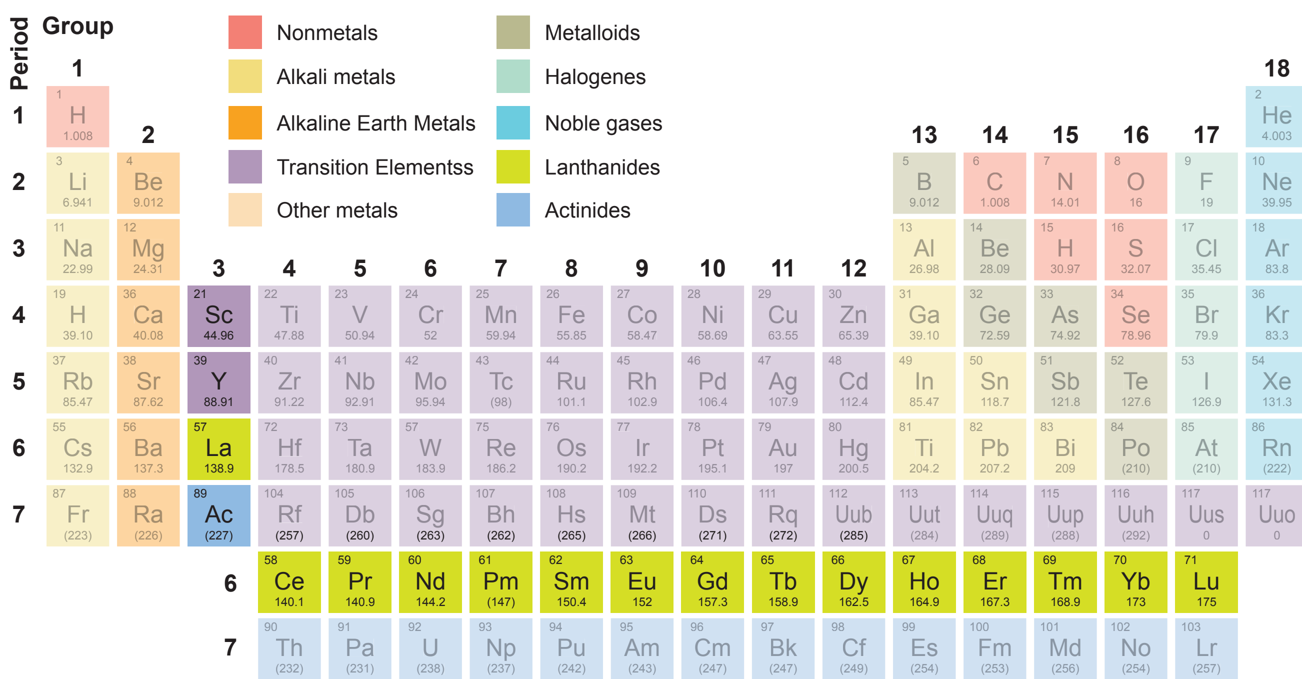


Figure 3.1: The periodic table showing 15 elements of the lanthanide series and two elements in Group 3 (all 17 elements are considered critical elements) (Rare Element Resources, 2023)

[15] Rare-earth element | Uses, Properties, & Facts | Britannica (20 Jan. 2023)

Rare earth oxides (REO) extracted from bastnasite and monazite are of the mineral-type, which contain mostly LREE (91% LREE, 9% HREE) (Figure 3.2). Typical mineral-type rare earth deposits contain an average of 5% total rare earth oxides (TREO).

FIGURE 3.2

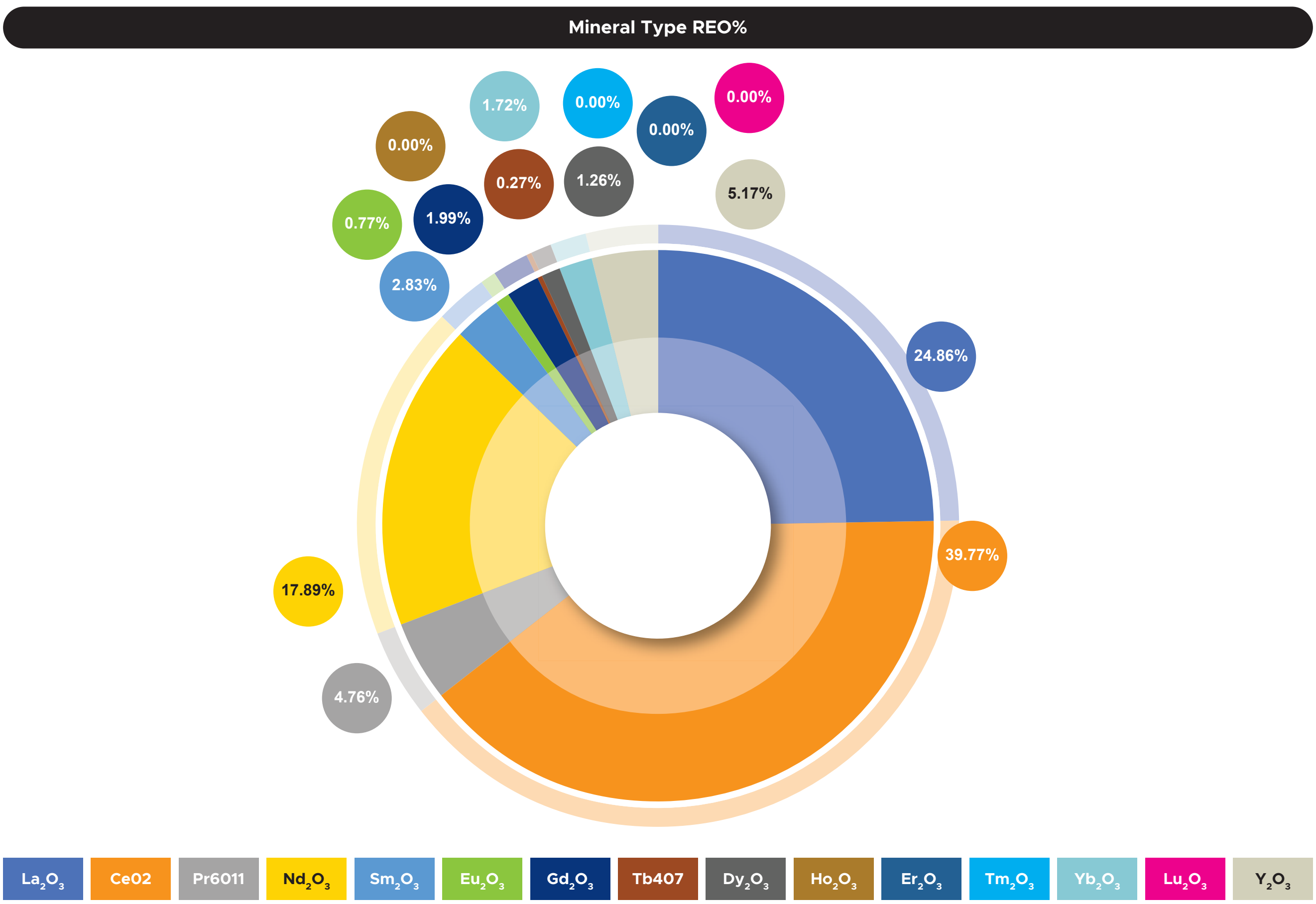


Figure 3.2: REO fractions in mineral-type rare earth deposits (Greenchem Nanotech Solutions Sdn Bhd.)

In tropical and sub-tropical areas, the weathering of igneous rocks releases REE ions from the REE-minerals, which are mainly adsorbed onto the surface of clay minerals within the soil profile. Prolonged ion exchange activities result in the enrichment of REE in the soil. REO extracted from this type of deposit is known as the ion adsorption clay (IAC-) type. They are enriched in HREE (69% LREE, 31% HREE) (Figure 3.3).

IAC-type deposits range from 300 to 3,500 ppm (0.03–0.35%) of TREO. The shallow occurrences in soil layers, ease of extraction by leaching, and the higher percentage contents of the valuable HREE make IAC-type deposits more economical despite their low grades. IAC-type deposits were first discovered in Southern China. Recently, more IAC-type deposits have been found in Southeast Asia, South America, and Tropical Africa.

IAC-type deposits demand a completely different approach in terms of exploration, mining, and processing as opposed to hard rock mining for REE from minerals. Unlike mineral-type REE, rare earth products can now be produced without involving radioactive residues as the thorium and uranium contents generally occur at very low levels, in the range well below 1 Bq/gm[16]. It is known as IAC-REE in Malaysia.

FIGURE 3.3

Ion Adsorption Clay Type REO%

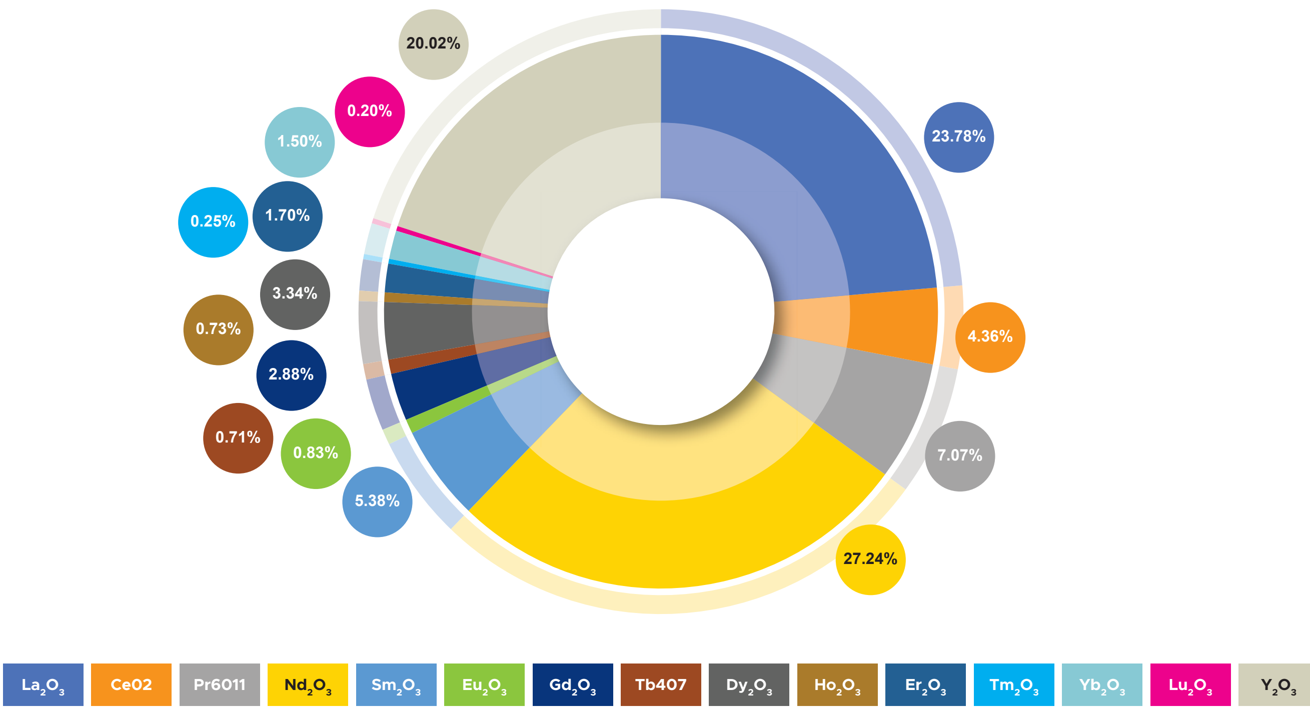


Figure 3.3: REO fractions in IAC REE deposits (Greenchem Nanotech Solutions Sdn Bhd)

16 1 Bq/gm represents the radioactivity limit, as stated in the Atomic Licensing Board Act (1984)

3.2 Uses of REE

REE are used in new technologies, and their uses can generally be grouped into the following (Figure 3.4):

(i) Magnetics (Nd, Pr, Tb, Dy)
(ii) Metal alloys (La, Ce, Nd, Pr, Y)
(iii) Defence (La, Nd, Pr, Sm, Eu, Tb, Dy, Lu, Y)
(iv) Catalysts (La, Ce, Nd, Pr)
(v) Glass and polishing (La, Ce, Nd, Pr, Gd, Ho, Er)
(vi) Ceramics (La, Ce, Nd, Pr, Eu, Gd, Dy, Lu, Y)
(vii) Phosphors (Ce, Nd, Pr, Eu, Gd, Tb, Er, Y)

* REE expressed in bold are heavy rare earth elements (HREE).

Among others, HREE, terbium (Tb), and dysprosium (Dy) are essential components in the manufacturing of high-performance NdFeB super-magnets. More importantly, HREE are also critical materials for the high-technology industries, such as turbine engines, alloys for fuel cells, laser, data transmission, n-vision, fibre-optics, decoy flares, X-ray machines, medical devices, sonar, stress gauges in submarines, stabilisers for navy ships, and electric combat vehicles.

FIGURE 3.4

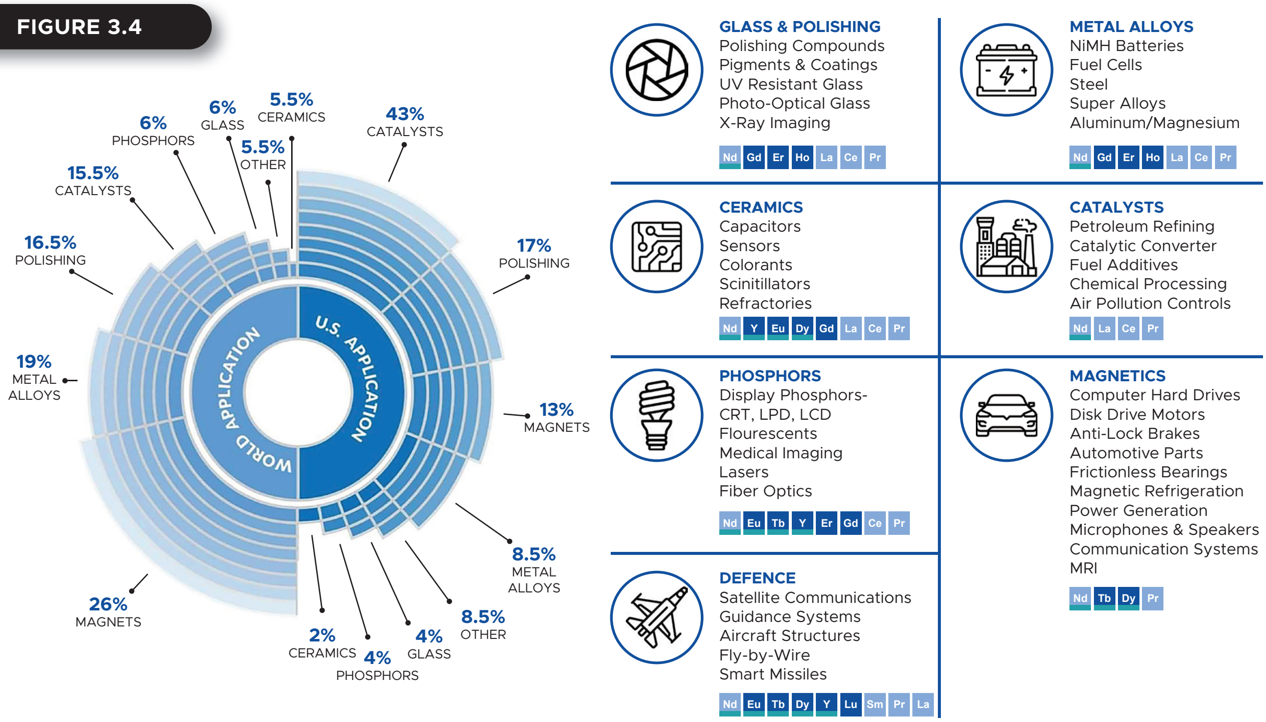


Figure 3.4: Uses of rare earth elements (National Energy Technology Laboratory, n.d.)

3.3 Increasing Demand for Rare Earth Magnets with the Race to Net Zero

With the signing of the Paris Agreement (UNFCCC) 2016 (on the greenhouse gas emissions mitigation, adaptation, and finance), various countries have begun to commit to carbon-neutral goals (the net zero initiative) (Figure 3.5).

FIGURE 3.5

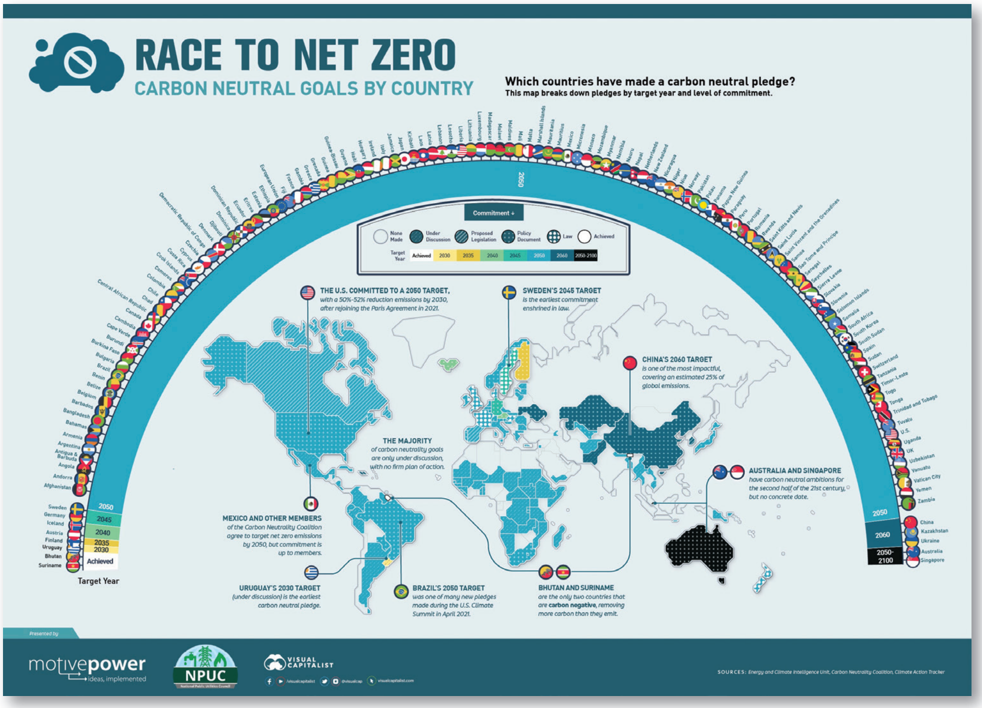


Figure 3.5: The race to net zero (Wallach, 2021)

The net zero initiative increases the demand for rare earth magnets dramatically. Specific rare earth metals like Nd, Pr, Sm, Tb, and Dy are required to make high-strength, high-temperature super-magnets for EVs and wind turbines. In addition, rare earth metals are essential in the manufacturing of miniaturised electronic devices used in communications, as well as in aerospace and defence industries. Table 3.1 shows the relative abundance, resources, production, and uses of various REE.

TABLE 3.1

Elements	Crustal Abundance (ppm)	Resources (tonnes)	Production (tonnes/annum; years of reserve)	Reference
Lanthanum (La)	32	22,600,000	12,500 (1,800)	Hybrid engines, metal alloys, catalysis, phosphors, carbon arc lamps, cigarette lighter flints
Cerium (Ce)	68	31,700,000	24,000 (2,000)	Phosphors, petroleum refining, metal alloys, corrosion protection, carbon arc lamps, cigarette lighter flints
Praseodymium (Pr)	9.5	4,800,000	2,400 (2,000)	Magnets, optical fibres, carbon arc lamps
Neodymium (Nd)	38	16,700,00	7,300 (2,300)	Catalysis particularly for petroleum refining, hard drives in laptops, headphones, hybrid engines, Nd-Fe-B magnets
Promethium (Pm)	NA	NA	NA	Nuclear battery
Samarium (Sm)	7.9	2,900,000	700 (4,100)	Sm-Co magnet, IR absorption in glass
Europium (Eu)	2.1	244,333	400 (610)	Red colour for TV and computer screens (5% Eu, 95% Y), green phosphor (2% Eu)
Gadolinium (Gd)	7.7	3,622,143	400 (9,100)	Magnets, nuclear magnetic resonance imaging, phosphors
Terbium (Tb)	1.1	566,104	10 (57,000)	Magnets, phosphors particularly for fluorescent lamps
Dysprosium	6	2,9800,000	100 (209,800)	Magnets hybrid engine increases the coercivity of Nd-Fe-B magnets
Holmium (Hm)	1.4	NA	10	Glass colouring agent, lasers
Erbium (Er)	3.8	1,850,000	500 (3,700)	Red and green phosphors, amplifiers for optical fibres transmission, pink in glass melts, sunglasses
Thulium (Th)	0.48	334,255	50 (6,700)	Medial X-ray units, X-ray sensitive phosphors
Ytterbium (Yt)	3.3	1,900,000	50 (38,00)	Laser, steel alloys, grain refiner, stress sensors
Lutetium (Lu)	NA	395,000	NA	Catalysts in petroleum refining, Ce-doped Lu-glass used in positron emission tomography (PET) as detectors
Yttrium	30	9,000,000	8,900 (1,011)	Fluorescent lamps, meta ls, Y-Fe-garnets resonators, red phosphors, ceramic
Scandium	22	NA	400 kg primary production; 1,600 kg/year from the Russian stockpile	Aluminium-scandium alloys for aerospace industry, defence industry, and high-intensity discharge light

Table 3.1: Relative abundance, resources, production, and uses of various REE (Haque et al., 2014; Sarfo, 2019)

3.4 NdFeB Demand

The fastest growing application using REE (Figure 3.6) currently lies in the super-magnets manufacturing industry, which potentially sustains for the next 10 years, at least. The super-magnet is able to generate the necessary magnetic field in a synchronous motor, which is normally generated by an electromagnet (consume electricity). This allows electric motors to operate with 15–30% reduced energy consumption and allows electrical cars to minimise the size of their batteries (a component of an electrical car that involves major cost), and for any electrical appliances (e.g., air conditioning, other home appliances, lifts, and robots) to reduce the electricity consumption, It also maximises the electricity generated by wind turbines, especially at low wind speed. In addition, these motors being twice smaller and lighter than alternative technologies can contribute to further reducing the energy required to move a car, as well as the size of a wind turbine structure.

FIGURE 3.6

Rare Earth Demand for Magnet

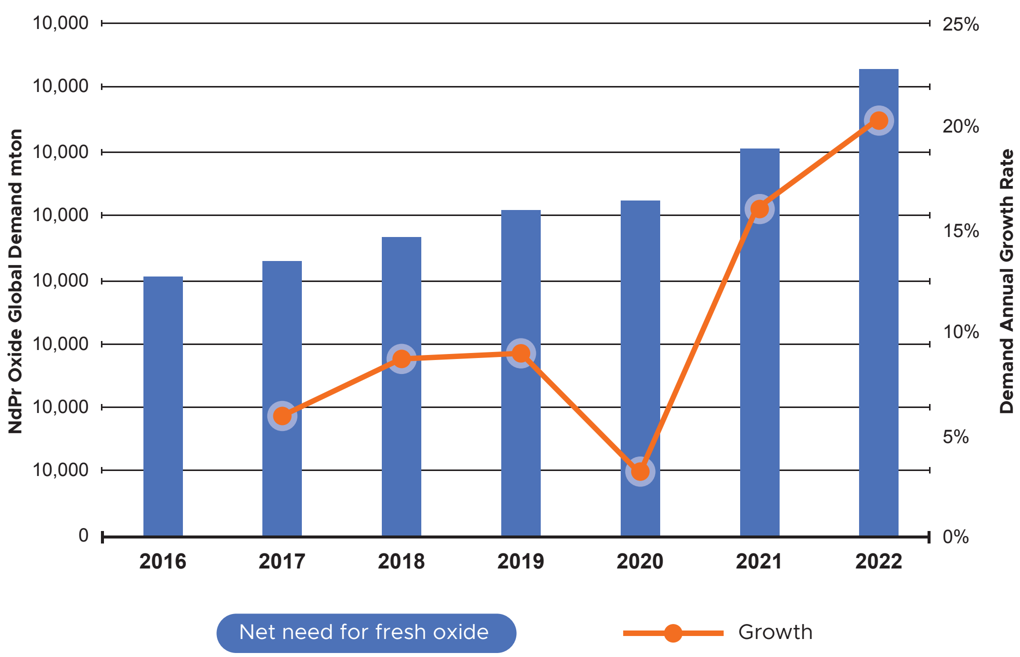


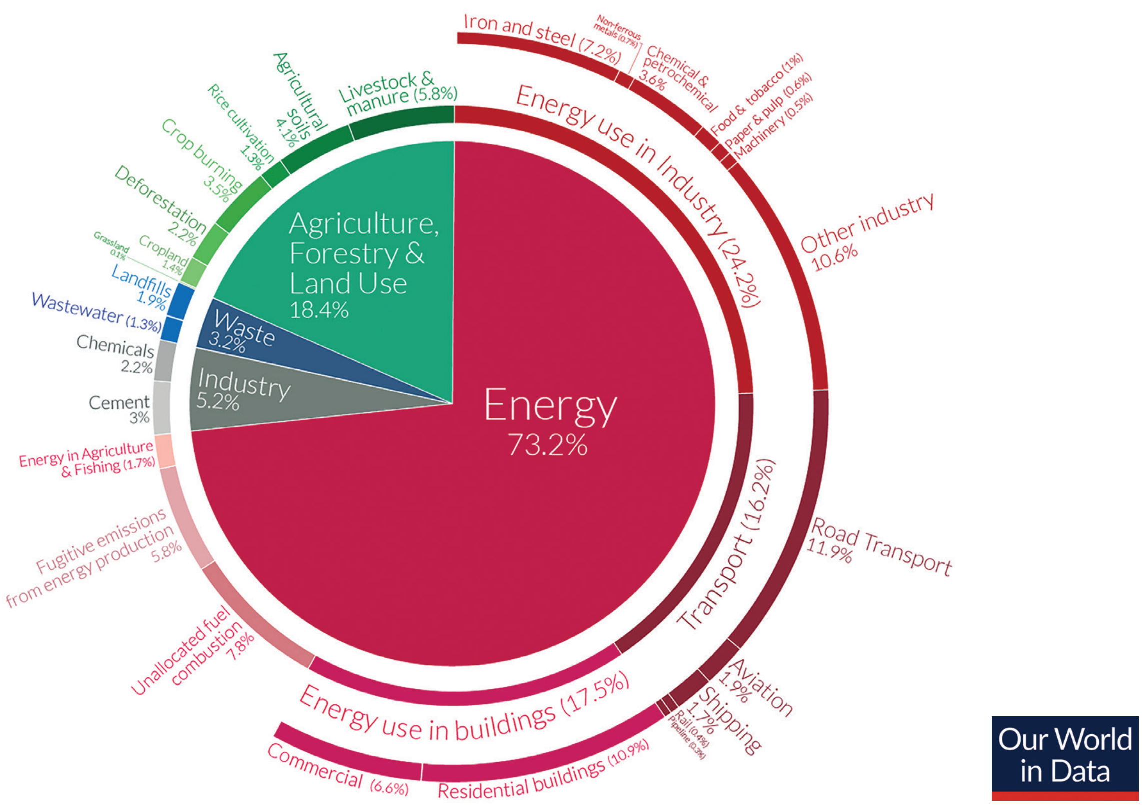
Figure 3.6: Rare earth demand for super-magnets (Lynas Corp & Lynas (M) Sdn Bhd, 2022)

As depicted in Figure 3.7, the energy sector emitted the highest amount of greenhouse gases (73.2% of global emission) in 2019 (Ritchie, 2020). In order to achieve the net zero target by 2050, reducing greenhouse gas emissions in this particular sector has become a priority. Efforts have been made to reduce CO_2 in the energy consumption and energy generation by promoting EVs and wind turbine generators through the application of high-powered NdFeB super-magnets. The demand for NdFeB super-magnets is projected to grow by 114% by 2030 and 293% by 2050 (relative to the recorded demand in 2020) (Wood MacKenzie, 2022a) (Figure 3.8).

FIGURE 3.7

2016 Global greenhouse Gas Emission by Sector

Global GHG emission were 49.4 billion tonnes CO_2eq – equivalent in 2016



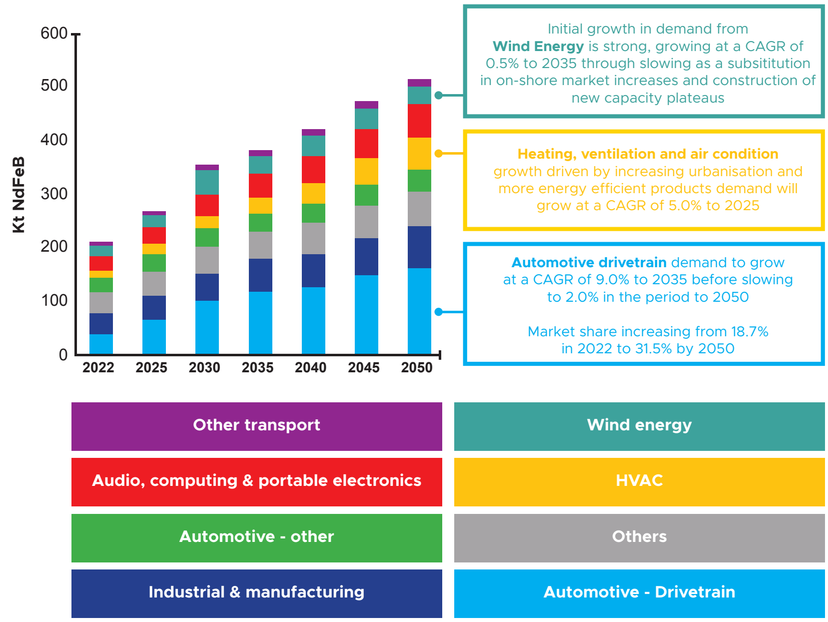
Source: Our World in Data, Climate Watch, the World Resources Institute (2020)

Figure 37: Global greenhouse gas emissions by sector (Ritchie, 2020)

FIGURE 3.8

Global Rising Demand of Rare Earths

1. The market value of rare earths (RE) reached USD 13.2 billion in 2019 and was estimated to reach USD 19.8 billion by 2026. This excludes the value of downstream manufactured products.
2. Energy-efficient motors market grew 16% (2021) and 20% (2022), which was expected to reach 10% growth in the coming years.
3. This trend gives rise to massive supply chain of RE as critical components in motor making (e.g., NdPr).
4. The preliminary estimation of IAC-REE resources value in Malaysia was reported to be around USD 182 billion (JMG, 2020).



Sources: WoodMac, Lynas Corporatation Ltd and Lynas Malaysia Sdn Bhd; Arafura (2022) https://www.arultd.com/products/supply-and-demand.html; JMG (2020)

Figure 3.8: Global rising demand for rare earths (Wood Mackenzie, 2022a)

The high-power electric motors used in EVs operate under higher temperature, which would require two specific REE, namely Dy and Tb, to improve magnet temperature resistance. These REE are in great demand and will continue to grow at even faster rate than the overall magnet demand.

The market for energy-efficient motors, which grew by 16% in 2021 and 20% in 2022, is expected to deliver around 10% growth in the coming 10 years, as all countries and industries seek to reduce their exposure to fossil fuels, improve their energy efficiency, and reduce their CO_2 emissions.

The other fastest growing market segment involves the chemical mechanical planarisation, where REE-based products allow the development of new generations of semiconductors.

These changes in technology are enabled by rare earths, which have triggered a massive growth in the whole industry's value chain (Table 3.2). Malaysia's participation in the REE value chain would reshape the automotive industry from Tier 1 – OEM positioning, differentiation, and innovation drive to services (highly limited maintenance on EVs as compared to that of traditional internal combustion engine cars) and fundamental market drivers (shared or individual).

TABLE 3.2

What does it take from resource to e-mobility?			
	Additional Requirements in Next 10 years	**Current Production Capacity**	**Additional Production Capacity Needed**
Resource	Double rare earth production by 2030	China: 63 ktonnes/year Lynas: 7 ktonnes/year	China and Lynas to double their existing production capacity over the next 10 years
High-performance magnets	+1,000 ktonnes HP magnets over 10 years (+100 ktonnes/year)	China: 35 ktonnes/year Japan: 15 ktonnes/year	Double the existing annual production capacity
Energy-efficient electric motors	+500 million motors over 10 years (+50 million/year)	25 million motors/year globally	Double the existing annual production capacity

Table 3.2: Resource to e-mobility (Lynas Corp. and Lynas (M) Sdn Bhd., 2022)

3.5 Critical Global HREE Supply

Figure 3.9 presents the gist of the global scenario, in connection with REE mining, processing, metals and alloys, magnets manufacturing, and recycling. Details on the global scenario are elaborated in horizon scanning (Appendix 2).

FIGURE 3.9

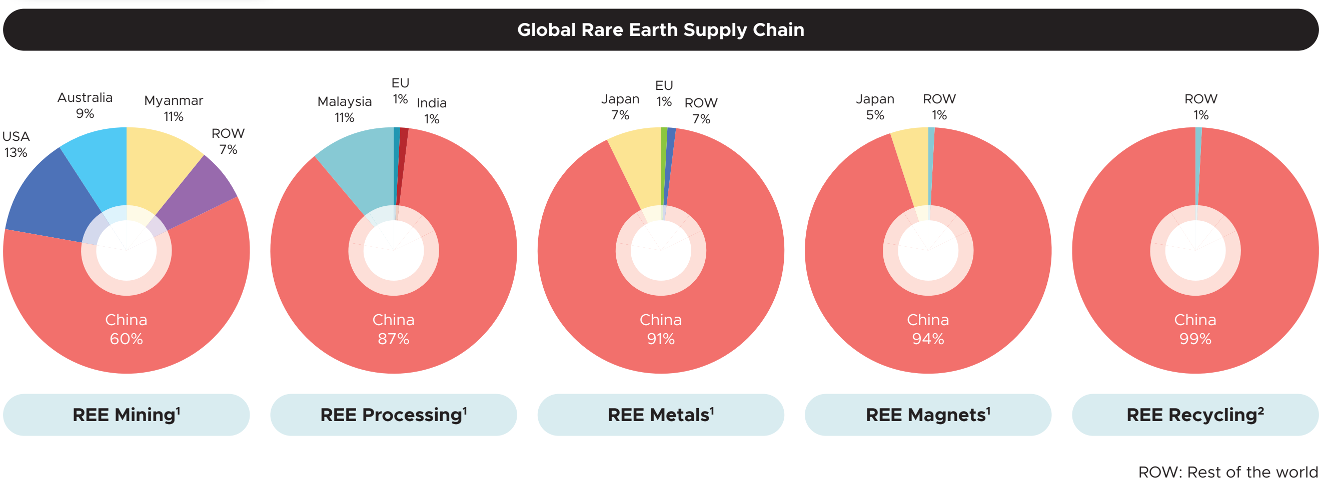


Figure 3.9: Global rare earth supply chain (Ionic Rare Earth, 2022)

Among others, Nd, Pr, Dy, Tb, Sc, and Sm record significantly higher demand globally as these are essential elements for the manufacturing of super-magnets. This implies the need for new mines to be brought into production. Currently, the main players with operating mines, apart from China, are Australia, Myanmar, and the United States of America (USA). New prospects have been identified in USA, Canada, Australia, Vietnam, Thailand, Malaysia, and Uganda. With respect to processing, apart from China that accounts for about 87% of the world supply of REE, Lynas Malaysia accounts for 11% of the world supply with significant potential of growth, while EU and India account for 1%, respectively.

The supply of HREE (such as Dy and Tb) is one of the most critical issues emerged in the current global rare earth scenario. HREE separation involves much more complex separation stages for the purification of individual heavy rare earth oxide (HREO) as compared to LREE. The fraction of HREE in mineral-type rare earth deposit is much smaller than the fraction of LREE, making it less economical for the separation of small quantities of HREE. Lynas's separation facility in Malaysia does not include the separation of HREE. Currently, China dominates 100% of global HREE separation capacities.

3.6 Ion Adsorption Clay (IAC-) Type Deposits

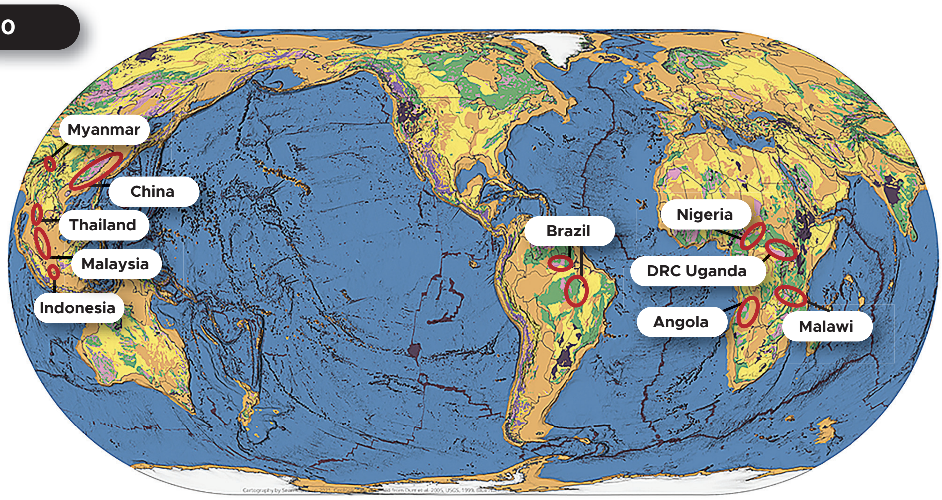
IAC-type deposits are formed in the weathering crusts of rocks with high REE content. Referring to the geology of Southern China's IAC-type deposits, rich IAC-type deposits are formed over igneous rocks, especially tin-bearing granites, where monazite is a common accessory mineral.

By inference, any tin-bearing granites located within high weathering zones of the tropics should possess IAC potential. As shown in Figure 3.10, granite areas within the tropics in the composite world geology map, with known tin mineralisation, are marked as potential IAC locations. A total of 10 high IAC potential locations are identified:

Asia	: South China, Myanmar, Thailand, Malaysia, Indonesia
South America	: Brazil
Africa	: Nigeria, Democratic Republic of Congo (DRC), Uganda, Angola, Malawi

Currently, most of the separated HREE come from IAC-type deposits found in China and Myanmar. China controls 100% of global purified HREE supplies. IAC-type deposits are secondary enrichment deposits. Coupled with their scarce distribution globally and ease of extraction, these deposits become the most sought-after HREE source.

FIGURE 3.10



Google base map: https://concord.org/blog/mapping-the-distribution-of-rock-types/

Sendiments	Igneous Rocks	Sedimentary Rocks	Igneous Rocks
Ocean Sediments	Granitic Rocks		
Continental Sediments	Andesitic Rocks		
	Basaltic Rocks		

Figure 3.10: Composite geology map of the world showing tin granite distribution (Pallant, 2022)

3.7 The Global Scenario and the China Factor

China has built their strength in the rare earth industry over the last 60 years. The REE industry in China is fully matured with the following features:

(i) China's market is more than 80% of the market volume of rare earth products;
(ii) China produces more than 90% of the world's rare earth magnets;
(iii) China has spent about 60 years of research, product development, and product refinement, aspiring to reach the highest achievable qualities;
(iv) China has several dedicated rare earth research facilities that solely and exclusively work on rare earth;
(v) China has industrial standards for rare earth, which enable commoditisation;
(vi) As a result of commoditisation, China can have mercantile exchanges for rare earth;
(vii) Positions in rare earth products may serve as collateral for loans.

Since 2015, China has established an International Organisation for Standardisation (ISO) working group, specifically ISO/TC 298, to internationalise China's rare earth industrial standards (The Rare Earth Observer). They have internationalised seven standards over these years, while another nine standards are in the pipeline:

(i) Two standards on vocabulary/terminology;
(ii) Two standards on recycling;
(iii) One standard on exchange of information;
(iv) One standard on packaging and labelling;
(v) One standard on traceability.

FIGURE 3.11

Notice on Public Comments on the Revised Catalog of Technologies Prohibited and Restricted from Export in China

中国禁止出口限制出口技术目录

China Export Prohibited / Export Restricted Technology Catalogue

In order to strengthen the management of technology import and export, in accordance with the relevant provisions of the "Foreign Trade Law" and "Regulations on the Administration of Technology Import and Export", the Ministry of Commerce, together with the Ministry of Science and Technology and other departments, reviewed the "Catalogue of Technologies Prohibited and Restricted from Export in China" (including the Ministry of Commerce and the Ministry of Science and Technology in 2008) Order No. 12 and Announcement No. 38 of 2020 by the Ministry of Commerce and the Ministry of Science and Technology (hereinafter referred to as the "Catalogue") have been revised.

This revision plans to delete 32 technical items, modify 36 items, and add 7 new items. After the revision, the "Catalogue" has a total of 139 items, including 24 items that are prohibited from exporting and 115 items that are restricted from exporting. This revision substantially cuts down on the "Catalogue", refines the control points of some technical items, and creates positive conditions for strengthening international technical cooperation.

Among the modifications we note **additions** to the **"Prohibited for Export"** part:

11	Non-ferrous metal smelting and rolling processing industry	213301J	Extraction, processing and utilization technology of rare earth	1. Rare earth extraction and separation technology 2. Production technology of rare earth metals and alloy materials 3. Preparation technology of samarium cobalt, neodymium iron boron and cerium magnets 4. Preparation technology of rare earth oxycalcium borate

Source: Ministry of Commerce of the People's Republic of China

Unchanged under the **"Restricted for Export"** part:

16	Non-ferrous metal mining and dressing industry	210901X	Mining Engineering Technology	Ion type rare earth mine leaching process

Source: Ministry of Commerce of the People's Republic of China

China is fully aware of her dominance in REE mine production, separation capacity, metals and alloys manufacturing, and magnets manufacturing. In order to sustain the REE monopoly, China has recently rectified their laws on the prohibition of the export of REE-related technologies (Figure 3.11).

With the anticipated surge in the number of new REE mines, especially the low-cost IAC mines, China maintains its supremacy in the field by banning the export of IAC leaching process technology and REE separation technologies. In doing so, prospective miners are required to collaborate with the Chinese IAC mining firms and to provide their mine products to China for REE separation.

China has consolidated REE production into two large firms—one in the north (China Northern Rare Earth Group Hi-Tech Co. Ltd.) and one in the south (China Rare Earth Group Co. Ltd.). The northern corporation continues its LREE production using the mineral-type rare earth deposit at Bayan Obo, Inner Mongolia, while the southern corporation focuses on the production of HREE from IAC in Southern China and Myanmar. These giant Chinese REE firms serve to further increase their pricing control power. The global scenario is presented in Appendix 2.

Figure 3.11: China's prohibition on the export of rare earth technologies (The Rare Earth Observer, 2023)

FIGURE 3.12

PROHIBITED LIST

Non-ferrous metal smelting and rolling processing industry

No.: 053301J

Technical name: Non-ferrous metal metallurgy technology

Control points: **ion adsorption type rare earth** heap leaching extraction technology and formula

No.: 053302J

Technical name: Rare earth refining, processing and utilization technology

Control points:

1. **Full extraction and continuous separation of rare earth** elements and "multi-exit" process and parameters of rare earth extraction
2. **Synthesis process** of rare earth extractant
3. **Process technology** for extracting single rare earth (purity ≥99%)
4. **Rare Earth Addition Technology** of Metal Materials
5. **Production technology of rare earth alloy materials and their products**
6. Process and parameters for extracting rare earth elements from **ionic rare earth ores**

Figure 3.12: China's technology export prohibition list (2008)

3.7.1 China's Dominance in the Rare Earth Midstream Sector

Currently, China controls 60% of REE mining, 87% of REE purification, and 94% of REE magnet supplies. In order to protect the country's dominance in the REE supply chain, China consolidated all REE firms into a single state-owned entity in 2022. All private REE mines in China were either nationalised or shut-down. The REE giant is encouraged to source REE raw materials from other countries around the world by investing in mining projects but is prohibited to provide technology transfer on rare earth mining and separation to the host countries. Figure 3.12 shows a snapshot of China's technology export prohibited list that has been in force since 2008. All rare earth mine products must be brought back to China for processing.

3.8 The Current Status of the IAC-REE Industry in Malaysia

Before the issuance of the approval for the pilot project (started in 2022) in Kenering, Perak, forward parties of Chinese REE workers (mostly displaced private REE miners from Jiangxi and Guangxi provinces) were already exploring potential IAC-REE areas in many states in Peninsular Malaysia. Despite the absence of approval for IAC-REE mining in Malaysia, the sales of REC from Malaysia to China were reported in the Chinese customs records, as shown in Figure 3.13.

The presence of IAC-REE resources has attracted the attention of major REE firms in China. Some of these firms had started sending technicians to Malaysia in order to explore IAC-REE opportunities. Two firms successfully identified IAC-REE resources in Kedah and Perak, respectively. They worked with the local companies and successfully procured mineral tenements over the potential IAC-REE areas.

In order to provide good mining practice, the SOP for IAC-REE mining in Perak was reviewed by the NRES-appointed Executive Committee, which consisted of experts from academia, industry players, and an NGO before it was finally approved by the Federal Cabinet and the State Exco in 2021. NRES then collaborated with the state government in 2022 following the granted approval for the pilot project of IAC-REE mining using the ISL mining in Perak.

FIGURE 3.13

China rare earth imports

In Q1 2022 China imported 33,530 mt of rare earths raw materials, 14,760 t or 30% less than in Q1 2021.

While shipments from almost all origins were reduced, the big declines were Myanmar, -9,400 t or -95% compared to Q1 2021 and -8,800 t (100%) of monazite from Madagascar and low TREO monazite from Rio Tinto, whose commercials may have been killed by increased freight rates to China.

Increased volumes came from Malaysia at 2,120 t, up 255% y-o-y, as we see for the first time mixed rare earth concentrate 1,130 t from Malaysia to China. Another part of the increase is someone offloaded some 500 t of lanthanum/cerium carbonate to China at a knock-down, drag-out and once-and-only price, but at the same time shipped less heavy rare earth "SEG" than Q1 last year to China.

China's imports of monazite concentrate, mixed rare earths and other concentrate from Vietnam went up nearly 250% to 3,000 t.

Also Bastnaesite exports from USA to China came in slightly higher than last year at 24,500 t.

Figure 3.13: Sales of REC to China reported in Chinese customs records (The Rare Earth Observer, 2022)

3.9 Malaysia's IAC-REE Potentials

Figure 3.14 shows the distribution of IAC-REE occurrences in the Malaysian granites with respect to tin fields. Monazite, zircon, and xenotime (all REE-bearing minerals) are common by-products of heavy minerals recovered along with cassiterite in the alluvial tin mining operations. The source of these REE minerals can be traced to the Malaysian granites. Tropical weathering of the Malaysian granites facilitates the formation of these IAC-type deposits.

FIGURE 3.14

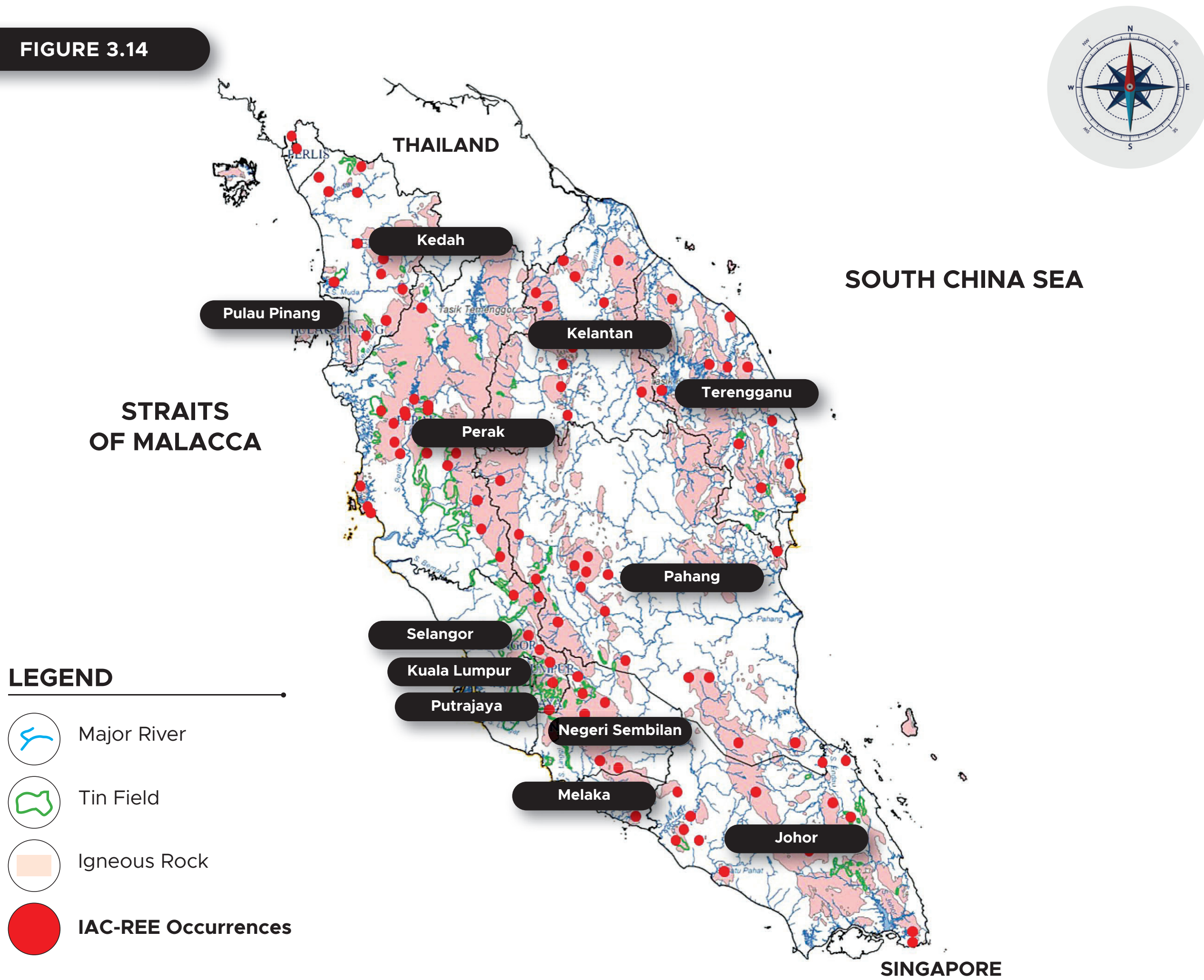


Figure 3.14: IAC-REE occurrences in the granites of Peninsular Malaysia with respect to tin fields (JMG, 2020)

3.10 Malaysia's Strategic Advantage in IAC-REE

The unique widespread occurrence of tin granites in Malaysia has placed the country as one of the 10 regions around the world with high IAC-type REE deposits. JMG, in its reconnaissance of the REE survey undertaken since 2014, identified some 16 million tonnes of Inferred Resources of TREE in Malaysia, which were deemed potentially upgradable to 60,000 tonnes of mineable resources. Coupled with the typically high (> 30%) HREE in this resource, Malaysia is in a strong position to be a leading player in the supply of HREE. Malaysia must optimise this strategic HREE advantage through the development of a full-value chain of IAC-REE deposits, that is, a vertical integration of mining, separation, and the downstream super-magnets and electric motors manufacturing.

3.10.1 Mining

The extraction of REE from IAC-REE is relatively simple. REE values occur as ions are loosely attached to the clay minerals in the granite regolith. Leaching by an appropriate lixiviant would release the REE ions, which can be re-concentrated by precipitation or other hydrometallurgical means into an intermediate mixed rare earth product for further processing into useful REO. Mining methods for the leaching of metal values are simple, which are typically in the forms of heap leaching, vat leaching, agitated tanks leaching, or in-situ leaching. The selected method depends on the location of the target resources and must be in compliance with ESG conditions.

3.10.2 Midstream Sector Processing

Currently, with Lynas's REO processing plant in Gebeng in 2013, purified REO are contractually sold to Japan, Europe, China, and North America for the manufacturing of metals and alloys, which are used for the manufacturing of super-magnets, among other products, in those countries. As of now, it serves as the only REO separation and purification plant in the country. It is also noted that Lynas's raw materials are sourced from its mine in Mount Weld, Australia, which produces mineral-based rare earth oxides.

A private firm sets up a research facility to process and produce separated and purified REO from IAC-REE samples. However, this facility is still in its development stage and has yet to obtain a license from MITI. It is highly challenging to gain the needed technical knowledge and experience. On the other hand, technological innovations can also be an area of competitive advantage when the facility can overcome initial hurdles, especially if newly developed techniques can improve the methods currently in use.

Back in the 1950s, REO separation technologies started in the USA but have been perfected by China since 1970s. China now controls 87% of the global REO separation capacities and 100% of HREE separation. HREE separation is more complex than LREE separation. After all, there are no mining projects outside of China's control that have enough HREE to justify the setting up of HREE separation plant. Even Lynas Malaysia sends their HREE-mix products to China as the quantities involved are small.

In order to protect its technical monopoly, the Chinese government has banned the export of in-situ-leaching and rare earth separation technologies. Chinese rare earth operators are encouraged to mine REE overseas but must send the raw mine products back to China.

3.10.3 Metals and Alloys Manufacturing

As all of Lynas's products are sold overseas, there are no rare earth metals and alloys manufacturing plants established locally.

3.10.4 Downstream Super-Magnets Manufacturing

On the other hand, magnet-making technologies are available. However, it is difficult to set up a downstream magnet-making in Malaysia due to the lack of purified magnet REO (Nd, Pr, and Dy) supplies. The same reason applies for the manufacturing of electric motors. It is hoped that, when the Malaysian REE separation plant is up and running, its local IAC-REE resources would provide the necessary feed materials for the downstream sector.

The timely development of the Malaysian IAC-REE industry, including the separation and purification of the REC products, would preserve Malaysia's valuable IAC-REE values, putting the country onto the world map as the supplier of REE and rare earth magnets. With the implementation of this business model in full vigour, Malaysia should envision itself to be the global REE supply hub.

4

CHAPTER

NATIONAL IONIC-ADSORPTION CLAY RARE EARTH ELEMENTS SECTORAL TARGETS AND BUSINESS MODELS

4.1 National Targets for Rare Earth Elements

In setting the national targets for Malaysia, local and global market demands for EVs are considered as the main driver for the demand surge of REE. This is attributed to the fact that the most important component for an EV is the drive train, which requires NdFeB super-magnets (Yunos, 2022). Individual global automakers have set varied goals for Evs, but the total numbers to be achieved by 2030, at least, are very much in excess of 23.5 million units of Evs (Table 4.1).

TABLE 4.1

Automotive Firms	Commitments	Target Year
Tesla	20 million Evs	2030
BMW	1. 50% of global sales (10 million Evs) 2. Interim target of 2 million Evs	2030 2025
Ford	1. 600,000 Evs 2. 270,000 Mach-Es 3. 150,000 electric transit vans 4. 150,000 lightnings	2023 2024 2024 2024
General Motors	1. Fully zero emission cars and trucks 2. 1 million Evs annually by mid-decade	2035
Honda	2 million Evs per year	2030
Hyundai	1. 1.9 million Evs annually 2. 1.2 million Evs (by KIA)	2030 2030
Mazda	25–40% of cars to be electrified	2030
Toyota	3.5 million units of Evs	2030
Volvo	50% of car sales to be Evs	2025
Nissan	50% electrification mix	2030
Stellantis	5 million units	2030
Volkswagen	1. Evs represent half of the vehicle sales 2. “Nearly” all sales in major markets to be Evs	2030 2040
Subaru	40% of battery Evs or hybrids	2030

Table 4.1: Global EV goals set by automakers (Source: Rubio-Licht & Roach, 2022)

In Malaysia, Perodua has set an annual goal of 35,000 EVs (5% of total industry volume (TIV)) by 2030, while Proton has set an annual goal of 10,000 EVs by 2027.

Assumptions

There are a number of assumptions towards achieving the national targets, which are presented as follows:

(i) The global demand for NdFeB super-magnets is projected to be approximately 350,000 tonnes by 2030 (Wood MacKenzie, 2022b).

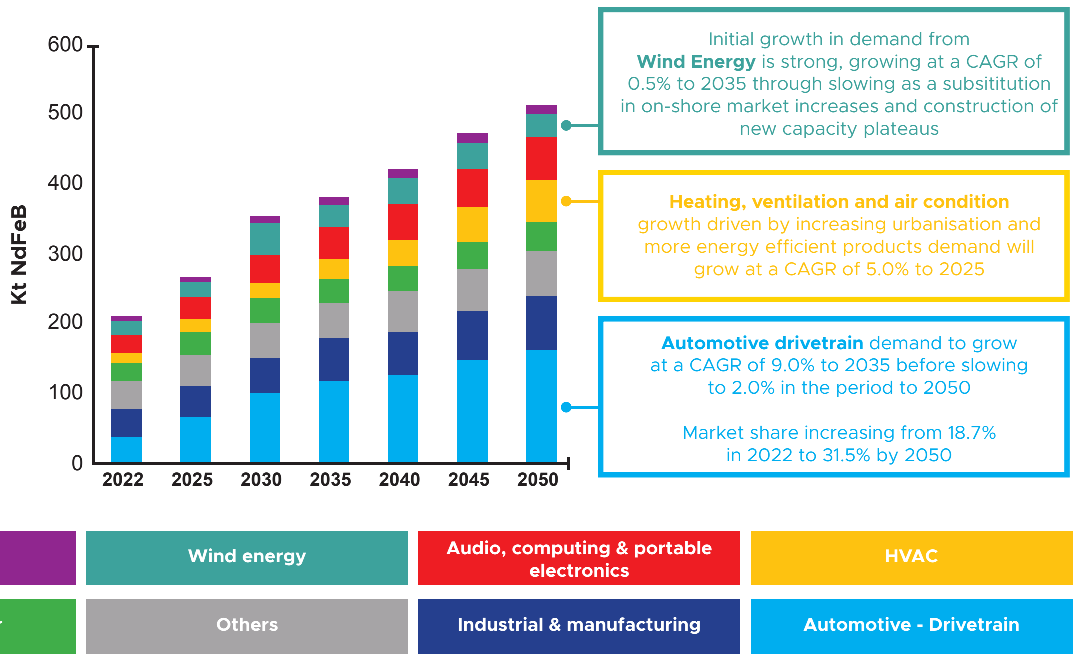
(ii) In the case of NdFeB super-magnets, Nd is assumed to amount to 30% of the total of NdFeB super-magnets (Figure 4.1), that is, equivalent to approximately 10,000 tonnes of Nd.

(iii) Based on the National Automotive Policy 2020 and Low Carbon Mobility Blueprint 2021–2030, Malaysia envisions that 15% of vehicle total industry volume (TIV) are EVs by 2030, amounting to 183,000 units annually[17].

(iv) With each EV requiring 2.5kg of Nd annually, the 183,000 units of domestic EVs would require some 457,500kg (or 457.5 tonnes) of Nd.

FIGURE 4.1

NdFeB SUPER-MAGNET DEMAND BY END-USE APPLICATIONS (kt NdFeB) 2022-2050



Source: WoodMac

Figure 4.1: NdFeB super-magnets demand by end-use applications, 2022–2050 (Wood Mackenzie, 2022b)

[17] Based on data from KASA's Low Carbon Mobility Blueprint (LCMB) (2021–2030) and the TIV target to be achieved by 2030 in the National Automotive Policy 2020; the TIV target stipulated in the NAP 2020 is 1.22 million units.

National targets

Malaysia targets to produce 10% of the global demand of super-magnets, amounting to 35,000 tonnes of NdFeB super-magnets by 2030.

(i) Upstream sector annual target is expected to amount to 30,000 tonnes of TREO by 2030.
(ii) Midstream sector annual target is to process 30,000 tonnes TREO yearly by 2030, that will produce approximately 10,000 tonnes NdPr (Assuming the 30,000 tonnes TREO contains a 34.56% of NdPr).
(iii) The annual target for the downstream sector is to manufacture 35,000 tonnes of NdFeB super-magnets annually by 2030.

The overall sectoral national targets for the year 2030 are shown in Figure 4.2.

FIGURE 4.2

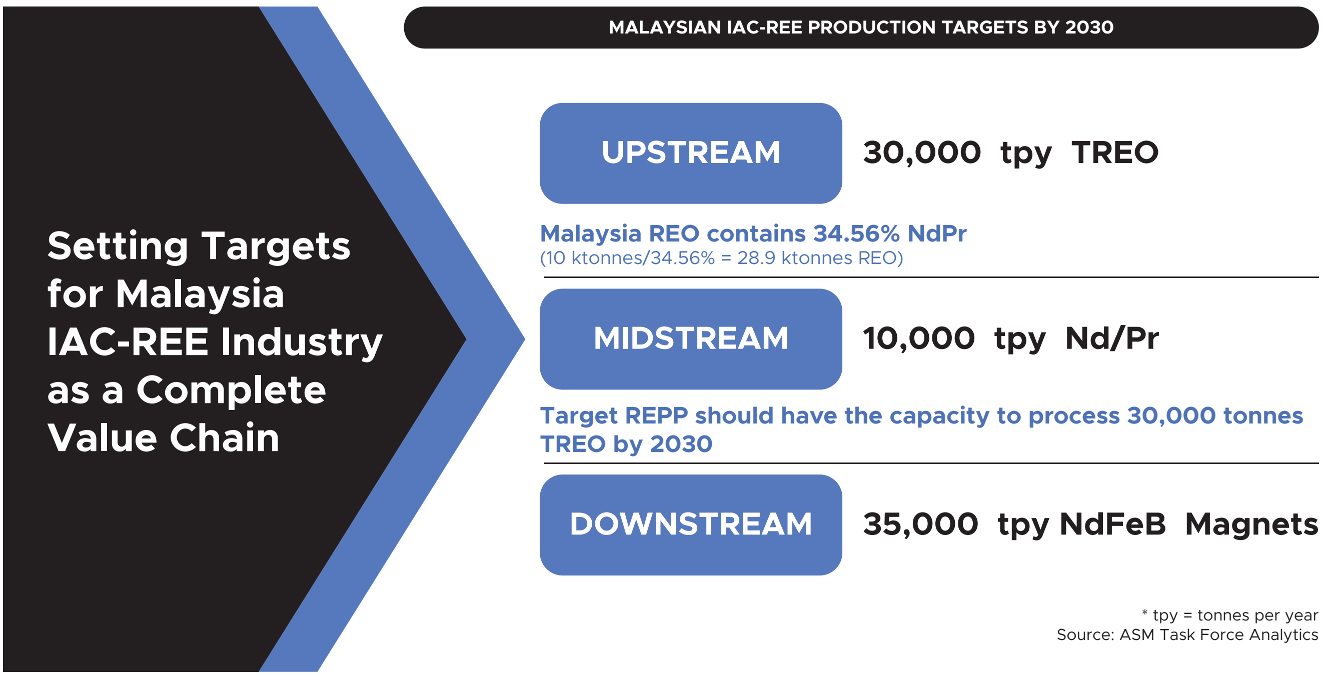


Figure 4.2: Overall sectoral national targets for Malaysia's IAC-REE industry

4.2 Upstream Sector

4.2.1 Introduction

This section covers the exploration for and mining of REE in IAC-REE deposits, as well as the on-site processing of the REE extracted into commercial products, specifically in the form of REC. As for the formulation of the business model for the development of the upstream sector of Malaysia's IAC-REE industry, the following major challenges are taken into consideration:

(i) Does Malaysia have IAC-REE resources to justify the establishment of a full value chain of the rare earth industry in the country?
(ii) Can the products from the mining and on-site processing of the local IAC-REE resources meet the requirements, in terms of quality and quantity, of the possible midstream IAC-REE processing industry in Malaysia?
(iii) Can the development of the IAC-REE resources provide the country's expected ROV?
(iv) Can the resources be developed and mined in a responsible and sustainable manner that meets the environmental and social requirements, as well as the expectations of the country and society at large?

4.2.2 Exploration for IAC-REE Resources

i. Stocktake of exploration for IAC-REE resources in Malaysia

The success of the business model for the upstream sector hinges very much on the availability of IAC-REE resources in Malaysia, both in terms of quantity and quality. Hence, the most important part of this business model is to ascertain the existence of the resources, and if so, how much, where they are, and of what quality.

Following the publications of ASM in 2013 and 2014, which identified the possible existence of economic IAC-type deposits in Malaysia, the collaboration of ASM with JMG initiated a project to explore for IAC-REE deposits in the country, with the main purpose of confirming the existence of IAC-REE deposits with promising economic potentials in Malaysia and their locations. The study produced encouraging results and recommended the need for additional studies. Under the 11th Malaysia Plan (11MP), an allocation of RM 3.8 million was provided for JMG to undertake IAC-REE reconnaissance survey in selected areas throughout Malaysia. Subsequently, under the 12th Malaysia Plan (12MP), an allocation of RM 15.0 million was approved for JMG to carry out follow-up studies on potential areas delineated in the previous studies.

The 11MP reconnaissance survey, which was carried out from 2017 to 2020, covered 13,000 km² over 10 states. Prior to that, JMG had compiled and published a guideline for the exploration of REE, entitled *"Garis Panduan Eksplorasi Unsur Nadir Bumi"* (JMG.GP.20) (Jabatan Mineral dan Geosains [JMG], 2015). Focusing on exploration techniques, the guideline includes sampling and analytical procedures used by JMG in the above-mentioned IAC-REE exploration programme.

ii. Exploration results by Jabatan Mineral dan Geosains

The 11MP reconnaissance survey and previous studies identified about 16 million tonnes of REE resources, including numerous anomalous locations suitable for follow-up and detailed investigation (Figure 4.3 and Figure 4.4). REE resources were calculated based on the area, thickness of the weathered zone, and concentration of TREE. The resource of REE in metric tonne, TREE, is the total volume of the soil (expressed in m^3) multiplied by the bulk density of the soil (taken as 1.9 tonne/m^3) and the average concentration of TREE equivalent. TREE resources were then converted to the equivalent TREO resources by multiplying by a factor of 1.165.

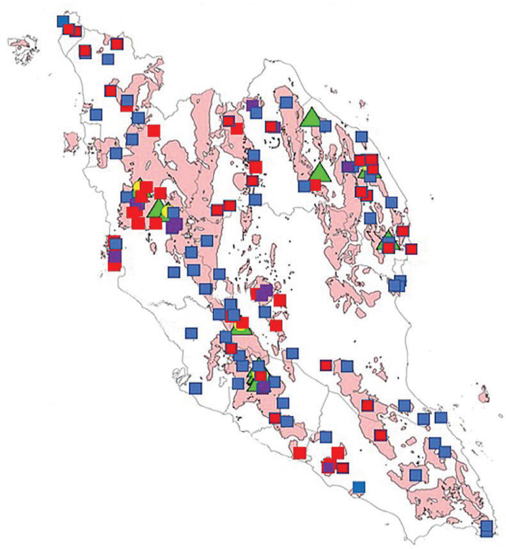
As regards resource and reserve classifications, for the purpose of this study report, the Malaysian Mineral Resource and Reserve Reporting Code (MMRC) (2022), which is based on the Australasian Code for Reporting of Exploration Results, Mineral Resources, and Ore Reserves (JORC) and International Reporting Template for the Public Reporting of Exploration Results, Mineral Resources, and Mineral Reserves (CRIRSCO) code, was used. Based on the sampling spacing for the 11MP reconnaissance survey, which varied from 500 m to 1,000 m, the identified resources were classified as "Inferred Resources" – the category with the lowest level of confidence.

FIGURE 4.3

REE POTENTIAL IN MALAYSIA

Reconnaissance Study RMKe-11

- REE > 300-500 ppm
- REE > 500-1000 ppm
- REE > 1000 ppm



Collaboration survey with ASM 2014

- Total HREE > 100 ppm
- Total HREE > 50 ppm
- Granite

Figure 4.3: REE results of the 2014 ASM-JMG survey and the 11MP (2017–2020) reconnaissance survey in Peninsular Malaysia (JMG, 2019)

FIGURE 4.4

REE POTENTIAL STUDY, SCANDIUM AND THORIUM SABAH & SARAWAK

- REE, Scandium & Thorium
- REE > 300 ppm
- Sc > 100 ppm
- REE > 500 ppm
- Soil Sample

Figure 4.4: REE results of the 11MP (2017–2020) reconnaissance survey in Sabah and Sarawak (JMG, 2019)

Notes: Location No. 2 in Sabah denotes occurrences of Sc in hard-rock and nickel laterite (not from IAC). The contents of REE are less than 300 ppm.

TABLE 4.2

State	Potential Area (km^2)	Inferred Resource (tonnes)	
		TREE*	TREO*
Terengganu	5,750	7,187,500	8,373,438
Kelantan	2,050	2,562,500	2,985,313
Perak	1,350	1,687,500	1,965,938
Kedah	1,005	1,256,250	1,463,531
Pahang	1,000	1,250,000	1,456,250
Selangor	600	750,000	873,750
Negeri Sembilan	550	687,500	800,938
Johor	450	562,500	655,313
Sarawak	100	125,000	145,625
Melaka	100	125,000	145,625
Total	**12,955**	**16,193,750**	**18,865,721**

Table 4.2: A summary of the Inferred Resources of the identified IAC-REE in 10 surveyed regions/States surveyed

Notes: *TREE converted to TREO through the multiplication by a factor of 1.165 (Source: JMG)

The top five States with high economic potential for the discovery of IAC-REE deposits are Terengganu, Kelantan, Perak, Kedah, and Pahang. It must be noted that, although the samples were mostly taken from soil profiles overlying weathered granites, some samples were also taken from weathered limestone, weathered ultrabasic rocks, and even bauxite. Apart from the initiative taken by the Malaysian government to explore for the IAC-REE resources in the country, several states have also issued licences for the private sector to undertake the exploration work.

iii. IAC-REE resources in Perak

In line with the objective of the study, IAC-REE resources in the State of Perak were considered. Four anomalous areas were identified for further investigation, namely Gerik (Kenering) in the district of Hulu Perak, Selama/Trong in the district of Kerian, Kati in the district of Kuala Kangsar, and Batu Gajah in the district of Batu Gajah. Details on the extent of the areas of potential and the estimated Inferred Resources are presented in Figure 4.5.

iv. Major industry players and institutions involved in the exploration/mining and R&D for IAC-REE resources

In the current national landscape, a few major industry players have started the exploration/mining-related activities and R&D for IAC-REE resources in Malaysia. Many of them also collaborate with local universities and research institutes in these endeavours. Table 4.3 shows several examples of Malaysian industry players undertaking exploration/mining and R&D for IAC-REE, and Table 4.4 shows Malaysian research institutions undertaking REE-related R&D.

v. Assessment of the sufficiency of IAC-REE resources and facilities to support, drive, and sustain a full value chain of IAC-REE industry

To date, JMG, from its reconnaissance surveys, has identified some 16 million tonnes of TREE (or 19 million tonnes of TREO) as Inferred Resources, covering 13,000 km^2 across 10 regions/states. Based on preliminary estimations, assuming that follow-up and detailed investigations, 5% of the Inferred Resources can be converted to the Measured Resources, some 950,000 tonnes of TREO, covering 650 km^2, will be available for the private sector to undertake feasibility studies. If 75% of the Measured Resources can be converted to Probable or Proved (mineable) Reserves after feasibility studies by the private sector, then Malaysia will have the potential to produce 710,000 tonnes of TREO. With the target of producing 30,000 tonnes of TREO annually, 710,000 tonnes of mineable Reserves should be able to sustain the production of IAC-REE for 23 years.

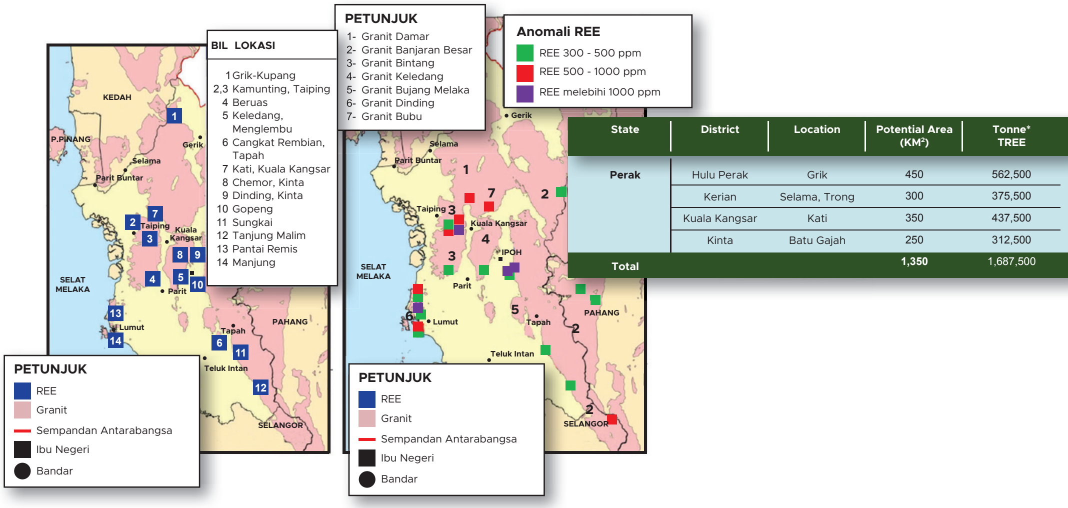
JMG can manage the reconnaissance, follow-up, and, to a certain extent, detailed surveys; all of which require minimal funding. The detailed surveys and feasibility studies should be assigned to private firms that have the funds, knowledge, and expertise, and are willing to take the risk of investing into the development of IAC-REE resources.

vi. Analytical facilities

The analysis of samples forms a major component in the exploration for IAC-REE resources. Currently, the cost of analysing all 17 elements ranges from RM 1,500 to RM 2,000 per sample. Although there are several local laboratories that can undertake the analysis of REE, only one local laboratory is found reliable in terms of facilities and accreditation, that is, the Technical Services Division (BPT-JMG) laboratory in Ipoh. Appendix 1 lists various local laboratories that can undertake the analysis of REE. As a result of the lack of reliable analytical facilities, the cost of analysis can be rather high and involves long turnaround time. Therefore, certain firms that undertake exploration have turned to having their samples analysed overseas instead.

FIGURE 4.5

REE POTENTIAL IN PERAK



State	District	Location	Potential Area (KM²)	Tonne* TREE
Perak	Hulu Perak	Grik	450	562,500
	Kerian	Selama, Trong	300	375,500
	Kuala Kangsar	Kati	350	437,500
	Kinta	Batu Gajah	250	312,500
Total			1,350	1,687,500

Figure 4.5: IAC-REE potential in Perak (JMG, 2019)

TABLE 4.3

	GreenChem Nanotech Solutions Sdn. Bhd. and Malaco Group	Myah Mines Sdn. Bhd.	Perbadanan Kemajuan Negeri Pahang (Kuala Lipis)	Falah Al Hadid (M) Sdn. Bhd. (Gua Musang)	Pahang Mining Corporation (Kuantan, Kuala Lipis, Raub, Muadzam)	Petronas Research Sdn. Bhd. and Universiti Teknologi Petronas (Bangi)	Aras Kuasa Sdn. Bhd. (MCRE), MB Incorporated Perak, and MBI Kedah	Gold, Rare Earth, and Material Techno-preneurship Centre, UMK	Ranhill Utilities Berhad	Nazwil Resources Sdn. Bhd.
Mineral Exploration and Mining	R&D on irrigation sequences for ISL, optimised lixiviant chemistry; recovery of REC without using large precipitation ponds	IAC-REE research station for leaching and extraction system (collaboration with UMP	Mineral characterisation, ISL, research station for leaching and extraction system (collaboration with UMP)	Mineral characterisation, mineral recovery from manganese mining tailings (collaboration with UMP)	Mineral testing lab for state authorisation (collaboration with UMP)	REE future positioning project – Greening the rare earths; new chemical to replace ammonium sulphate (collaboration with UMP)	Medium-sized lanthanide mineral mining (subsidiary of Aras Kuasa Sdn. Bhd.)	Establishment of mineral lab consortium specialising in gold and critical mineral (collaboration	Feasibility study to secure domestic REE for magnets and batteries; consulted Japan and Australia for technology transfer	Exploration, mining and marketing of REE
Mining Rehab/ Sustainability Practices	R&D on waste recycling; the use of rainwater harvesting system for separation plant	NIL	NIL	NIL	R&D in mining rehab and sustainable practices	NIL	Soil reconditioning, replanting, recycling of the used pipes, and covering the pit holes with paddy husks	NIL	NIL	NIL

Table 4.3: Existing/potential firms (exploration/mining and R&D) for the upstream sector

* List is non-exhaustive (Source: ASM focus group discussions and site visits)

TABLE 4.4

	UMP	Nuklear Malaysia	UTP	SIRIM	UKM	UTM	PPM (JMG)	UPM	USM	UM
Mineral Exploration and Mining	Chemical and physical properties of REE; characterisation of REO elements, elucidation of the kinetics and mass transfer mechanism of leaching process	Radioactivity survey of mineralised areas in Malaysia; study on the determination and distribution of patterns for REE	NIL	NIL	R&D on REE extraction, distribution area, and rare-earth extraction residue	Characterisation of REO elements, determination of REE concentration at different depth profiles, sensor study for mineral exploration, element distribution	Identification of major phases of REE (e.g., ion exchange, colloidal, mineral and water soluble); extraction from ion adsorption clay and bauxite, alternative lixiviant for in-situ leaching mining; REE reserve exploration capability studies	Characterisation of REO elements; element distribution	Characterisation of REO elements; geospatial studies; rare earth metal recovery	Characterisation of REO elements; geochemical characteristics of REE; evaluation of radiological risks around plant
Mining Rehab/ Sustainability Practices	Methods and opportunities of recycling rare earth from e-waste; comprehensive air pollution and radiation monitoring system; human capital development case studies	NIL	Utilising radioactive water leach purification (WLP) for other products	Testing, inspection, and certification services to help companies comply with safety and sustainability standards	Inspection on thorium, uranium, and REE content in lanthanide concentrate (LC) and water leach purification (WLP) residue of LAMP	NIL	Alternate sources of REE from mining waste, environmentally friendly method to remove impurities from pregnant solution	Public response to the rare earth industry in Malaysia; local community acceptance (Lynas case study)	Risk perceptions on the Lynas project	Remediating rare-earth wastewater; study on local community acceptance of the rare earth industry
Separation and Purification	Replicate system similar to Lynas for R&D and training purpose, with the aim of reducing the processing steps, separation REE by ion exchanger polymer resins and electrolysis method, ionic liquid, and separation	Development of mineral processing and REE extraction technologies; provide material characterisation services for minerals and REE; provide facilities for rare earth carbonate or rare earth chloride separation	NIL	NIL	NIL	NIL	Solvent extraction	NIL	NIL	NIL
Metal and Alloy Making	NIL	NIL	Rare-earth based compounds studies	Sharing of equipment	Study on neodymium magnet and other forms of rare earth alloys	Rare-earth based compounds studies (e.g., barium orthosilicate)	Planning to produce mischmetal (alloy) by electrowinning process	Rare-earth based compounds studies (development of rare earth doped fibre) on superconducting properties	Rare-earth based compounds studies (e.g., tungstates and metal-doped TiO) on superconducting properties	Electronic and magnetic investigations of rare-earth alloy; rare-earth based compounds studies
Manufacturing/ End Use	R&D on catalyst and capacitor	NIL	Study on the roles of rare-earth in alteration of magnetic properties to establish Centre for Automotive Research and Electric Mobility (CAREM)	Advances Manufacturing Research Centre (AMREC) R&D on RE materials (i.e., coating)	R&D on byproducts processing	NIL	Planning to fabricate magnet, battery, polishing Powder, catalyst, and other products	Usage of byproduct from rare-earth metals processing	Impact of Lynas on market price, EVs, and wind-turbine supply chains study	REE applications (e.g., catalyst, laser-related usage, and glass)

Table 4.4: REE-related R&D research institutions

* List is non-exhaustive (Source: ASM focus group discussions and site visits)

vii. Targeted scenarios for exploration

The scenario planned for the evaluation of IAC-REE resources in Malaysia is as follows:

At least 50% of the identified anomalies from the 11MP reconnaissance survey and previous studies should have been investigated in detail to the level of the Measured Resources by 2025. Additionally, all IAC-REE resource data at JMG should have been digitalised by then. At the same time, the private sector should be able to undertake detailed surveys and feasibility studies through the issuance of more Exploration Licences (EL) and Mining Leases (ML).

Following that, all identified anomalies from the 11MP reconnaissance survey and previous studies would be investigated in detail to the level of the Measured Resources by 2030. All these anomalies would also be investigated to the level of reserves with the participation of the private sector. Additionally, all IAC-REE data nationwide should have been digitalised and accessible by and shared with other agencies and the private sector.

After 2030, Malaysia should have the capabilities in terms of knowledge, experience, and talent stock for oversea ventures to develop IAC-REE resources and to secure supply of materials for Malaysia's midstream and downstream sectors of the country's rare earth industry.

viii. Issues, challenges, and gaps in exploration

Regarding exploration, there are several issues, challenges, and gaps encountered in the efforts of developing the upstream sector of the IAC-REE industry:

(a) Exploration programmes cannot progress fast enough due to the lack of funding and talent stock.
(b) The IAC-REE resource data at JMG are not fully digitalised and not available for sharing with other agencies and the private sector.
(c) The Malaysian government has yet to finalise the relevant national policy and regulations for the development of IAC-REE resources, which has affected the participation of the private sector in the IAC-REE resource development.
(d) There is a policy that bans mining activities in permanent forest reserves (PFR) and environmentally sensitive areas (ESA).
(e) The exploration for, and mining and on-site processing of, IAC-REE are relatively new in Malaysia, and is currently still highly dependent on the ISL technology from China.
(f) There is a lack of international best practices and guidelines on the development of IAC-REE resources for benchmarking.
(g) Apart from the costly and long turnover time for sample analysis, there is only one reliable accredited laboratory facility in Malaysia (located at BPT-JMG Ipoh) for the REE analysis.

ix. Way forward for exploration

The following actions are needed to enable the established targets to be reached in a timely manner:

(a) Adequate allocation should be given to JMG to fast track its exploration programmes.
(b) The State governments should be more liberal in its issuance of EL and ML through the exploration of alternative areas, apart from PFR and ESA.
(c) Malaysia should reduce its reliance on foreign technology and provide PPM the appropriate funding to undertake its own R&D programmes and collaborate with other research facilities locally and internationally to share experience and knowledge.
(d) Malaysia should develop its own best practices and guidelines on the development of IAC-REE resources.
(e) The Federal and State governments, as well as the private sector should jointly undertake the CEPA programmes.
(f) More laboratories, including commercial laboratories, should be upgraded and accredited to undertake reliable REE sample analysis.

4.2.3 Mining and On-Site Processing of IAC-REE

Up until the mid-2010s, China was the only country that mined IAC-REE-type deposits and produced HREE therefrom. Subsequently, in the mid-2010s, the mining of IAC-REE-type deposits started in Myanmar, with the assistance from China. Extending beyond China and Myanmar, public-listed firms, namely Ionic Rare Earths Ltd operating at Makuutu, Uganda and Aclara operating at Penco Bio Lantanidos, Chile, and one private firm, namely Mineracao Serra Verde at Minacu, Brazil, are hopeful of developing their prospects into a mine. There have been unsubstantiated reports that the mining of IAC-REE-type deposits have taken place in Thailand, Laos, and Vietnam.

Leaching methods are typically used to mine IAC-REE-type deposits, extracting REE from the REE-rich ion adsorption clays. Traditionally, three types of leaching methods have been used, namely heap leaching method, tank/pool/pond leaching method, and ISL mining methods. REE are extracted by ion exchange using electrolyte solutions (lixiviant), such as ammonium sulphate. All methods have an impact on the environment at varying degrees.

The heap leaching method involves excavating the REE-rich clay ("ores"), placing them in a heap, and spraying them with lixiviant. Tank/pool/pond leaching involves immersing the "ore" into a tank/pool filled with lixiviant. In the case of ISL mining method, lixiviant is introduced into the generally undisturbed REE-rich ion adsorption clay, which permeates down by gravity and, in the process, by ion exchange, desorbs the REE into a pregnant solution that is collected and channelled into a pool for processing.

In general, the heap leaching method and tank/pool/pond leaching method have been phased out and banned in certain places due to their negative environmental impact. ISL mining is now the dominant method considering that the method involves less topsoil removal, can be performed on site, and contributes lower environmental impact (Yaraghi, Ariffin & Baharun, 2019).

i. In-situ leaching method of mining IAC-REE deposits

Figure 4.6 shows a schematic diagram of the ISL mining set-up. In simpler terms, the ISL mining method involves setting up of a system of vertical injection pipes bored into the soil and weathered rock soil at regular spacing, where the lixiviant (ammonium sulphate) is introduced, and another near the horizontal but inclined system of piping below for the collection of the pregnant solution that is channelled into a collection pool. The ISL mining method is better suited for hilly terrains, where there can be effective gravitational flow of lixiviant and pregnant solution downwards. In any case, this method is only suitable for IAC-REE deposits on hilly terrains as it needs to be carried out above the water table to avoid polluting the groundwater and diluting the leaching solution by groundwater.

FIGURE 4.6

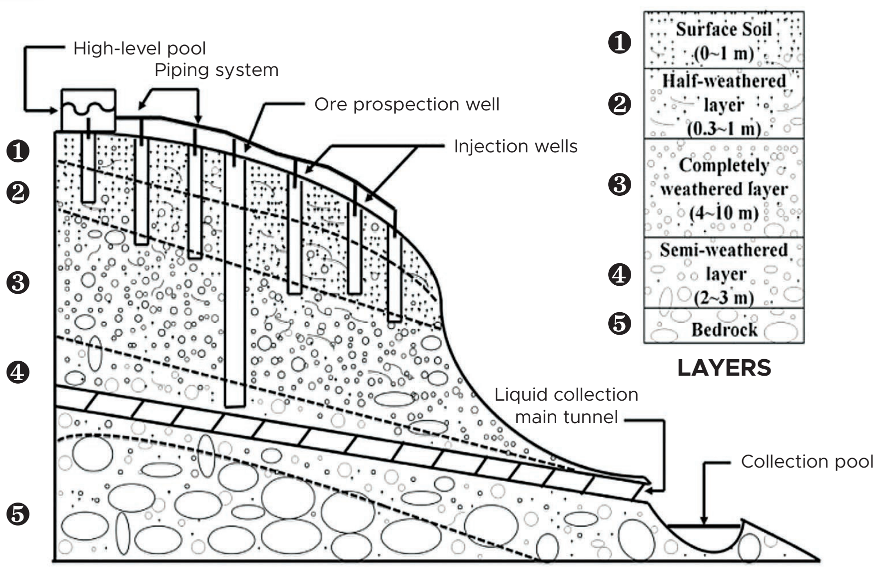


Figure 4.6: Schematic diagram of in-situ leaching mining set-up (Vahidi, Navarro & Zhao, 2016)

The leaching process starts by introducing the lixiviant into the vertical injection pipes at a predetermined rate. As the lixiviant flows downwards, the ion exchange process takes place, where a pregnant solution is formed through the desorption and impregnation of REE (adsorbed in the clay structure) with lixiviant. Upon reaching the bottom, the pregnant solution flows into the inclined piping system and is channelled into the collection pool. The rate of flow depends on the permeability of the soils.

ii. R&D initiatives to improve the current ISL mining method

Several R&D initiatives have been undertaken to improve the current China-based ISL mining method. In Malaysia, a local private firm found that the use of its proprietary GNano on-site processing method can reduce the REC precipitate settling time from about 12 hours in the ponds to 20 minutes in the tank. This 36-times reduction in the precipitate settling time can enable miners to use smaller settlement tanks, instead of large ground ponds of about 24,000 m^3 in volume. It is claimed that the new footprint is about 1/6 that of the pond method. However, the new method is still at the R&D stage and yet to be tested in the field on a commercial basis.

Meanwhile, in South Korea, Min (2022) presented a possible improvement in the reaction rate during the leaching process through the application of pneumatic fracturing to the host clay. Wang et al. (2022) reported a design of an innovative electrokinetic mining (EKM) technique, which enables green, efficient, and selective recovery of REE from weathering crusts. Unlike the conventional techniques, EKM can achieve about 2.6 times higher recovery efficiency, an 80% decrease in leaching agent usage, and a 70% reduction in metallic impurities in the REE recovered from the IAC-REE-type deposits.

The electrokinetic technology involves the application of a direct or alternating electric field to accelerate the migration of metals, organic compounds, and/or water. The newly developed EKM, which has undergone successful bench-scale and scaled-up experiment, is now being tested out via an on-site field experiment. It is projected to feature the following characteristics: (1) the migration of REE is enhanced by the applied electric field relative to conventional leaching techniques, where ion migration is governed by slow physical processes, such as gravity, flow, and/or concentration gradients; (2) the addition of leaching agent is substantially reduced as REE are transported predominantly by the applied voltage gradient, rather than by the flow of leaching agents; and (3) the use of lower amounts of leaching agents reduces the co-leaching of metallic impurities from the IAC-REE-type deposits.

PPM in Ipoh has also embarked on several research initiatives, including on the techniques to extract REE from IAC-REE and bauxite, the isolation of specific elements from the pregnant solutions through solvent extraction, as well as the recovery of REE from metallic mine effluent as a secondary source of local REE. However, these initiatives are all on at the laboratory scale. Figure 4.7 shows three R&D initiatives being undertaken to improve the current ISL mining and on-site processing methods.

iii. On-site processing

Figure 4.6 shows a schematic diagram of the ISL mining set-up. In simpler terms, the ISL mining method involves setting up of a system of vertical injection pipes bored into the soil and weathered rock soil at regular spacing, where the lixiviant (ammonium sulphate) is introduced, and another near the horizontal but inclined system of piping below for the collection of the pregnant solution that is channelled into a collection pool. The ISL mining method is better suited for hilly terrains, where there can be effective gravitational flow of lixiviant and pregnant solution downwards. In any case, this method is only suitable for IAC-REE deposits on hilly terrains as it needs to be carried out above the water table to avoid polluting the groundwater and diluting the leaching solution by groundwater.

A typical on-site processing system to produce rare earth carbonate is described as follows:

(a) Collection of pregnant solution
The pregnant solution leached from the ore bodies flows by gravity into collection tunnels, diversion holes, and collection ditches and then into a transferring tank, where it is transported to an on-site processing plant through the pump and pipelines for subsequent treatment.

(b) Purification process
At the processing plant, the pregnant solution is transferred into the impurity removal tank for the purification process. By varying the pH of the solution, various deleterious materials are precipitated out and removed from the system. Typically, they are compounds of Al, Fe, Ca, and Mg. Impurities precipitated from the impurity removal tank are generally in the semi-solid form. As these "rejected" materials may still contain REE, the precipitants are transferred into another pool, treated with concentrated sulfuric acid, and subsequently, diluted with clear water after the dissolution is completed. After the removal of impurities, the supernatant is transferred into the impurity removal pool again for the recovery of rare earths.

(c) Pregnant solution precipitation

After the purification process, the pregnant solution is transferred into a sedimentation tank that contains saturated ammonium bicarbonate solution. The mixture is continuously stirred with air pumps, and dosing of the ammonium bicarbonate solution is controlled until the pregnant solution in the pool achieves pH 6.7, where the REC starts to precipitate out. The generated supernatant is transferred into the liquid preparation tank for reuse.

(d) Aging crystallisation of REC

The precipitated REC is kept at the sedimentation tank for a period of time to allow the complete formation of REC crystals. These REC crystals are then put through a filter press system to remove excessive water. The filter-pressed product is stored and packaged in bags for dispatch. The supernatant generated from the filter press is then returned into the liquid preparation tank.

FIGURE 4.7

R&D Towards Improving the Current In-situ Leaching (ISL) Mining and On-site Processing

MINERAL RESEARCH CENTRE (PPM)

Improvements:

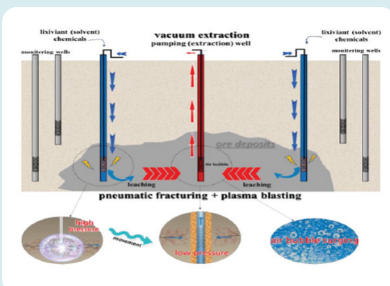
- Extract REE from IAC-REE (42% to 46% grade)
- Recovery of REE from metallic mine effluent (36%)
- Solvent extraction to separate HREE and LREE

ON-GOING R&D INNOVATIONS

In-situ leaching with pneumatic fracturing + plasma blasting + vacuum (Min, 2022)

Improvement:

Faster leaching process



ON-GOING R&D INNOVATIONS

Electrokinetic mining (EKM) (Wang, et al., 2022)

Improvements:

- 2.6 times higher recovery efficiency
- 80% decrease in leaching agent usage
- 70% reduction in metallic impurities in REE

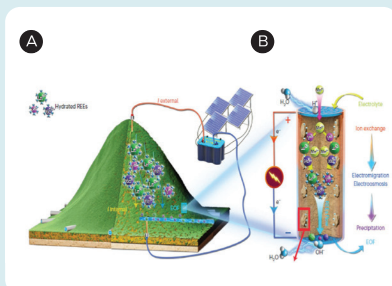


Figure 4.7: R&D initiatives to improve the current ISL mining and on-site processing methods

iv. Targeted scenarios for mining and on-site processing

By 2025, the legal framework should have been updated to suitably cover the mining of IAC-REE that uses the ISL mining method. The detailed SOP for the mining of IAC-REE should have been approved for nationwide usage, and JMG is expected to use the SOP as a guide for the approval of the Operational Mining Scheme (OMS). Commercial full-scale mining of IAC-REE should have started in various States by then.

By 2030, JMG should have undertaken and completed further exploration in areas with Inferred Resources of the IAC-REE category, specifically on raising them to the Measured Resource category. Following the identification of the resources, the mining of IAC-REE is expected to take place in different states nationwide.

By 2050, Malaysia is projected to be able to export the technology and talent stock sent to mine IAC-REE overseas to secure supply of raw materials for the domestic midstream and downstream sectors of the rare earth industry.

v. Issues, challenges, and gaps for mining and on-site processing

Regarding mining and on-site processing, there are several issues, challenges, and gaps in the upstream sector of the IAC-REE industry which needs to be addressed.

(a) There are still scepticisms about the ability of miners to mitigate possible environmental impact of the ISL mining method.
(b) There is strong lobby from environmental NGOs against the mining of IAC-REE using the ISL mining method.
(c) The national SOP for the mining of IAC-REE needs to be reviewed periodically for further improvements.
(d) Malaysia has limited experience in the mining of IAC-REE using the ISL mining method.
(e) Apart from China, almost all countries are still at the start of a steep learning curve.
(f) The policy on the banning of mining in PFR and ESA will essentially sterilise a large proportion of the country’s resources.
(g) Like any other industrial activities, illegal mining has been an issue of concern worldwide. The economic and environmental consequences of illegal mining are apparent. Numerous views have been put forward on the prevalence of such activities, which are mainly related to the shortcomings of the management and enforcement of the relevant regulatory requirements.

In the Malaysian context, there are adequate statutory provisions governing the whole spectrum of the mining industry, commencing from the exploration, mining, and processing stages to the abandonment stage. In fact, the dealings and operations of mining in Malaysia are regulated by specific laws and regulations. It is further compounded with other statutory requirements, but certain aspects in terms of coverage and authority appear to be overlapping. The overly regulated perception of the industry, as reflected through the tedious approval process requirements by a large number of authorities, has been seen as a challenging process. There are opposing opinions about the introduction of new requirements, such as tagging mechanism and certification in combating illegal operations; of which are considered as unnecessary. The availability of comprehensive laws and regulations, specifically for mining with specific administrative and enforcement agencies, in the country offers adequate infrastructure to combat illegal mining activities. However, improvement in the approval process at all levels related to the mining industry is the key way-forward towards overcoming the issues of illegal mining.

vi. Way forward for mining and on-site processing

The recommended way forward for the mining and on-site processing of IAC-REE involves the following:

(a) Strengthen the legal and regulatory framework to cater for the mining of IAC-REE using the ISL mining method
(b) Expedite the approval of the SOP for the mining of IAC-REE to enable the execution of mining activities nationwide
(c) Ensure the compliance of operators with legal requirements, their adherence to SOP, and voluntary implementation of ESG and sustainability initiatives
(d) The adoption of voluntary disclosures and reporting by operators
(e) R&D for or adoption of better and more environmentally-friendly technologies, of either home-grown or imported from overseas
(f) Implementation of a strong CEPA programme by the Federal and State governments towards obtaining the social licence to operate
(g) Prioritise other areas apart from PFR and ESA for the exploration and mining activities of IAC-REE through the issuance of more EL and ML
(h) Undertake a pilot ISL project in a controlled environment within the PFR area under the supervision of JMG for a feasibility study

4.2.4 Review of the Governance Ecosystem

This section presents the current governance ecosystem with respect to the mineral resource development in general and the development of IAC-REE resources. In particular, it includes the review of mineral-related policies and legislations, including acts, regulations, SOP, guidelines, and best practices, to ensure that the mineral resource development, particularly IAC-REE resources, are undertaken in an orderly and responsible manner. Examples of mineral-related policies, plans, acts/enactments, and the SOP are presented in the following:

(i) National Mineral Policy 2
(ii) *Kerangka Pelan Transformasi Industri Mineral Negara* 2021–2030
(iii) Mineral Development Act 1994
(iv) State Mineral Enactment
(v) SOP for NR-REE Mining in Malaysia

4.2.5 ESG Perspectives on the Upstream Sector

Although the main objectives of a business model are to enhance the contributions of the IAC-REE industry to the country's socioeconomic development, equally if not more important, is the respect for ESG and sustainability requirements; both of which should not be compromised. These twin objectives can only be achieved through the efficient, responsible, and sustainable development of the IAC-REE resources and their value-added products, backed by a projected increase in ROV.

4.2.6 Scenario Planning and Critical Path Analysis

Based on the compiled data and information gathered, the situation with regard to the development of IAC-REE resources in Malaysia has been reviewed and depicted in the strength, weaknesses, opportunities, and threats (SWOT) analysis.

4.2.7 Business Model for the Upstream Sector of the IAC-REE Industry

The objective of a business model is to enhance the contributions of the IAC-REE industry to the country's socioeconomic development through the efficient, responsible, and sustainable development of the REE resources and their value-added products, backed by a projected increase in ROV without compromising the need to comply with both ESG and sustainability requirements. The business model for the upstream sector revolves around creating value from the IAC-REE resources in Malaysia through the activities of successful exploration, responsible mining, and production of marketable value-added products involving efficient on-site processing.

(i) Synthesis of the business model

An analysis of the business model was carried out using two tools, namely 8i STI ecosystem enablers (ASM, 2020) and SWOT analysis, to evaluate the current ecosystem of the upstream sector of the IAC-REE industry in Malaysia. In line with TIM 2021–2030, the following guiding principles of the business model for the development of the upstream sector of the IAC-REE industry are adopted:

(a) ***Responsible mining:*** Mining that involves and respects all stakeholders, minimises and takes account of its environmental impact, and prioritises a fair division of economic and financial benefits
(b) ***Sustainable mining:*** The application of sustainable development concept in the mine development and operation
(c) ***Competency:*** Mine development and operation carried out by competent entities, both technically and financially
(d) ***Value-added products:*** Mining products of optimum value with multiplying impacts;
(e) ***Adherence to the high standards of industrial norms:*** Best management practices, self-regulatory, and competent and professional human resources
(f) ***Control on strategic mineral resources:*** Mineral security for strategic minerals in ensuring the maximum benefits to the nation
(g) ***Resource efficiency:*** An efficient mine in the way the resources are managed and extracted, with the optimisation of resource extraction through the collaborations of mining engineers, geologists, mineral processing engineers, chemical engineers, metallurgists, and other professional experts

(ii) The upstream business model value creation process

Minerals remained in the ground have no value; it is only when these minerals are mined and processed into useful products that the mineral endowments bring benefits to the country and its people.

The IAC-REE Inferred Resources identified by JMG through their reconnaissance surveys are estimated to be approximately 16 million tonnes of TREE, covering 13,000 km^2 in 10 States/regions. Follow-up and detailed investigations are carried out under the 12MP.

As mentioned in Section 4.2.2, assuming that through the follow-up and detailed investigations, 5% of the Inferred Resources can be converted to the Measured Resources, some 950,000 tonnes of TREO, covering 650 km^2 will be available for the private sector to undertake feasibility studies. Additionally, if 75% of the Measured Resources can be converted to Probable or Proved (mineable) Reserves after feasibility studies by the private sector, then Malaysia will have the potential to produce 710,000 tonnes of TREO. With the target of producing 30,000 tonnes of TREO annually, 710,000 tonnes of mineable TREO should be able to sustain the production of IAC-REE for 23 years.

The minimum saleable grade of REC in the Shanghai Metal Market involves 42% of TREO. In order to achieve the targeted production of 30,000 tonnes of TREO annually, Malaysia will have to produce 70,000 tonnes of REC, containing 43% of TREO per year. Assuming the price of REC is RM 30,000 per tonne, the annual production of 70,000 tonnes of REC will be worth RM 2.1 billion. This production value can be taken as the potential contribution of the upstream sector of the IAC-REE industry to the national GDP annually.

In addition, the Federal government can collect corporate taxes when mining firms make profits and, if introduced later, cess can also be collected, as in the case of tin mining.

In terms of the direct revenue, IAC-REE-producing States will benefit the most. The combined royalty for rare earth-producing States will amount to RM 252 million annually based on the 12% royalty ad valorem rate. Landowners will receive 3% tribute if all mining and on-site processing are to be carried out in alienated land. The total amount due to the landowners will be RM 63 million annually.

In terms of valuation, the potential (in-situ) value of the estimated 710,000 tonnes of TREO (equivalent to 1,650,000 tonnes of REC) is RM 49 billion. A summary of the value creation process in the business model is presented in Figure 4.8.

FIGURE 4.8

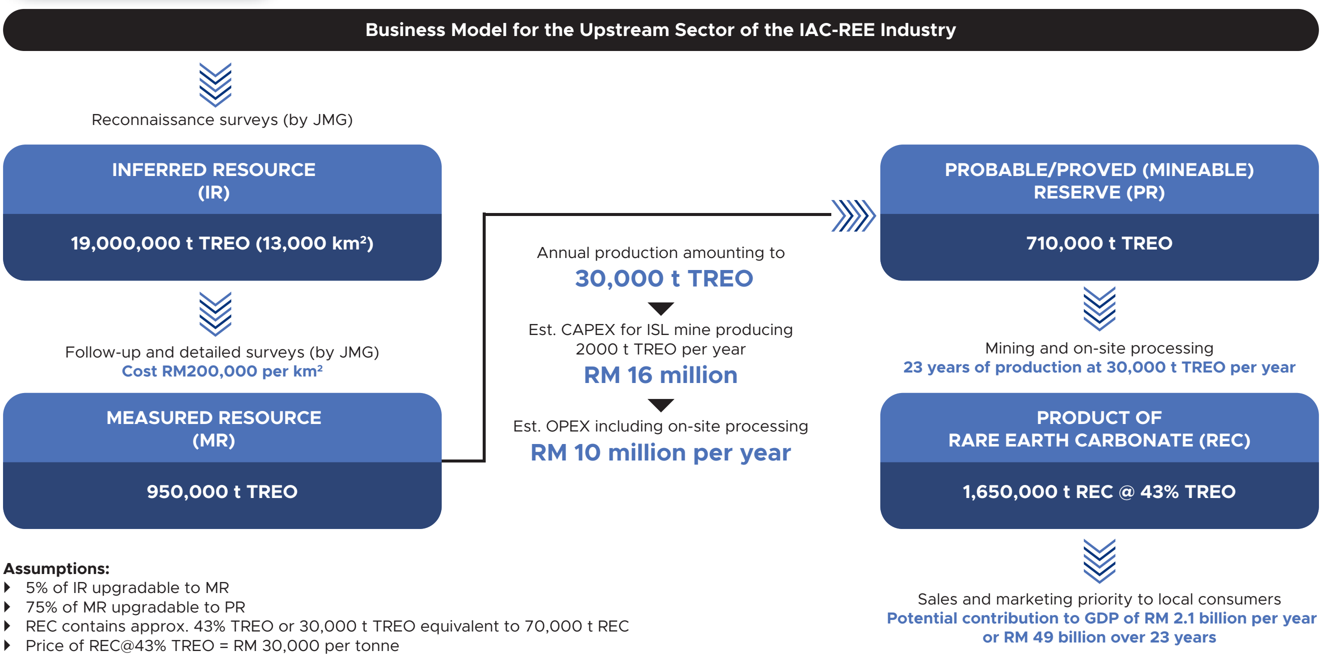


Figure 4.8: Business model for the upstream sector of the IAC-REE industry (value creation process)

The value creation process needs to be facilitated by national strategies that build an enabling ecosystem. Figure 4.9 summarises the essence of the business model – the key recommendations and the ROV – for the development of the upstream sector.

FIGURE 4.9

ESSENCE OF THE BUSINESS MODEL FOR THE DEVELOPMENT OF THE IAC-REE UPSTREAM SECTOR

	Exploration	Mining	On-Site Processing
	EXPLORE AND IDENTIFY ECONOMIC IAC-REE DEPOSITS	**MINE IN A RESPONSIBLE MANNER**	**PROCESS INTO USEFUL PRODUCTS**
Recommendations	‣ Effective application of scientific knowledge and latest exploration technology ‣ Fast track exploration for IAC-REE resources ‣ Incentives to promote investment ‣ Digitalised data for seamless sharing ‣ Review ban on mining in PFR and ESA	‣ Fast-track approval of SOP for use nationwide ‣ Adopt advanced environmentally friendly mining technology ‣ Ensure the compliance of operations with legal requirements, adherence to SOP, voluntary implementation of ESG, and sustainability initiatives ‣ Voluntary disclosures and reporting	‣ Adopt advanced environmentally friendly processing technology ‣ No harmful residue ‣ Recycle or reuse in regards of the circular economy ‣ Implement material traceability and chain of custody ‣ Priority to local purchasers
Return on Value	‣ Monetisation of resources benefiting nation and citizens ‣ Additional revenue to the state and federal governments ‣ Creation of employment, uplifting of livelihood of communities ‣ Enhances nation's economy and global competitiveness	‣ Capacity building including talent creation, innovations, and advancement in technology ‣ Stimulate establishment of value-adding and spin-off industries ‣ Supports import substitution ‣ Net positive foreign exchange earnings/loss	‣ Products meet the needs of present and future generations (renewable energy generation, manufacture of EV, decarbonisation, etc). ‣ Towards greening the mining sector with embracement of ESG and sustainability ‣ Get social licence to operate

Figure 4.9: Essence of the business model for the development of the upstream sector

(iii) Contributions of mineral resource development to the economy

In general, mining plays an important role in boosting the country's economic development. The direct and indirect contributions of mineral resource development are outlined in Figure 4.10.

FIGURE 4.10

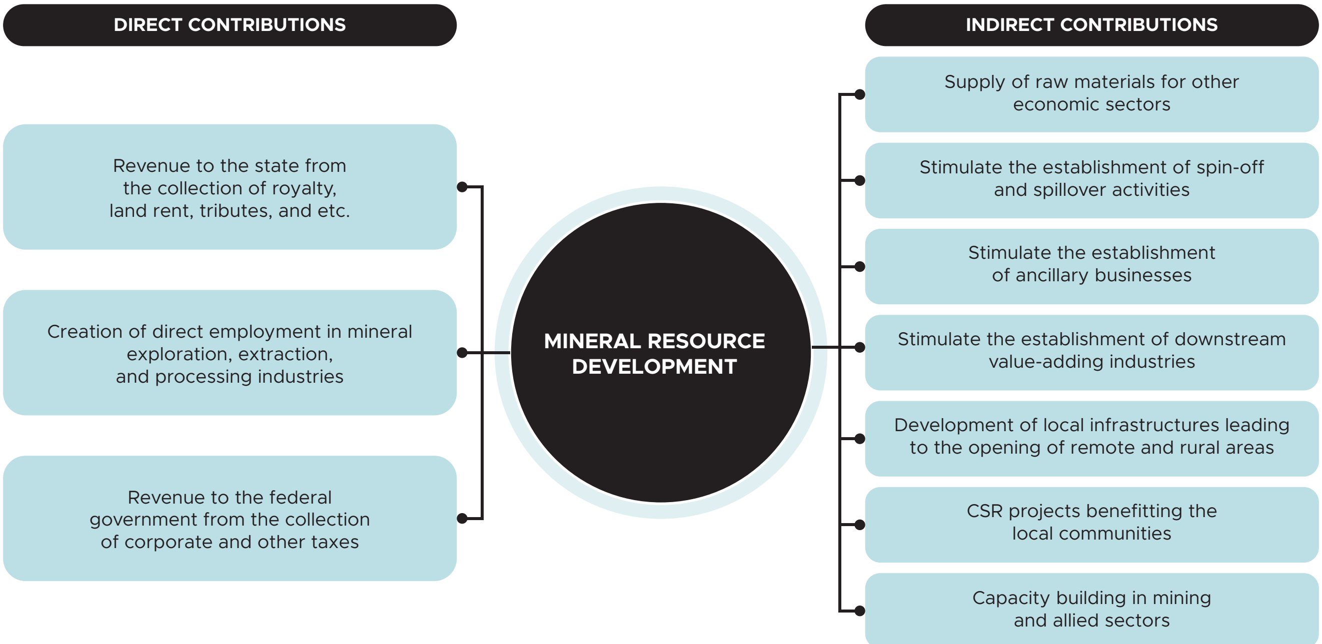


Figure 4.10: Contributions of mineral resource development to the economy

Direct contributions:

(i) The collection of revenue for the state from mineral extraction, production, and sales (e.g., royalty, land rent, and etc.)

(ii) The creation of direct employment in the mineral exploration, extraction, and processing industries (e.g., geologists, mining engineers, mineral processing engineers, semi-professional support staff and workers in the mines, quarries, and mineral processing plants, and etc.)

(iii) The collection of federal taxes (e.g., corporate tax, windfall profit tax, export duty, and etc.)

Indirect contributions:

(i) The supply of raw materials for other economic sectors like the construction and infrastructure development, manufacturing, energy generation, and agriculture
(ii) Stimulate the establishment of spin-off and spillover activities (e.g., fabrication and foundries)
(iii) Stimulate the establishment of ancillary businesses (e.g., supply of spare parts, provision of maintenance services, transport, housing, and etc.)
(iv) Stimulate the development of value-adding midstream and downstream sectors using the mine products
(v) Stimulate the development of local infrastructure leading to the opening up of remote and rural areas
(vi) Corporate social responsibility (CSR) projects benefitting the local communities
(vii) Capacity building, not only within the mining industry but also in allied sectors, such as engineering and fabrication

The indirect contributions of mineral resource development are far-reaching and, in some areas, are deemed more important than the direct contributions. The strategic importance of mineral raw materials from the mineral resource development is commonly not well-recognised and appreciated. Table 4.5 summarises the upstream sector's contributions to the country's GDP in 2025 and 2030.

In comparison to the midstream and downstream sectors, the tangible potential returns from the development of the upstream sector are relatively less. However, the upstream sector plays a highly crucial role in the establishment of an REE industry in Malaysia. Without the upstream sector, the main purpose of establishing a full value chain rare earth industry in Malaysia becomes meaningless as the main purpose of establishing the industry is to capitalise on the country's fortuitous endowment of IAC-REE. Furthermore, foreign and local investors are generally reluctant to invest in the midstream and downstream sectors unless there is a readily available or potential source of supply of REE raw materials locally.

TABLE 4.5

No.	Proposed National Target	KPI by 2025 (Short-Term)	KPI by 2030 (Mid-Term)	KPI by 2050 (Long-Term)
1.	Production capacity	30,000 tonnes of TREO	30,000 tonnes of TREO	30,000 tonnes of TREO
2.	Participation of the government and local firms	50%	75%	100%
3.	Job employment/labour (Local: Foreign)	3,000 (30% : 70%)	3,000 (50% : 50%)	3,000 (70% : 30%)
4.	Revenue	RM 2.10 billion/year	RM 2.10 billion/year	RM 2.10 billion/year
5.	Local content	20%	40%	60%
6.	Investment on exploration	RM 200,000 per km^2	RM 200,000 per km2	RM 200,000 per km2
7.	Annual investment on mining and on-site processing per mine	CAPEX = RM 16 million OPEX = RM 10 million (per mine)	CAPEX = RM 20 million OPEX = RM 12 million (per mine)	CAPEX = RM 25 million OPEX = RM 15 million (per mine)

Table 4.5: Projections of several economic parameters used in the synthesis of the business model for the upstream sector

Assumptions:

Row 1 = Short-term, mid-term and long-term annual targets of 30,000 tonnes of TREO per year
Row 2 = It is predicted that, after 2030, Malaysia should be able to manage the mining of IAC-REE on its own without FDI and even invest in and operate the mining of IAC-REE overseas.
Row 3 = Assuming a gradual increase in the ratio of local and foreign workforce
Row 4 = Based on the value of the produced REC at RM 30,000 per tonne (containing 43% of TREO per tonne); mineral commodity prices are generally cyclical in nature but, on the average, expected to increase, and it is difficult to forecast prices beyond 2025.
Row 5 = Assuming that the ammonium bicarbonate and other chemicals are mostly imported

4.3 Midstream Sector

As discussed in Chapter 2, the demand of super-magnets increases following the race to net zero target across the world. Nd, Pr, Sm, Tb, and Dy are specific rare earth metals that are required to make high-strength, high-temperature super-magnets for EVs and wind turbines.

4.3.1 Supply Chain of Rare Earth Super-Magnets

The supply chain for the rare earth super-magnets industry requires:

(i) Mineral resources containing REE in economic contents
(ii) Chemical engineering facilities that are capable of separating individual REO and purifying each REO from the rare earth mine products that contain a mixture of REE
(iii) Metallurgical facilities to produce pure rare earth metals and alloys from the separated REO
(iv) Downstream manufacturing industries to produce rare earth super-magnets and electric motors

The midstream sector is the bridge to expand the value chain of IAC-REE in Malaysia from the upstream sector to the downstream sector.

4.3.2 Current Status

The supply chain for the rare earth super-magnets industry would require the following:

(i) Current midstream players in Malaysia

In February 2013, Lynas Malaysia began its operations in Gebeng, Pahang, processing its own Mt Weld rare earth mineral concentrates and separating them into REO products that are mainly light REO. The separation plant uses the sulphate chemical route and has a rated capacity of 22,000 tonnes of REO products per annum. Currently, Lynas Malaysia processes about 16,500 tonnes of REO, producing 6,500 tonnes of Pr/Nd oxides. All Pr/Nd oxides are sold to Japan.

However, the current sulphate route separation plant is not suitable for IAC-REE separation. Currently, Lynas Malaysia is building a monazite-cracking plant at Kalgoorlie, Australia. Upon completion, the Kalgoorlie plant would crack the Mt Weld concentrates to produce mixed rare earth carbonate (REC), which would then be sent to Lynas Malaysia for separation through their new processing line, SX-9. Technically, SX-9 can separate REC from IAC-REE mines. Lynas Malaysia may expand its SX-9 capacity to cater for the separation of the Malaysian REC.

4.3.3 **Current R&D**

Current research focuses on solvents with better selectivity for certain REE, solvent extraction in combination with ion exchange chromatography, and ionic liquid precipitative stripping. Selective separation would reduce the number of stages required, thereby reducing the operating costs of the REE separation plant.

PPM undertakes R&D on the liquid separation of dissolved REC solution using appropriate reagents. Meanwhile, UMPSA conducts R&D on the replicated system similar to Lynas Malaysia for R&D training purposes, with the aim of reducing the processing steps and separation of REE by ion exchange polymer resins and electrolysis method, ionic liquid, and separation.

A local private facility has started R&D, specifically on the separation of the IAC-REE type of rare earth products since 2019. Extensive laboratory work was completed at their R&D plant. The plant is fully equipped with REE hydrometallurgical testing apparatus. The process quality control was done in-house with their own ICP-MS rare earth analysis equipment. With REC as feedstock, the test work established the baseline REO process methodology and operating parameters. The results of the laboratory work established parameters for a computerised solvent extraction system simulation. Several simulations were completed over the past 12 months. Testing is still ongoing to check on the feedstock variability from various mineral resources.

4.3.4 **ESG Perspectives**

ESG factors have become more important in many industries globally, as investors, shareholders, and stakeholders have set ESG as one of their major priorities in their businesses and new investments. As for the mining and mineral industries, the importance of ESG has grown tremendously following the pressure from various stakeholders on the issues of protecting the environment, society, and the management of resources like water and energy.

In this regards, Ernst and Young’s (EY) recent report on business risks and opportunities for mining and metals companies, listed environment and social and decarbonisation as the top two risks and opportunities in 2022, respectively (Mitchell, 2022). This section focuses on the model that should be implemented to meet ESG requirements for the midstream sector of the IAC-REE industry.

(i) Materiality model

In order to ensure the appropriate minimum approach for inclusion in ESG disclosures for the IAC-REE industry, the materiality model in Figure 4.11 provides an overview of the relationships involving the following key components considered in a materiality analysis in relation to the sectors within the IAC-REE industry, specifically for the midstream sector:

(a) Activities/products

Activities related to the midstream sector include the separation processes that produce three types of products, namely REO, rare earth metals, and rare earth alloys. Different kinds of separation techniques with multiple stages are employed to produce these three types of products.

(b) Lifecycle stages

The lifecycle stages of operation/production and waste management for the midstream sector occur concurrently. Typically, the lifecycle analysis is frequently reviewed, which includes the whole supply chain. As for the midstream sector, it begins with the introduction of raw materials (from mining) to the process and purification of products, by-products, and waste resulted from the operation/production.

(c) Materiality triggers

In the midstream sector, several factors like the changes in the process, plant expansion, and the introduction of new technology would trigger events requiring a materiality assessment to be conducted or updated in relation to the occurred changes. This would affect the activities and lifecycle stages, requiring appropriate reviews.

(d) Stakeholders

Activities either during normal operation or new circumstance triggered by the above materiality triggers would affect, directly or indirectly, several stakeholders, which include the government, communities, media, and consumers or shareholders.

(e) Materiality components

The inclusion of several materiality topics in the materiality assessment for the midstream sector within the IAC-REE ecosystem is recommended. Referring to the materiality component mapping in Figure 4.35 in Section 4.6.3, for the midstream sector, there are four materiality topics under environment, four materiality topics under social, and one materiality topic under governance. Under environment, these four materiality topics are waste and materials management, waste management, air quality, and greenhouse gas emissions. Meanwhile, the materiality topics under social include fair labour and terms of works, occupational health and safety, community health and safety, and security arrangements. Lastly, the materiality topic under governance includes revenue and payment transparency.

4.3.5 **Issues, Gaps, and Challenges**

i) Fragmented IAC-REE ecosystem

Currently, the Malaysian IAC-REE ecosystem within the value chain is fragmented (Figure 4.11). The upstream development is executed at Mukim Kenering, Daerah Hulu Perak, which is a pilot project in the state of Perak. Products from any subsequent mines after the adoption of the SOP may be sold to the foreign midstream plants, unless a local separation plant is set up in time.

Lynas Advanced Material Plant (LAMP) at Gebeng is the only midstream separation plant. Currently, LAMP processes only Lynas's own rare earth concentrates from Mt Weld in Australia, which is a mineral-type of rare earth. All LAMP's Nd/Pr oxides are fully committed to Lynas's Japanese partner for their magnet manufacturing plant in Vietnam.

The separation of IAC-REE products requires a different chemical route, as compared to the separation plant of the current LAMP. It was given to understand that LAMP is planning to set up a new separation line to process REC, which is designed to process their own REC produced from their cracking plant at Kalgoorlie, Australia, which contains mainly LREE.

FIGURE 4.11

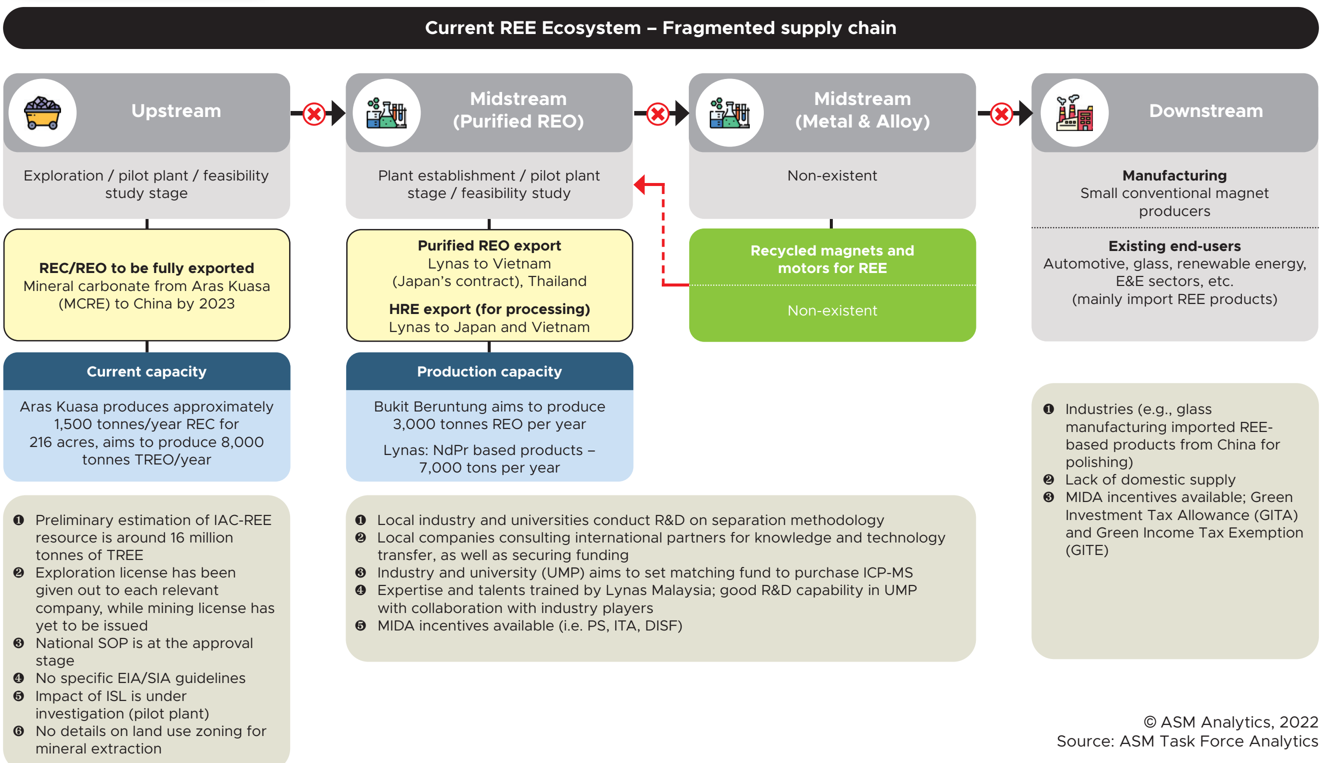


Figure 4.11: Fragmented current IAC-REE supply chain

Since there is no purified REO locally available, the midstream making plant of metals and alloys is non-existent. The lack of purified rare earth magnet metal oxides (Nd and Pr) supply has delayed the setting up of magnet manufacturing plants.

ii) Issues and challenges

The midstream sector's key challenges are identified based on the 8i's ecosystem analysis, which is shown in Figure 4.12:

FIGURE 4.12

Issues and Challenges in Midstream

Institutions

- Policy inconsistency and lack of consensus on the direction of the REE processing industry.
- Licensing period for existing company (i.e. Lynas) is too short which create uncertainty in supply for the downstream industry

Internationalisation

[the country encourages FDI, resulting in the setting up of Lynas]

- Lack of sufficient global knowledge transfer and collaboration with international knowledge institutions for research and innovation in rare earths processing (midstream).
- Lack of public acceptance in REE industry may hinder FDI

Intellectual capacity

[Malaysia has expertise & talent trained by Lynas Malaysia; Good R&D capability in UMPSA with collaboration with industry players]

- Knowledge creation for rare earths supported by several HILs, government research centres, and industry players (i.e., UMPSA, USM, UTP, Mineral Research Centre), as well industry-academia collaboration for industry-relevant talent development. However, there is insufficient research into rare earths processing (midstream).
- Lack of human capital/experts to support the midstream sector
- Low awareness among the public and NGOs on the rare earths industry in Malaysia. Among key reasons for public's largely negative perception regarding the industry.

Incentives

MIDA provides general incentives e.g. Pioneer status, ITA and R&D grant]

- Lack of targeted fiscal and non-fiscal incentives for research, innovation, and adoption of green technologies for sustainable IAC-REE industry.
- Insufficient financing schemes to overcome the high capital barrier for entry into the IAC-REE midstream sector.
- Nonexistence of insurance/assurance/funding in the case of disaster and contamination issues arises in the midstream sector.
- Midstream is capital intensive

Integrity

- Red tape and stringent requirement in applying licensing; construction approval of IAC-REE plant (EIA report)
- The Environmental Quality Act 1974 requires certain activities to have EIA or Detailed EIA (DEIA) done before relevant licenses are issued.
- Absence of specific guidelines and standards in setting up IAC-REE plant in Malaysia

Interaction

- Lack of information and knowledge transfer among government agencies
- Lack of CEPA program to improve NGOs' and public understanding on IAC-REE industry in Malaysia
- Lack of formal platform for stakeholder engagement (industry, academia, NGOs, society) in policy design and decision making.
- Potential fragmentation between the upstream and midstream players.

Infrastructure

[Lynas Malaysia is building SX9 to process IAC REE, expect to operate by mid 2023; Local company e.g. GreenChem is developing processing pilot plant & R&D and is expected to be ready by 2023]

- Infrastructure in the midstream is developing but is dominated by foreign player (i.e., Lynas Malaysia).
- Lack of strong government and short licensing period, firms are unwilling to fully invest into the processing infrastructure given it involves high capital investment.
- Due to the complex technologies involved, the costs of the separation and purification processes can become very high when include the costs to train experts and human capital to run RE processing facility.

Infostructure

- Weak data sharing and information availability of IAC-REE (i.e., not readily accessible for the industry players).
- Perpetuates fragmentation of the supply chain between upstream, midstream and downstream sectors.

Source: ASM (2014) Blueprint For The Establishment Of Rare Earth-based Industries In Malaysia Full Report, ASM (2019) Sustainable Mining, FGD, Task Force inputs; ASM Analytics, 2022

Figure 4.12: Issues and challenges in the midstream sector (ASM, 2014, 2019, 2022)

4.3.6 Way-Forward for the Midstream Sector

(i) Mines to magnets/electric motors concept

In order to achieve the vertical integration of the national IAC-REE industry, Malaysia must retain the REE value chain as far downstream as possible. Figure 4.13 shows the incremental steps of the REE value chain.

FIGURE 4.13

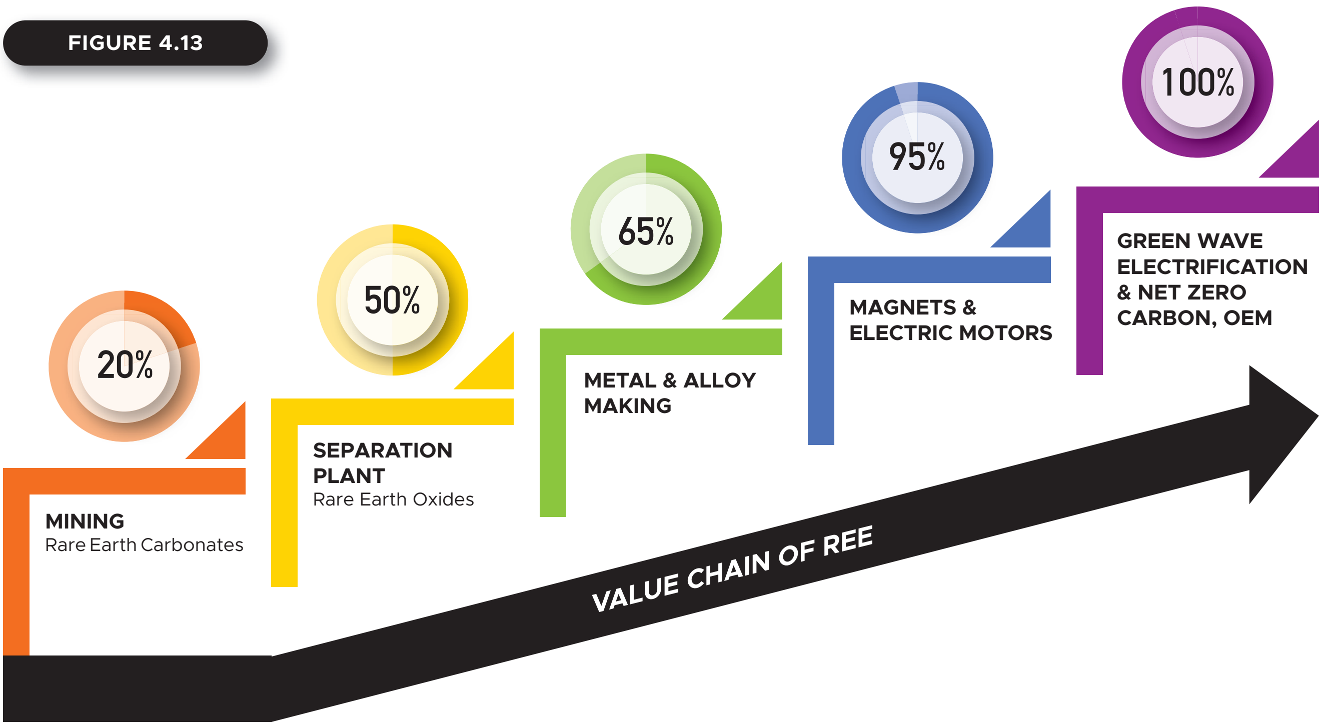


Figure 4.13: Incremental value chain of REE

Typically, Malaysian IAC-REE mine REC products contain 42% of rare earth magnetic metals (Pr, Nd, Sm, Tb, and Dy), as compared to 27% rare earth magnetic metals of the mineral-type of REE deposits (Duncan mine, Lynas). With the relatively higher rare earth magnetic metals, it is prudent for Malaysia to develop its own REE separation plant to separate and purify the rare earth magnetic metals for the subsequent downstream manufacturing of super-magnets and electric motors in the concept of “Mines-to-Magnets/Electric Motors”.

(ii) Vertical integration of the Malaysian IAC-REE industry

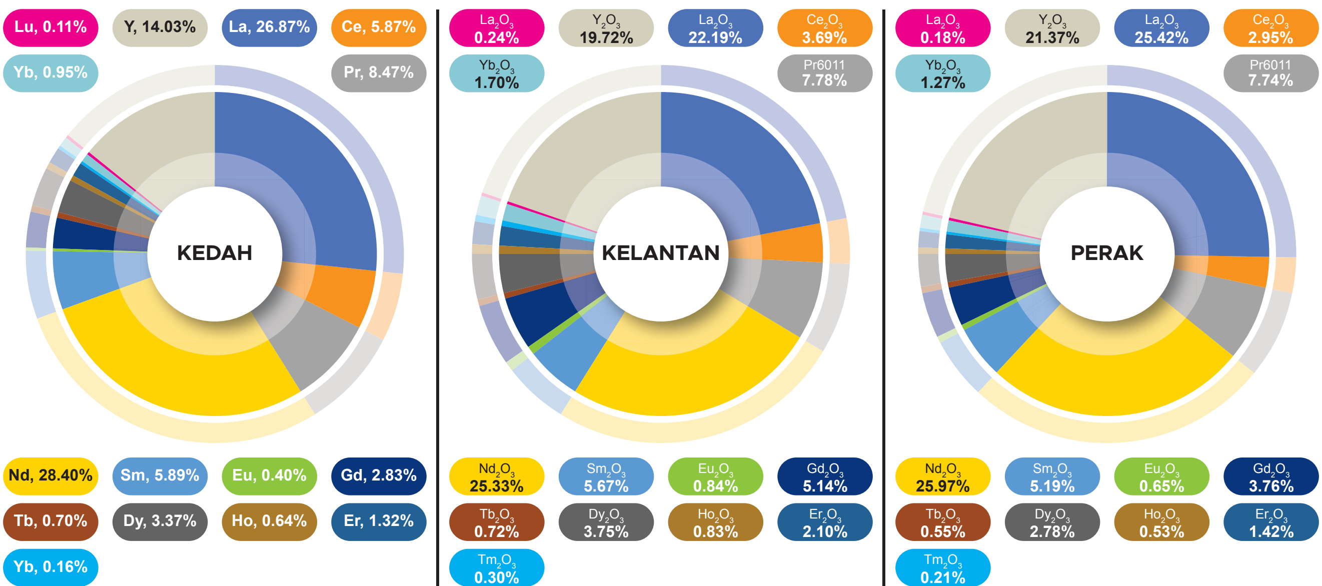
The midstream sector is a bridge to attain the concept of “Mines-to-Magnets/Electric Motors” for the local IAC-REE industry.

(iii) Characterisation of Malaysian IAC-REE products

Prior to building a separation scheme, the characterisation of rare earth products is important to ascertain the percentage constituent of the individual REOs; so that suitable separation chemistry and sequences can be designed to achieve maximum efficiency.

REC samples collected from Kedah, Kelantan, and Perak were analysed using ICP-MS, and their respective REO compositional fractions are presented as pie charts (Figure 4.13). Total magnetics (Pr, Nd, Sm, Tb, and Dy) from each sample were then summed up as the characterisation of the Malaysian IAC-REE products for the separation process design. REE characterisation of mineral-type rare earth deposits are depicted in Figure 4.14 for comparison.

FIGURE 4.14



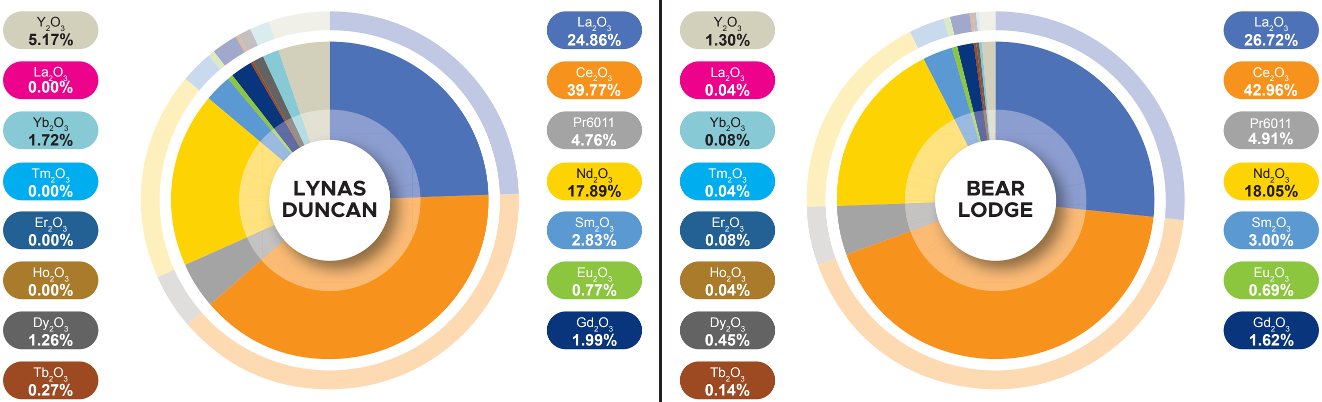
Total Magnetics	46.83%
Pr/Nd	36.87%
Sm	5.89%
Tb/Dy	4.07%

Total Magnetics	43.25%
Pr/Nd	33.11%
Sm	5.67%
Tb/Dy	4.47%

Total Magnetics	42.23%
Pr/Nd	33.71%
Sm	5.19%
Tb/Dy	3.33%

Figure 4.14: REE characterisation of IAC-REE deposits (Greenchem Nanotech Solutions Sdn Bhd.)

FIGURE 4.15



Total Magnetics	27.01%
Pr/Nd	22.65%
Sm	2.83%
Tb/Dy	1.53%

Total Magnetics	26.55%
Pr/Nd	22.96%
Sm	3.00%
Tb/Dy	0.59%

Figure 4.15: REE characterisation of mineral-type REE deposits (The Rare Earth Observer, 2022)

Table 4.6 shows the comparison of total magnetics in IAC-REE with the mineral-type, represented by the Lynas Duncan mine in Australia and the Bear Lodge Mine in USA. The Malaysian IAC-REE contain 64.7% more total magnetics than the mineral-type of rare earth deposits. Malaysian IAC-REE deposits are more valuable in basket price values as compared to the mineral-type rare earth deposits.

TABLE 4.6

State	IAC-REE	Mineral-Type REE
Total Magnetics	44.10 %	26.78 %
Pr/Nd	34.56 %	22.80 %
Sm	5.58 %	2.92 %
Tb/Dy	3.96 %	1.06 %

Table 4.6: Comparison of total magnetics of REE deposits

(iv) Focus on the separation and purification of rare earth magnet metals

Rare earth magnets constitute 95% of the total value chain of REE, and REC from the Malaysian IAC-REE deposits contain 44.1% in total magnetics. Considering these high percentages, it is proposed that Malaysia should focus on the separation and purification of rare earth magnet metals (Pr, Nd, Sm, Tb, and Dy).

(v) Selected IAC-REE separation technologies

Based on the characterisation and separation of R&D, the most effective separation technologies for the separation of REC involves the selective target separation of the magnetics, specifically through the use of conventional multi-stages solvent extraction (SX) method. Targeting magnetics to produce pure oxides of the magnetics and grouping the remaining in saleable mixed-oxides product can reduce the number of separation stages; thereby, reducing the capital and operating costs, as well as the development timeline of the firm.

4.3.7 Business Model

The business model proposes a vertical integration by establishing a Malaysian REE Technology Park (MRTP), which has REE separation and NdPr alloys making plants and super-magnets manufacturing, as well as recycling facilities (Figure 4.16).

FIGURE 4.16

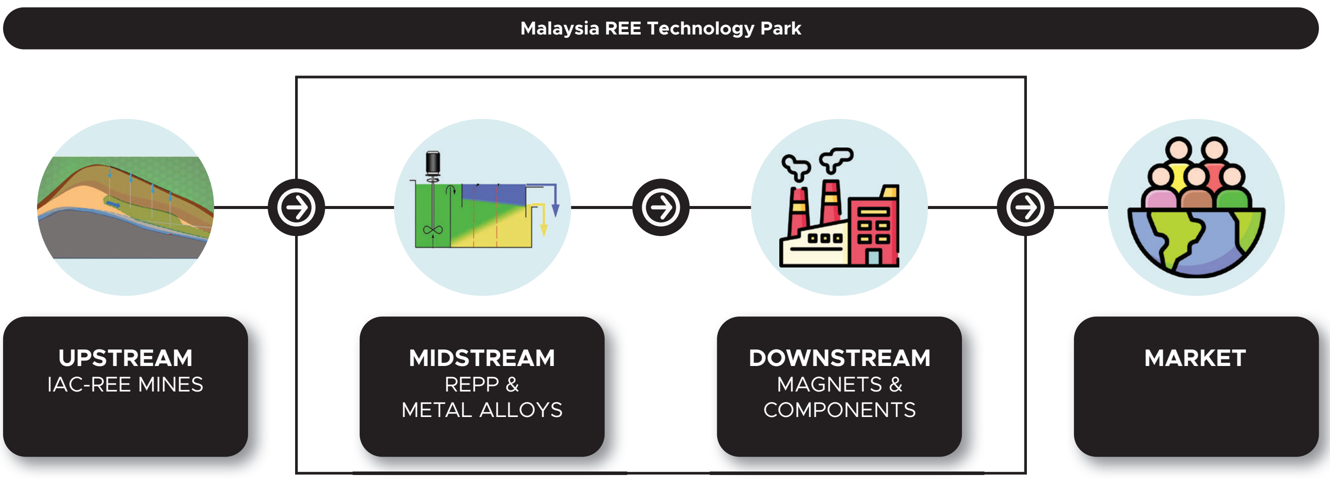


Figure 4.16: Business model for the Malaysian IAC-REE industry

The proposed business model for the Malaysian IAC-REE industry is described as follows:

(i) Designate the IAC-REE industry as a national strategic industry
- The IAC-REE industry is proposed to be designated as a national strategic industry to ensure the retention of downstream values in the country.

(ii) Limit the export of unprocessed REC so as to encourage more processing plants in Malaysia
- Policies should be enacted to limit the export of unseparated REC when the facilities of the midstream sector are established locally.
- All IAC-REE mined products must be separated in Malaysia, and the separated and purified products must first be offered to local midstream and downstream REE processing and manufacturing before any export is allowed.
- Fiscal incentives, including the introduction of a progressive taxation system on REC exports, are expected to drive the IAC-REE industry, especially the separation and purification and the production of metals and alloys for the midstream sector, as well as the manufacturing of super-magnets for the downstream sector.

(iii) Set up the state-of-the-art, ESG-compliant MRTP
- The plant should include REPP, REE metal refining and alloys manufacturing plants, and downstream magnets and other REE components manufacturing plants.
- REC products from all IAC-REE mines in the country are highly recommended to be sold to the REPP for separation and purification. A limit on exports of REC products can be imposed, while building the capacity of REPP.
- Purified oxides are refined to produce rare earth metals and alloys.
- Rare earth metals are to be supplied to the manufacturers of super-magnets.

(iv) Invite FDI to manufacture super-magnets, component modules, and downstream REE products in the MRTP

(v) Encourage federal and state governments to invest in the REPP

(vi) Promote Malaysia as the world’s REE products supply hub.

The details of the business model are described as follows:

i. Establishment of REPP

Malaysia must establish a REE midstream sector to capture the full value chain of IAC-REE. REE separation plants involve high capital outlay and highly complex chemical processes. China currently controls the purified REE market monopoly and bans any technology transfer on REE processing. Malaysia must develop its own processing technologies to establish the IAC-REE midstream sector. However, it can be rather challenging for Malaysia to gain the needed technical knowledge and experience in order to compete globally. On the other hand, technological innovation can also be an area of competitive advantage for Malaysia, especially if newly developed techniques improve the methods currently in use. Initially, local supplies of REO for R&D would facilitate the development of the separation techniques. It is proposed that Malaysia adopts an "adsorption, adaptation, and innovation" method to develop its own REE separation technologies. This particular method involves the following:

(i) A review of current REE separation and purification technologies
(ii) Deep understanding of the separation factors of adjacent REE ions
(iii) Adapt suitable separation chemistry to the REC fractions
(iv) Innovate techniques to focus on the extraction of target REE

ii. Interim rare earth carbonate separation plant

In the interim period, pending the establishment of the MRTP, the REC from IAC-REE mines may be treated in the following manner:

(i) Send to Lynas at Gebeng, provided that the purified super-magnets metals oxides (NdPr oxides) from the REC are first offered to the Malaysian rare earth metal/alloy makers for the local downstream requirements.
(ii) Send to the local REPP; when it is fully operational, the REC cakes can be separated into rare earth metal oxides (NdPr oxides), which should be first offered to the Malaysian rare earth metal/alloy makers before they can be exported.
(iii) If there is no operational IAC-REE separation plant in Malaysia, then REC should be allowed to be exported; in other words, Malaysia would only capture some 20% of the REE value chain (Figure 4.16).

In regards to the above implementation, it has to be noted that the Mineral Development (Licensing) Regulations 2016 has to be adhered strictly when the REC is transported from any mine site, either to Lynas in Gebeng or to the local REPP, or exported if there is no operational separation plant available locally at the time. In addition, it should also be taken into consideration that transportation of the REC to any other purchaser, other than the three listed entities, has to fulfil Act 525.

iv. Purification of REE for metals/alloys making and manufacturing of super-magnets

A corresponding REE super-magnets metal purification and metal refining plant is also proposed to be built next to the REPP. The plant capacity is set at 10,000 tonnes of Nd/Pr alloys per year. The capital cost for setting up a plant of this capacity is about RM 378.4 million.

Purified magnet metal oxides are smelted into alloys through the application of fused salt electrolysis method that employs fluorides. The estimated total upfront cost of a cell line designed to produce 1,000 tonnes of NdPr per year is about RM 37.84 million, including the costs of 25 cells, electrolytes for each cell and additional equipment, as well as engineering costs.

NdFeB alloys and powders are commonly produced close to where magnets are produced due to the challenges involved in transporting the magnet powders. The particle size used in magnet production is less than 10 microns. The powders are reactive with water and air and liable to spontaneously ignite, making them difficult to handle and transport. Furthermore, they must be shipped over land. Using a larger particle size would mitigate some of the handling issues, but the powder would then have to be further ground for magnet use, which would require certain processing at the manufacturing site (Dysinger & Murphy, 1994).

Therefore, it is prudent to house the REPP, metal alloys, metals making, and super-magnets manufacturing all within the MRTP, in order to minimise the transport of reactive magnet powders. The electric motors manufacturing plants can be set up in the vicinity of the existing motor vehicle plants.

In line with the concept of circular economy, the study proposed the recycling and repurposing of the used rare earth magnets and electric motors. It is prudent to house this plant in the MRTP. The costs of this plant would invariably depend on the products to be recycled and repurposed, as well as the REE to be recovered.

(v) Project development schedule

Subject to land and regulatory approvals, this REPP with the capacity of 70,000 tonnes of REC and the corresponding metal refining plant with the capacity of 10,000 tonnes of REE per year would be constructed and commissioned within 36 months. This would take about the same duration for the upstream mines to attain the optimal total production of 70,000 tonnes of REC per year or 30,000 tonnes of TREO. The project schedule is designed to position Malaysia as the world's major supplier of rare earth magnets, attaining 10% of the market share of rare earth magnets by 2030.

(vi) REE human resources training

The processes of REE separation and purification, as well as metal refining involve complex chemical engineering and metallurgical procedures. Local universities have started research on REE. More chemical engineering graduates are trained to fill the talent gap required to serve the unequivocal growth of the country's REE industry. Similarly, TVET graduates can be trained at local universities, such as Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA) or through the placement at any rare earth processing plant in various semi-professional and skilled areas.

(vii) Attracting foreign direct investment to the Malaysian REE industry

With the substantial IAC-REE resources and the availability of local REE separation and purification plant, FDI can be attracted to invest in the integrated REE Technology Park. Locally available, purified REO products would then be used to make these REE component items. Foreign firms would invest if a 10-year sustainable supply of REE can be guaranteed.

4.3.8 Scenario Planning and Critical Path Mapping

i. China-dominated supplies

The global market for REE is currently China-centric. China accounts for an estimated 89% of the total rare earth separation capacity, about 90% of the total metal refining capacity, and approximately 92% of the global sintered NdFeB magnets manufacturing. Figure 4.17 and Table 4.7 show the geographical market concentration of the main supply chain steps for the sintered NdFeB magnets by country. More significantly, the concentration of production in China increases at every downstream stage, rising from a 58% share of annual global rare earth mining in 2020 to a 92% share of annual global magnets production, with the highest added value.

One way of measuring the level of geographic concentration of production involves the Herfindahl–Hirschman index (HHI), a USA measure of market concentration. Accordingly, HHI is calculated by squaring the market share of each firm competing in the market and then summing the resulting numbers, which may range from a value near zero (if there are many countries producing equal amounts of a product) to 10,000 (if all production is done in the same country).

FIGURE 4.17

Geographical concentration of suppy chain stages for sintered NdFeB magnets

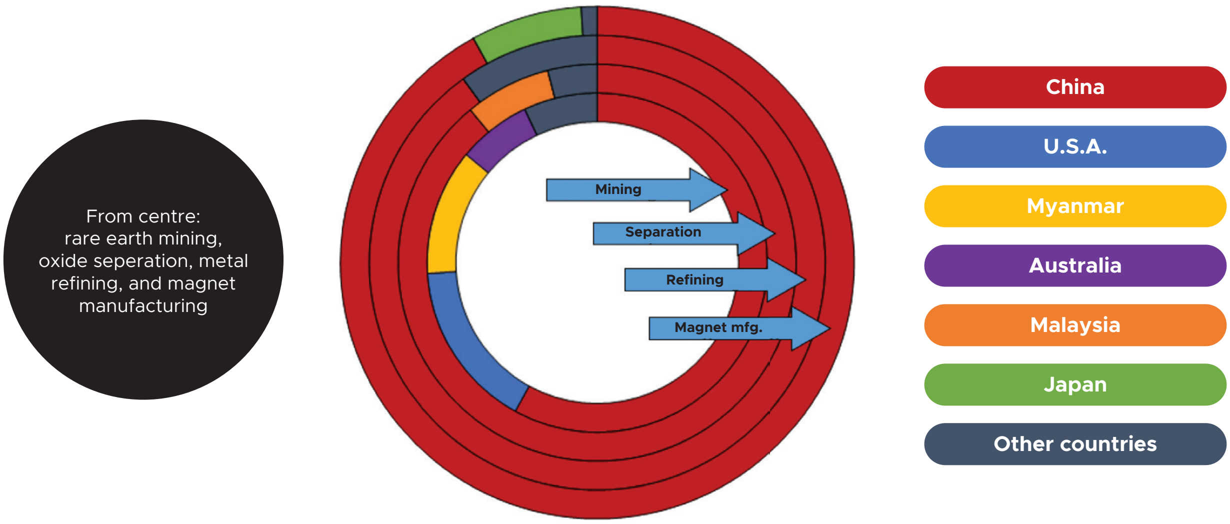


Figure 4.17: Geographical concentration of NdFeB super-magnets supply chain

TABLE 4.7

Country	Mining	Separation	Metal refining	Magnet alloy manufacturing
China	58%	89%	90%	92%
U.S.A.	16%	–	–	<1%
Myanmar	12%	–	–	–
Australia	7%	–	–	–
Madagasar	3%	–	–	–
India	1%	1%	–	–
Russia	1%	–	–	–
Thailand	1%	–	-3%	–
Malaysia	–	7%	–	–
Estonia	–	1%	-2%	–
Japan	–	–	–	7%
Vietnam	–	–	-3%	1%
Laos	–	–	-2%	–
Germany	–	–	–	<1%
Slovenia	–	–	–	<1%
Finland	–	–	–	<1%
U.K.	–	–	<1%	–
Other countries	1%	2%	<1%	<1%

Table 4.7: Geographical market share of various countries in NdFeB super-magnets supply chain

Table 4.8 shows the Global HHI at each stage of the supply chain using the market shares data from Table 4.7. The value increases from 3,826 to 8,514 as the supply chain stage progresses from mining to the production of magnets. The HHI for the whole spectrum of rare earth value chain exceeds 2,500, which shows that the rare earth market is highly concentrated.

TABLE 4.8

	Mining	Separation	Metal Refining	Super-Magnets Manufacturing
HHI for the country concentration of operating mining or manufacturing facilities (Monopoly = 10,000)	3,826	7,976	8,200	8,514

Table 4.8: Global HHI of rare earth supply chain

Apart from the geographic concentration of production, a relatively small number of individual firms operate at most of the stages within the supply chain. Even at the mining stage, where the least geographic concentration is involved, two firms, namely Lynas Malaysia and MP Materials Corp., make up a large share of production outside of China and Myanmar. This concentration may make the supply chain less resilient to disruption if one of these firms cease to exist (US Department of Energy).

Meanwhile, China has consolidated rare earth production into a single of state-owned entity (China Rare Earth Holdings Limited) since 2022. The country has control over the international markets for raw materials, metals, magnets, and components through market manipulations, such as restricting output to increase the prices or price dumping to lower the prices in order to discourage investment or make competing firms outside of China less profitable.

The Chinese government can influence the markets through various policies and regulations, such as the economic and trade policies (e.g., export quotas, subsidies, tariffs, exchange rate targeting, and etc.), economic and trade regulations (e.g., trade embargoes, price controls, and etc.), and environmental regulations (e.g., permitting, emission standards, and clean water standards).

In February 2021, President Biden of USA signed the “Executive Order on America’s Supply Chains” (EO 14017), directing executive agencies to evaluate the resilience and security of the country’s critical supply chains and to develop strategies for the industrial bases that underpin its economic and national security (Smith et al., 2022).

ii. Demand growth by 2050

Driven by the goal of net zero, the total global demand for rare earth super-magnets is projected to reach up to 387,000 metric tonnes by 2030 and 753,200 metric tonnes by 2050. Table 4.9 shows the projected demand growth of rare earth super-magnets. Figure 4.18 shows the projected global NdFeB super-magnets demand by applications.

iii. Scenario planning

With the concentrated global rare earth super-magnets supply and growth scenario, an opportunity for an alternative, reliable supply of rare earth super-magnet metals exists. Malaysia should plan to implement the development of the midstream sector vigorously in order to capture the current void in the rare earth separation capacities outside of China. The salient points are listed as follows:

(a) Midstream separation is the critical step in providing purified REO for the rare earth metals and alloys refining for the making of magnets.
(b) Malaysian IAC-REE deposits contain higher concentrations of Nd, Pr, Tb, and Dy than that of the mineral-type rare earths produced by China, Australia, and USA.
(c) A specially designed REPP, focusing on the separation of Nd, Pr, Tb, and Dy, would render Malaysia as the only supplier (outside of China) of purified Tb and Dy for high-temperature magnets manufacturing.

iv. Potential disruptions from the current market leader

The current market leader may discourage challenges to their supply monopoly through various trade policies and regulations. They may dump their stocks to the market to lower the product prices below the production costs of new entrants or embargo the export of chemicals, extractants, and technologies-related to the IAC mining and separation.

TABLE 4.9

Application	Part of Energy Sector Industrial Base?	Demand in 2020		Projected Demand in 2030 (high growth)		Projected Demand in 2050 (high growth)	
		Amount (kt)	Share	Amount (kt)	Share	Amount (kt)	Share
Offshore wind turbines	Yes	16.9	14.2%	139.2	36.0%	273.7	36.3%
Electric vehicles	Yes	7,3	6.1%	114.1	29.5%	266.0	35.3%
Consumer electronics (Hard disk drives, cell phones, loudspeakers, others)	No	35.1	29.4%	41.0	10.6%	65.4	8.7%
Industrial motors	No	36.0	30.2%	53.7	13.9%	85.7	11.4%
Non-drivetrain motors in vehicles	No	9.4	7.9%	18.3	4.7%	29.3	3.9%
Other sintered magnets (power tools, electric bikes)	No	6.5	5.5%	9.6	2.5%	15.3	2.0%
Bonded magnets	No	8.0	6.7%	11.1	2.9%	17.7	2.3%
TOTAL	**–**	**119.2**	**100.0%**	**387**	**100.0%**	**753.2**	**100.0%**

Table 4.9: Projected global super-magnets demand growth for selected NdFeB super-magnet applications (US Department of Energy, 2022)

FIGURE 4.18

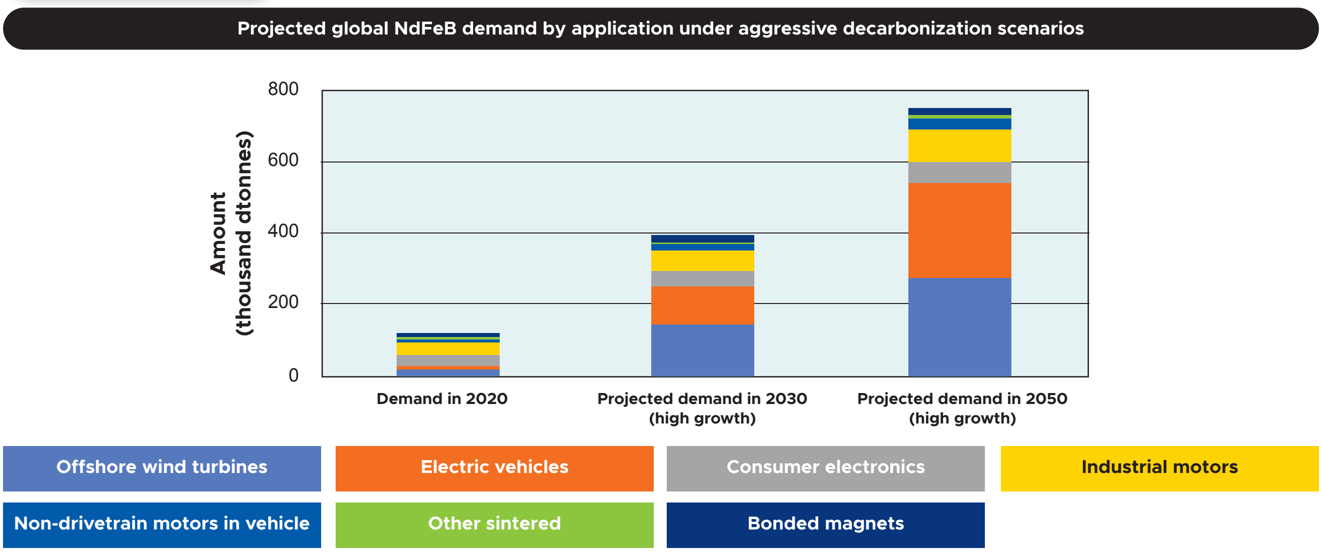


Figure 4.18: Global NdFeB demand growth by applications (US Department of Energy, 2022)

v. Fast-tracking mining, processing, and manufacturing

It is critical to have sufficient REC feedstocks to set up the REPP and sufficient REO feedstocks to set up the downstream magnets manufacturing. The upstream mining may take three years to reach the optimum annual capacity production of 70,000 tonnes of REC. In order to accelerate the development of the Malaysian IAC-REE integrated industry, the following measures are proposed:

(i) Initiate the upstream, midstream, and downstream sectors concurrently
(ii) Retain at least 20% of locally produced REC (at the market prices) for the pilot separation plant optimisation
(iii) A central buying house to purchase all locally produced REC and REC from foreign upstream IAC mines in order to build up operational stocks in the interim period, pending the completion of REPP with the capacity of 30,000 tonnes of TREO per year, and to place a limit on the exports of REC from local mines
(iv) Accelerate the construction and commissioning of the REPP
(v) Procure recycled REO for both midstream and downstream sectors

4.3.9 Business Model Canvas

The proposed midstream business model canvas consists of the following:

(i) Key activities

The key activities of the midstream sector include the capturing of the downstream values of Malaysian IAC-REE resources by separating and purifying the rare earth magnet metals for the downstream magnets manufacturing.

(ii) Key resources

The key resources are the REC feedstocks from the IAC-REE mines, skilled chemists to support the REO separation processes, separation extractant chemicals, power, and water.

(iii) Key partners

The key partners of the midstream sector are the upstream miners, chemical and consumable manufacturers, transporters, and downstream consumers.

(iv) Customer relationships

As for the security of long-term businesses, the midstream sector would create customer relationships through the REC off-take agreements with the upstream mines suppliers and the products off-take agreements with the major downstream magnets manufacturers.

(v) Revenue stream

The revenues of the midstream sector would be from the sales of specialised purified REO products, such as HREE-mix, magnets metal oxides, and NdPr alloy.

(vi) Customer segments

Purified REO and rare earth metal alloys are for niche market specialised customers, including magnets manufacturers and HREE separation plants.

(vii) Cost structure

The rare earth midstream sector business model is a value-driven model. The focus of the midstream sector is to create the best quality/purity REO products for the downstream consumers. Rare earth midstream is a chemically complex business that involves multi-stage processing, high start-up capital costs, and fixed costs. In order to keep the business competitive, efforts should be made to attain economies of scale and economies of scope by prioritising selective extraction of target products that command the highest revenues.

(viii) Channels

Purified REO and rare earth metal alloys are niche, essential technology metal products with very few global suppliers outside of China. The availability of these products in Malaysia would be easily transmitted through the niche rare earth industrial circle forums, advertisements, and conferences.

(ix) Value proposition

The sector's value proposition is to provide REE products with the origin of REO, extractants, product outputs, and the conditions under which they are produced in compliance with the requirements regarding health and safety, ESG, and quality-related aspects that are traceable in every stage of the production cycle under the identity preservation/segregated model claims of the chain-of-custody scheme. This uniquely clean, traceable production scheme would be a competitive marketing advantage for Malaysian products.

4.3.10 Strategies and Recommendations

(i) Set up a REPP of large capacity

The demand growth for rare earth magnets indicates long-term market for purified rare earth magnet metal oxides. Correspondingly, the growth of rare earth mining projects in countries with IAC deposits is expected. Setting up an efficient REPP of large capacity in Malaysia would provide an alternative market for the REC products from the IAC mines, which in turn boosts Malaysia's HREE outputs. Therefore, it is proposed that the Malaysian REPP has excess capacities over and above the local upstream mines production.

(ii) Develop own rare earth mining and separation chemicals

In preparation of the possible future disruption of extractants and lixiviant chemicals for IAC-REE mines, Malaysia must focus on the development of own efficient lixiviant and extractant chemicals using as much locally available chemicals as possible.

(iii) Set up a REC central buying house

Apart from the high HREE content, REC from IAC mines are critical sources of two important additives for super-magnets, specifically Tb and Dy. With the demand growth of high-temperature magnets, future markets for Tb and Dy would be high, and REC would become a critical high-tech commodity. Setting up a central buying house is proposed in order to purchase all REC produced from the Malaysian upstream mines, as well as to procure ISCC-certified REC from other countries that develop IAC mines (Myanmar, Laos, Vietnam, Thailand, Uganda, DRC, Brazil, and Chile). Building up a stock of critical high-tech commodity would establish Malaysia's strong position in the rare earth magnets supply chain. Stocks would be separated into purified REO by the REPP.

(iv) Establish an integrated MRTP

It is proposed that a dedicated integrated MRTP is set up in an appropriate location in Malaysia. The study proposed the setting up of a fully integrated MRTP to house a REPP and metals and alloys production plants to facilitate the development of the downstream sector of the rare earth industry. The MRTP is ideally placed in the environs of automotive industrial areas. By building from the drawing board up, the MRTP would incorporate ESG perspectives, employing the state-of-the-art, environmentally-friendly technologies, such as solar power, rainwater harvesting, artificial intelligence (AI) communications and security systems, power grid control, water supply, water, and waste management systems – all in the form of an Eco-Technology Park.

Besides that, it is anticipated that, at a steady state, the total production capacity of the Malaysian IAC-REE from all states can achieve 70,000 tonnes of REC, containing 30,000 tonnes of TREO per year. Therefore, a REPP with an annual processing capacity of 70,000 tonnes of REC needs to be set up in MRTP to separate 30,000 tonnes of REO, including 10,000 tonnes of Nd/Pr oxides. In addition, some 6,000 tonnes of mixed HREE can be recovered. The REPP would then be at the production capacity of 150% of the current Lynas Malaysia in Gebeng.

Considering that, it is suggested that some 80 hectares (200 acres) in MRTP are designated for REPP, metal refining plant, and alloys manufacturing plant. The remaining area would be reserved for the manufacturing of super-magnets, components modules, EVs, and end-user products. The estimated capital costs for setting up a REPP with the capacity of 70,000 tonnes of REC per year are RM 1.76 billion. The MRTP would be promoted as a global hub that supplies REE products, and FDI would be invited to set up factories and research facilities in MRTP.

4.3.11 KPI

Production targets, revenues, and contributions to the GDP are presented in Table 4.10 and Table 4.11 for TREO separation and NdPr alloy manufacturing, respectively.

TABLE 4.10

Proposed National Targets	KPI by 2025 (Short-Term)	KPI by 2030 (Mid-Term)	KPI by 2050 (Long-Term)
Separated TREO	15,000 tonnes/year	30,000 tonnes/year	90,000 tonnes/year
Participation of local company	100%	100%	65%
Job employment (direct)	500	1,000	3,000
Revenue*	RM 3.63 billion	RM 7.26 billion	RM 21.78 billion
Local content	100%	100%	35%
Investment	RM 880 million	RM 1.76 billion	RM 5.28 billion

* Estimated basket value of separated TREO at RM 242,000/tonne

Table 4.10: Production targets for midstream TREO separation

TABLE 4.11

Proposed National Targets	KPI by 2025 (Short-Term)	KPI by 2030 (Mid-Term)	KPI by 2050 (Long-Term)
NdPr alloys production*	5,000 tonnes/year	10,000 tonnes/year	30,000 tonnes/year
Participation of local company	100%	100%	65%
Job employment (direct)	150	300	900
Revenue**	RM 2.08 billion	RM 4.15 billion	RM 12.45 billion
Local content	100%	100%	35%
Investment***	RM 189.2 million	RM 378.4 million	RM 1.14 billion

* NdFeB alloy contains 30% of NdPr. The Malaysian TREO contains 30% of NdPr; so the projected NdPr alloys produced per year equals to the amount of TREO purified in the respective projected year.
** As of 4 April 2023, the selling price of NdPr alloys is RM 415,000/tonne (RMB 648,000).
*** The capital cost for the NdPr alloys plant is RM 37.84 million per 1,000 tonnes of NdPr alloys.

Table 4.11: Production targets for midstream NdPr alloys manufacturing

4.4 Downstream Sector

4.4.1 Introduction

The overall value chain of the IAC-REE industry comprises the upstream, midstream, and downstream sectors. The processed materials of REO from the processing plant at the midstream sector need to undergo separation and purification, as well as the production of metals and alloys. These metal and alloy products are then transported to the downstream sector, which focuses on the manufacturing activities to produce rare earth-based products. Rare earth-based products are then supplied as end-products to the system integrator (SI) and OEM, such as EVs, electronic appliances, and defence system. The downstream sector is highly crucial as it provides multiplier economic impact from the high-value-added products to positioning the country and firms within the global supply chain.

In addition, the establishment of the downstream ecosystem would give domino effects in terms of job employment, foreign and domestic direct investments and GDP contribution from the manufacturing and services sectors. It is projected that the demand for IAC-REE would become significant in various industrial sectors, such as automotive, energy, medical, aerospace, and defence. Products and applications, ranging from catalytic converters, magnetics in motors, and satellite communications to energy storage, makes them valuable and highly sought by many countries and industries. As such, it is imperative for Malaysia to leverage its available resources and capabilities to establish and fortify the currently available ecosystem, providing a winning situation for the environment, society, and governance. The following subsections further elaborate on how Malaysia can gear its efforts to obtain this opportunity for the expansion of the downstream sector for national prosperity.

4.4.2 **Current Status**

As per data and information from the Malaysia External Trade Statistics, Malaysia's trade in electromagnets (permanent magnets, magnet chucks, and clamps) registered an average import value of around RM 877.2 million and average export value of RM 529.6 million. Meanwhile, the electric motors (EM) recorded an average import value of RM 3.9 billion and average export value of RM 664.2 million from 2017 to 2021 (Figure 4.19). On the other hand, the traded value of catalysts was reported to be far less than that of the permanent magnets and electric motors despite being recognised as the second-largest potential of REE application. In 2017, the export value for catalysts was reported at RM 53 million, and the recorded import value was RM 70 million.

FIGURE 4.19

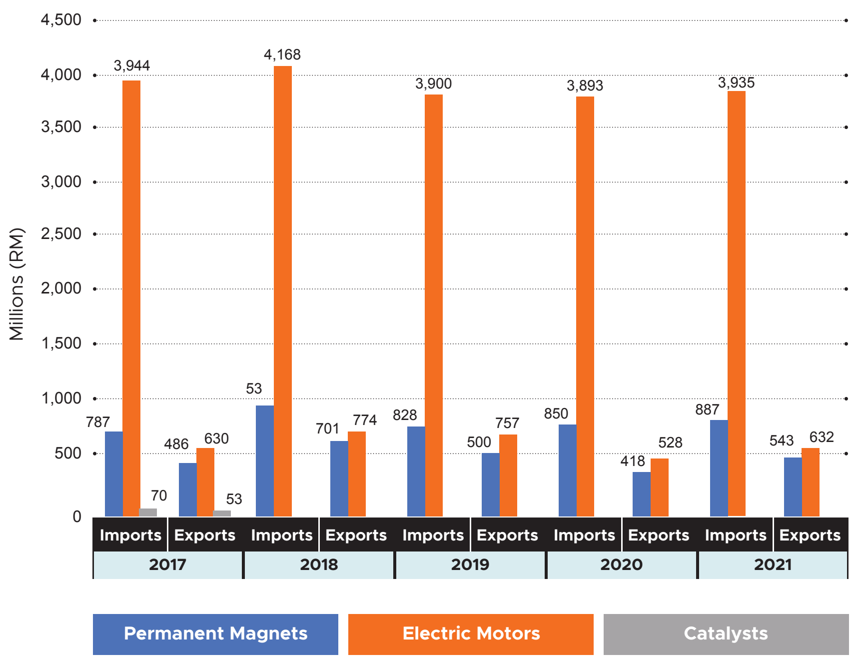


Figure 4.19: Malaysia's import and export activities for permanent magnets, electric motors, and catalysts (DOSM, 2021)

Observatory of Economic Complexity (OEC) identified Malaysia as the seventh-largest exporter of permanent magnets in 2020, with export value of USD 78.8 million. Meanwhile, Malaysia was also identified as the ninth-largest importer of permanent magnets in the same year, with export value of USD 127 million (Figure 4.20). With total magnet REO demand forecasted to increase at a compound annual growth rate (CAGR) of 8.3% and prices projected to increase at CAGRs of 3.2–3.7% over the same period, it was forecasted that the value of global magnet rare earth oxide consumption would triple by 2035, from USD 15.1 billion in 2022 to USD 46.2 billion by 2035 (OEC, 2022).

Constrained by an expected under-supply of Nd, Pr, Dy, and Tb from 2022 onwards, it was also forecasted that the global shortages of NdFeB alloys and powders would amount to 66,000 tonnes annually by 2030 and 206,000 tonnes annually by 2035 – nearly one-third of the total market. Besides that, constrained by the lack of new primary and secondary supply sources coming to market from 2022 onwards, coupled with the inability of existing producers to increase output steadily at the rate of demand growth, the global shortages of Nd oxide, Pr oxide, and Dy oxide (or oxide equivalents) would collectively rise to 21,000 tonnes annually by 2030 and 68,000 tonnes by 2035 – an amount roughly equal to China's total production in 2018 (Adamas Intelligence, 2019).

FIGURE 4.20

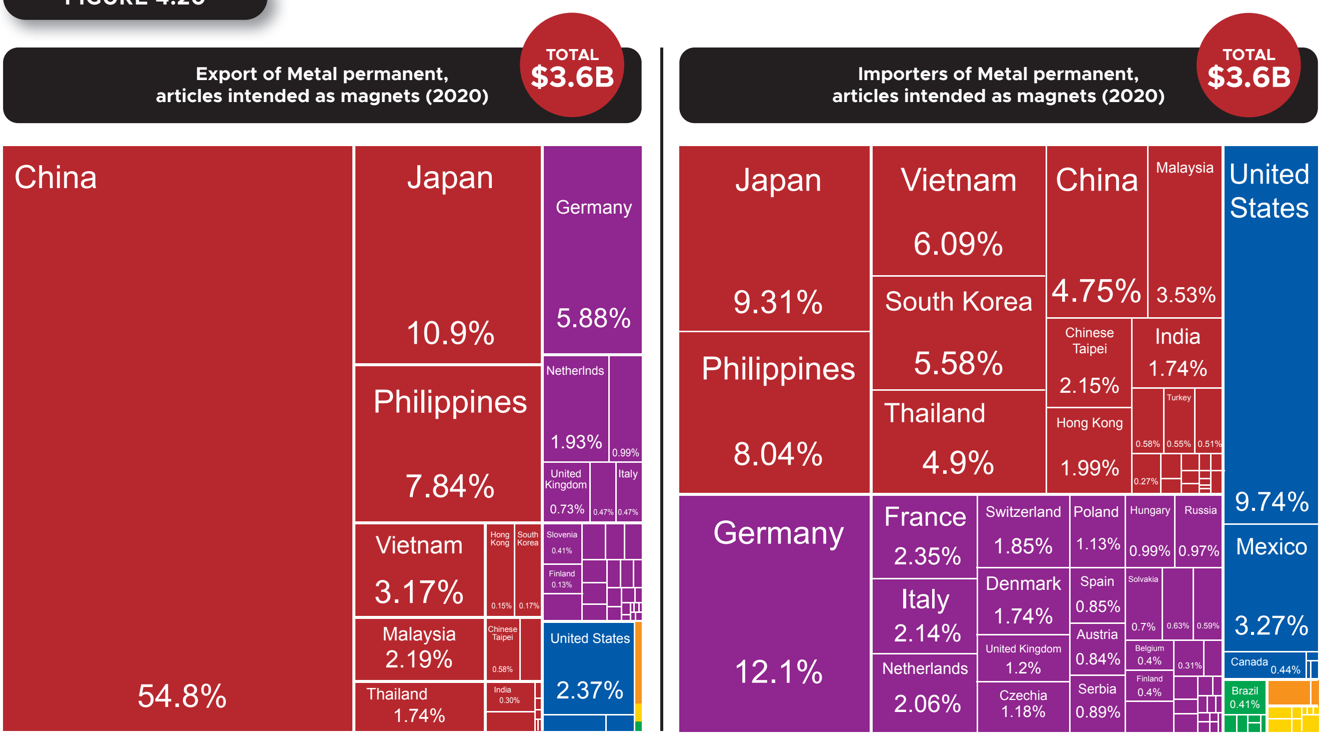


Figure 4.20: Exporters and importers of metal permanent magnets (OEC, 2022)

The chemical elements of rare earths involve complex atomic structures, providing each of them highly specific properties, such as optical, magnetic, electrical, and chemical properties. Hence, once separated, purified, and, in some cases, combined, rare earths are essential materials for a variety of applications. Table 4.12 and Table 4.13 illustrate the main usages of rare earths as high-value-added products (Lynas Corp., 2022).

For the next 10 years, the fastest-growing application using rare earths would involve the manufacturing of super-magnets. With its generation in a synchronous motor and the necessary magnetic field sourced from an electromagnet (thus, consuming electricity), a super-magnet made of Nd and Pr can reduce carbon emissions from electric motors by 15–30%. This allows EVs to minimise the size of their batteries (a component of an EV that involves major cost) and for any electrical appliances (e.g., air conditioning, other home appliances, lifts, and robots) to reduce the electricity consumption or to maximise the electricity generated by wind turbines, especially at low wind speed. In addition, these motors being twice smaller and lighter than alternative technologies can contribute to further reducing the energy required to move a vehicle, as well as the size of a wind turbine structure (Lynas Corp., 2022).

TABLE 4.12

REE Used	Specific Properties	Applications	Final usage
Neodymium, praseodymium	Magnetic power density	Strongest permanent magnets	Energy-efficient electric motors, energy-efficient electric generators, medical ventilators, electronic components (e.g., speakers and microphones)
Dysprosium, terbium	Structural stabiliser at high temperature	Improve temperature resistance of permanent magnets	High-power energy-efficient electric motors
Cerium, lanthanum, neodymium, praseodymium	Oxygen control in catalytic reactions	Automotive exhaust gas catalytic convertors, automotive diesel particle filter regeneration, oil refineries fluid catalytic cracking	Gasoline and diesel automobiles, gasoline production
Cerium	Chemical selectivity and abrasive properties	Chemical mechanical planarization	Manufacturing of semiconductors
Lutetium	Optical transmission	Scintillators	Medical pet scanners
Cerium, lanthanum	UV barrier, diffraction index improvement	Anti-UV glass, diffraction-free glass	Automotive windshield, sunglasses, camera lenses
Cerium, lanthanum	Abrasive	Glass polishing	Flat displays (TV screens), crystals (Swarovski) glasses

Table 4.12: High-value-added rare earth-based products and its applications (Lynas Corp., 2022)

Through NRES, the Malaysian government aspires to build an EV ecosystem with the introduction of the Low Carbon Mobility Blueprint 2030 and one of the action plans emphasising the further development of an EV ecosystem towards maturity. In addition, MITI developed the National Automotive Policy (NAP), with the emphasis on the Next Generation Vehicle (NxGV), specifically electric vehicle inter-operability centre (EVIC). Therefore, the downstream sector's value chain of rare earth would help spearhead the EV industry and bring down the manufacturing costs through local production. As car electrification translates into an increasing demand for high-power electric motors, motors operating at higher temperature would require two specific REE, namely Dy and Tb, to improve magnet temperature resistance. Lynas Corp. stated that the other fast-growing market segment involves chemical mechanical planarisation, where rare earth-based products allow the development of new-generation semiconductors. Table 4.13 shows the benefits and effects of the rare earth applications for product development.

TABLE 4.13

Found In	Type of REE	Rare Earth Applications	Benefits	Final Effects
Windmill	NdPr	Permanent magnet generator	▸ No need for gear box ▸ Save electricity	▸ Low-cost energy consumption ▸ Improve facilities
Vehicles	NdPr, Dy, Tb, La	Permanent magnet motor	▸ Save electricity ▸ Weight reduction	▸ Energy-saving ▸ Safe for environment
		Store electric energy	Usage of HEV battery	
		Reduce catalytic	Reduce air pollution	
Wastewater plant	$CeCl_3$	Arsenic removal by absorption	Utilising seawater usage	▸ Energy-saving ▸ Safe for environment
Refinery plant	La Oxide	Improving catalytic reaction	Fuel saver	▸ Energy saving
Appliances	NdPr, Nd, Ce, La	Permanent magnet motor	Save electricity	▸ Energy-saving
Light	Y, Ey, Tb, LaCe	Efficiency (x3)	Energy-saving	▸ Energy-saving
		Long-lasting (x5)	Long-lasting sources	▸ Safe for environment
Electronic	NdPr, Ce, LaCe Oxide	Smaller components for electronic communications	Improve usability functions	▸ Operational efficiency
Medical equipment	NdPr, Gd, Lu	Magnetic and chemical substances for MRI, PET scans	Enhances medical equipment Reduce astigmatism	Improved health outcomes and diagnostics

Table 4.13: Benefits and effects of rare earth applications (Lynas Corp., 2022)

A ranking process of rare earth-based product applications via stakeholders' engagement during the focus group discussion[18] (FGD) involving the downstream sector indicated magnets, batteries, and catalyst as the top three products that should be prioritised (Figure 4.21). The prioritisation process was guided based on the product complexity, market opportunity, and technology trends.

FIGURE 4.21

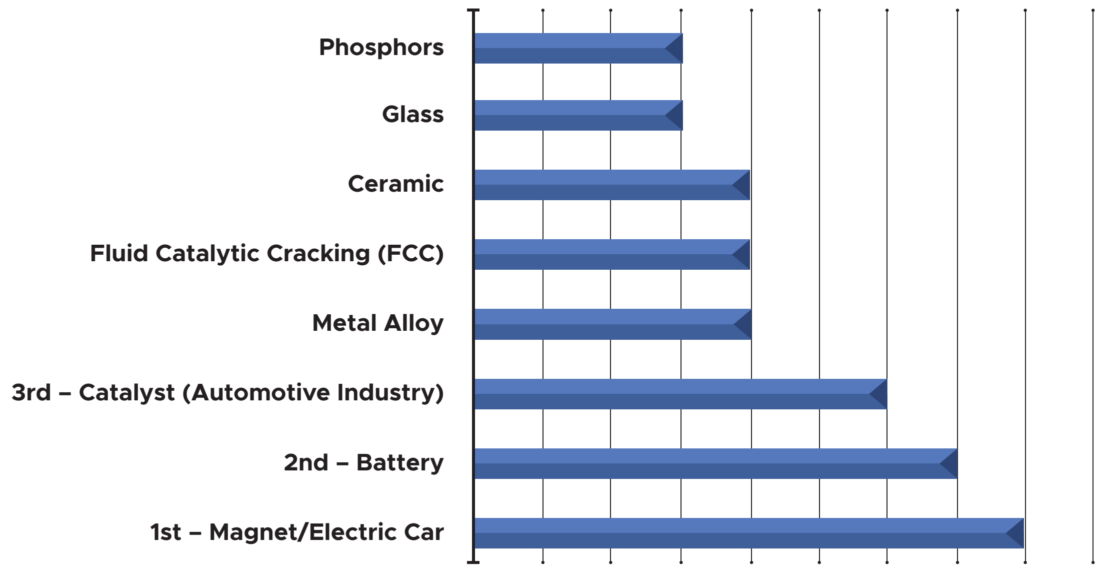


Figure 4.21: Prioritisation of rare earth-based product applications (FGD RE industry development, ASM & task force study team, 2022)

[18] Held on 29 November 2022 at MIGHT, Cyberjaya

The ecosystem of the downstream sector is illustrated in Figure 4.22. The manufacturing activities of rare earth-based products would be supported by the industry value chain and stakeholders. Table 4.14 summarises the identified industry players and stakeholders in the downstream sector.

TABLE 4.14

Supporting Industries	Equipment and machinery	Local players of engineering and supporting industries (ESI), such as machining, metal casting, metal fabrication, metal casting, and etc. Overseas: Specialised equipment
	Chemical and raw materials	Local source: Lynas for rare earth, Petronas BASF for chemicals, Pharmaniaga Berhad, Chemical Company of Malaysia Berhad (CCM), Duopharma Biotech Berhad
	Industrial gas	Local: Gas Malaysia Bhd
	Packaging	Local players
	Logistics	Local players
Enablers	Research universities and institutions	UMPSA, UTP
	Training	Technology transfer from Korea and Japan
	Financial institutions	Developmental Financial Institution (DFI)
	Testing and services	MDFA, SIRIM
Manufacturers	Manufacturing and assembly	International players: Essen Magnetics (China), Star Group Industries Co. Ltd (Korea), Shin Etsu (Japan), POSCO International (Korea) Local players (manufacturers, assembler & system integrator): Bomatec, Elegance Seaview, Action Machinery and Engineering (AME)

Table 4.14: Industry players and stakeholders in the downstream sector (UMW Analytics, 2022)

FIGURE 4.22

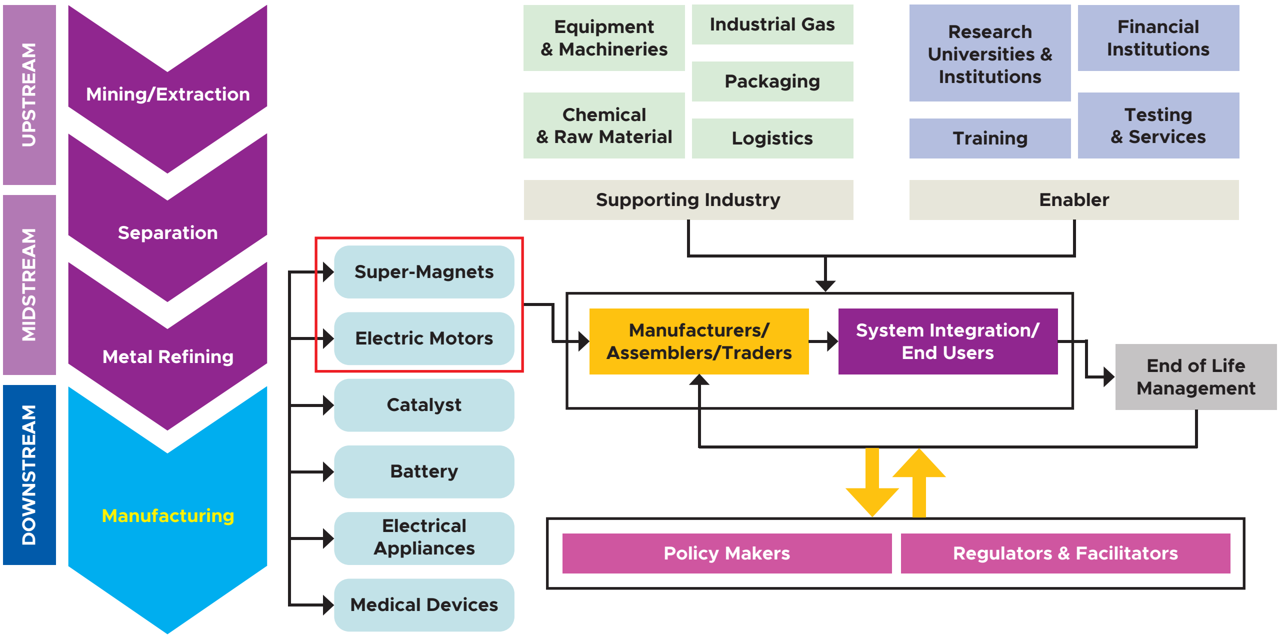


Figure 4.22: Value chain of local rare earth downstream sector (MIGHT, 2023)

With the readiness of industry value chain in Malaysia from the upstream sector to the downstream sector, Malaysia can create more than 10,000 job opportunities for the rare earth downstream sector by 2030 based on the investment of RM 3.5 billion for the production of super-magnets and RM 3 billion for the production of electric motors. Currently, several local players are involved in the industrial magnets, such as Bomatec, Action Machinery, and Engineering and Elegance Seaview. The development of super-magnets needs to be emphasised by establishing the overall industry value chain, such as in the segment of supporting industry and enablers. Supporting industries consist of equipment and machinery, chemical and raw materials, industrial gas, packaging, and logistics. The existing supporting industries are based on the footprint of other industrial sectors, such as electrical and electronics, automotive, machinery and equipment, and chemical industry. The magnet industry can be amplified by leveraging on the existing strengths of these supporting industries by having a strategic industry platform to stimulate industrial collaborations.

The enabler segment consists of the talent development programme, R&D, financial institutions, and testing services. Currently, Malaysia still lacks in terms of having a recognised talent development programme for the magnet and electric motor industries given the need for partnerships with related firms to provide training to the blue- and white-collar groups. R&D of rare earths are very much concentrated in the upstream sector, spearheaded by PPM JMG. A few local public research universities, including the Central Lab located at UMPSA in Gambang, Pahang, have been involved in the upstream and midstream sectors, such as Central Lab located at UMPSA in Gambang, Pahang. In addition, a few local academic institutions, such as UTP, Universiti Malaysia Kelantan (UMK), Universiti Sains Malaysia (USM), and the upcoming Universiti Sultan Azlan Shah (USAS), provide knowledge related to the rare earth industry, emphasising the upstream and midstream sectors.

UMPSA demonstrates strong capability to provide testing and services for the upstream and midstream sectors. UMPSA plans to develop the capability for the testing services, focusing on the downstream product applications – it has been proposed to be set up in Pekan, Pahang. The needs to have local testing and services are highly critical and aligned with the international requirements. Existing magnet manufacturers like Yonjumag and Essen Magnetics adopt product testing and inspection, such as automatic optical inspection machines, automatic magnetic angular deviation testers, high-temperature magnetic property testers, and trilinear coordinates measuring instruments. With viable economic opportunities, Malaysia should take advantage to establish a centre for testing and services via public-private partnership by leveraging the existing capacity of local testing certification bodies, such as SIRIM. The development of testing and services should adopt the public-private partnership mode in order to optimise the resources and minimising the costs.

The involvement of local research universities and institutions for the downstream sector should be encouraged to boost new product innovations and optimise the production process. Malaysia also needs to strategise for the establishment of local testing and services for the downstream product applications, such as super-magnets and electric motors. As for the catalysts, currently, several local institutions have the capability to provide lab testing. However, the enhancement of the local capability in providing the testing as an accredited body needs to be emphasised. The involvement of financial institutions is also critical to enable the development of the downstream sector since this would involve high capital investment. The support from the Ministry of Finance (MOF), GLCs, and private investors are critical to realise activities of the downstream sector.

The presence of reputable GLCs in the downstream segment to strategize product manufacturing can further stimulate the needed interests. Several GLCs involved in transportation equipment manufacturing, such as UMW Holdings Berhad and Proton Holdings Berhad, possess significant potentials for the production of super-magnets and electric motors. Both firms have their own high-value manufacturing park that can be a strategic location for the development of the downstream sector of the rare earth industry, namely the UMW High Value Manufacturing (HVM) in Serendah and Proton in Tanjung Malim. UMW HVM Serendah can well be a strategic location for future mobility manufacturing centre in Malaysia. Besides that, as for the chemical industry, several GLCs, such as PETRONAS, Pharmaniaga Berhad, Chemical Company of Malaysia Berhad, and CCM Duopharma Biotech Berhad, possess the potentials for catalyst product development. The national utility company, such as Tenaga Nasional Berhad (TNB), can also be positioned for the emerging industries of EVs and wind energy.

4.4.3 **ESG Perspectives**

According to a report from Future Market Insights (2021), Electric Motor Market Forecast 2021–2031, the electric motor market exhibited year-on-year (YoY) growth of 4.2% in 2021, up to a total of 1.2 billion units. Driven by the increasing focus on R&D and investments in the industrial sector, the electric motor market was projected to rise at 5.6% CAGR between 2021 and 2031, in comparison to the above 3.8% CAGR registered during the timeframe of 2016–2020. According to International Energy Agency (IEA), Energy Efficiency Policy Opportunities for Electric Motor-Driven Systems (2011), electric motor-driven systems were reported to account for more than 40% of the global electricity consumption and 70% of the industrial electricity consumption. Hence, electric motors hold substantial opportunities for sustainable development. Most of the environmental impacts are from the use stage and the disposal or recycling of the motors. Focusing on the environmental impacts of the lifecycle of electric motors, a small portion of 1–5% of the impacts come from the manufacturing stage, while the rest comes from the use stage and the disposal or recycling of the motors. The design is critical considering its environmental impacts. The design defines how a motor behaves during its usage, and thereby, the amount of energy it ultimately consumes.

Currently, the manufacturing of electric motors refer to the standard EN 50598 (Ecodesign) for power drive systems, motor starters, power electronics, and their driven application. This standard goes beyond a single motor and requires the consideration of the entire motor system. This includes frequency converters, motor starter equipment, gears, and others. Beyond the standards, manufacturers have to consider improving the efficiency by having a higher power-to-weight ratio – for instance, by downscaling the size of motors. In a nutshell, manufacturers need to prove the extent of the environmental impacts of their products over the entire lifecycle to the end-consumers.

At present, manufacturers only pay directly for energy. However, that would undoubtedly change when carbons are taxed. Even now, large firms make commitments to become carbon-free businesses. In other words, they need to provide carbon footprint information for their products. Such information allows their consumers to know the amount of CO_2 is procured and the amount of CO_2 is avoided. They are provided with the information of how much green (carbon-free) energy they need. Besides that, the information indicates how much of the remaining emissions must be offset for the firm to become carbon-neutral. Current industries are facing new challenges, especially in the efforts of achieving the highest efficiency at the lowest cost for demanding carbon-free solution users.

A motor system with the lowest electricity demand (during the use stage) and the lowest carbon emissions from manufacturing and from end-of-life is the best option for zero-carbon consumers. Consumers pay per kilowatt hour of the consumed electricity as any other consumers would. However, they may end up paying more for their energy if that energy is carbon-free electricity, and they would have to pay for CO_2 emissions that are unavoidable through the offsetting. Such possibilities of paying for carbon offset may take place if the motors contained within a product do not meet the carbon-free manufacturing requirements. This is reflected back at the manufacturer who is responsible for the emissions. To conclude, the best manufacturer produces carbon-neutral motor systems with the highest energy efficiency for the consumers' intended applications, which ultimately translate into the cheapest carbon-free solution.

Currently, induction motors stand higher than the permanent magnet motors due to their ability to be recycled as they reach their end-of-life period. Demagnetisation and contamination from metal debris and production fluids can be observed at the permanent magnet motors rotors from a recovered motor. Similar to induction motors rotors, the most effective method to remove contaminants from the permanent magnet rotor is to bake at high temperature within a certain period. The risks of baking permanent magnet motors rotor magnets at high temperature can cause partial demagnetisation, resulting in the non-compliance of the permanent magnet motors rotors with the performance specifications. Therefore, more R&D work on reuse and recycling of permanent magnet motors must be done in a strategic way, potentially at the national level. The highly volatile and doubling of value for magnetic materials strengthen the justifications to consider recycling permanent magnet motors rotors and switching induction motors with permanent magnet motors.

Besides that, a local firm with the interest of manufacturing magnets has pledged carbon neutrality by 2050. Sustainable manufacturing to reduce waste and increase activities of reusing, recycling, renewing, and remanufacturing are among the initiatives taken by the industry. In regards to the R&D initiatives, the industry has been actively developing green solutions to implement in future products and exploring new business areas, focusing on sustainability. Another firm has also committed to planting 300,000 mangrove trees by the end of 2023 and performing emission accounting and reporting. All these initiatives are governed by the management sustainability committee, specifically on the board of directors to monitor matters related to sustainability governance.

4.4.4 Issues, Gaps, and Challenges

Various issues and challenges for the downstream sector were identified during the brainstorming session with the stakeholders based on 8i's perspectives. With the involvement of the IAC-REE industry development FGD, ASM, and Task Force Study Team (2022), the list of the identified issues and challenges and a SWOT analysis of the 8i's perspectives can be found in the sectoral report.

4.4.5 Business Model

The proposed business model for the downstream sector was developed based on the inputs provided by the stakeholders. Figure 4.23 presents the suggested business model canvas for an REE downstream sector of the IAC-REE industry in Malaysia (IAC-REE industry development FGD, ASM, and Task Force Study Team, 2022).

FIGURE 4.23

Key Partners

Federal Government:
- MITI (G2G-Collaboration, market penetration, transfer technology), MOSTI, KeTSA, MOHR, MIDA, MATRADE, Royal Malaysian Custom (RMC), DOE (JAS), DOSH, NCER, National Advanced Material Consortium

State Government:
- EXCO, PBT (License), UPEM, PTG (Management), NCER, IM Inc, JMJ, PNT, Alam

Downstream:
- Financial Institutions (FDI, developmental bank, commercial bank), national company for REE (e.g., Petronas), miners, TNB, and investors (motor or super-magnet manufacturers like Shin-Etsu)

Key Activities

Federal Government:
- R&D grant
- CEPA on REE
- Free Trade Zones (FTZ) gazettement, Trade Apache
- National CoE on IAC-REE
- Issue manufacturing license (MITI)
- Exporting strategies by phases

State Government:
- CEPA on REE
- Issue land title
- Exporting strategies by phases

Downstream:
- Manufacturing
- Logistics
- Trade & Services.

Value Propositions

Federal and State Governments:
- REE business friendly policies
- Increased public awareness
- Safeguarding Malaysia's resources
- Industrial symbiosis park @ Gua Musang
- Quit rent, premium, and assessment fee reduction for five years
- RISE programme, NTIS programme
- Smart regulator
- Talent projection
- Provide clear policy on RE upstream to downstream
- Training of skilled workers at all levels of entry through TVET community colleges
- Review on export duty
- High income (royalty) for government
- Creation of free trade zone-friendly policies: e.g., Silver valley tech park model; Perak high tech valley park
- Public-private partnership that enables profit sharing
- Built-to-Suit and Lease (BTSL)
- Incentives (tax and import duty exemption for downstream processing)

Downstream:
- Establishment of downstream REE ecosystem
- Price advantage locally developed technologies
- Logistics/supply chain expansion
- Create employment to people
- Micro-credentials on job training
- Provide upskilling competencies for IAC-REE talent
- High value product (Super Magnet, wind turbines) – don't have the Ip and players for Automotive

Customer Relationships

Federal and State Governments:
- G2G (bilateral trade)
- Social obligation
- Environmental protection (decarbonisation)
- Subsidies for end-users and customers

Downstream Industries:
- Global market: Supplying REE products to ASEAN countries
- Establish Public private initiatives
- B2B partnership - Downstream component Manufacturer to collaborate with end-users (e.g., automotive industry).
- Provide services and support to customers

Customer Segments

Magnets and Electric Motors

Federal and State Governments:
- Market promotion and business matching
- Upgrade logistics (port facility) for REE export to ease of China and oversea markets

State Government:
- Market promotion and business matching

Downstream:
- Marketing and promotion
- Look for market
- Customer feedback and product improvement
- Medical and healthcare services
- Automotive
- Warehousing
- Energy
- E&E
- Mobility

Key Resources

Federal Government
- R&D funding
- Funding for Human capital development
- Provide national data depository for REE information; provide open-access as public domain
- Industrial hub
- Tabung Amanah to collect % of revenue generated from industry for development & waste management purpose. E.g. federal use the fund to build renewable energy infra
- Incentive scheme to improve Malaysia's product competitiveness globally considering China is the biggest competitor.
- Funding for renewable energy
- Enable import of RE raw materials from other countries (e.g. Indonesia) as feedstock to expedite local REE development in terms of production capacity and technology
- Professional visit pass

State Government
- Infrastructure (land, water, energy, waste disposal, and port)
- Land tax exemption

Downstream Industries
- Industrial hub
- Landbank
- REE Expertise
- Waste Disposal Service
- Job and training

Channels

Federal Government:
- Dialogue for government - Industry engagement, especially with state government, e.g. Perbadanan Kemajuan Negeri Perak (PKNP)
- Provide a platform for internationalisation engagement
- Market access
- One-stop agency for various law; licenses application

State Government:
- One stop centre
- Export port using Lumut port and avoid tax/cut cost in warehousing.
- Provide land lease of 20-35 years for industries

Downstream:
- Service centre and market outlet

Cost Structure

Federal Government:
- R&D Costs, Infrastructure, Human Capital Development (HCD)
- Provide international negotiation on trade, tax, and incentives
- Double tax reduction/redemption

State Government:
- OPEX
- **Example:** Investments State: 80 acres and cost RM 181 billion for three phases and infrastructures
- Kelantan state: Needs federal grant
- Carbon tax
- Cost incorporating renewable energy (reduce carbon tax)

Revenue Streams

State Government:
- Leasing income, royalty, end product JV (state government: industry partnership)
- Federal grant to support the state
- Profit sharing partnership with industry players

Federal Government:
- Receive income tax

Figure 4.23: Business model canvas for the downstream sector of the IAC-REE industry in Malaysia (Source: FGDs and site visits)

Two possible products deemed to command the majority of the demand in the industry were proposed: super-magnets and electric motors. Two business model canvas were proposed based on the industrial and governmental perspectives. The elaboration of the business model canvas (Table 4.15) is as follows:

TABLE 4.15

No	Items	Details
1	Key Partners	**Federal government:** MITI (e.g., G2G collaboration, market penetration, transfer technology), MOSTI, NRES, MOHR, MIDA, MATRADE, Royal Malaysian Custom (RMC), Department of Environment (DOE), DOSH, NCER, National Advanced Material Consortium, SIRIM **State government:** EXCO, local authority (License), UPEN, PTG (Management), NCER, IM Inc., JMJ, PNT, Alam **Downstream Industries:** Financial institutions (FDI, Developmental Bank, Commercial Bank), National company for rare earth (e.g., Petronas), miners, TNB, investors (e.g., manufacturers of motors/super-magnets like Shinetsu)
2	Key Activities	**Federal government:** ▸ R&D grant ▸ CEPA on REE ▸ Free trade zones (FTZ) gazettement, Trade Apache ▸ National CoE on IAC-REE ▸ Issuance of manufacturing license (MITI) ▸ Exporting strategies by phases **State government:** ▸ CEPA on REE ▸ Issuance of land title ▸ Exporting strategies by phases **Downstream industries:** ▸ Manufacturing ▸ Logistics ▸ Trade and services

<table>
<tr><th>No</th><th>Items</th><th>Details</th></tr>
<tr><td>3</td><td>Key Resources</td><td>Federal government:
• R&D funding
• Funding for human capital development
• Provide national data depository for REE information (open access as public domain)
• Industrial hub
• “Tabung Amanah” to collect revenues generated from the industry for development and waste management purposes, such as the federal use of the funds to build renewable energy infrastructure
• Incentive scheme to improve Malaysia’s product competitiveness globally considering China is the biggest competitor
• Funding for renewable energy
• Enable the import of rare earth raw materials from other countries (e.g., Indonesia) as feedstock to expedite the local REE development in terms of production capacity and technology
• Professional visit pass

State government:
• Infrastructure (land, water, energy, waste disposal, and port)
• Land tax exemption

Downstream industries:
• Industrial hub
• Landbank
• REE expertise
• Waste disposal service
• Job and training</td></tr>
<tr><td>4</td><td>Value Propositions</td><td>Federal and state governments:
• REE business friendly policies
• Increased public awareness
• Safeguarding Malaysia’s resources
• Industrial symbiosis park at Gua Musang
• Quit rent, premium, and assessment fee reduction for five years
• Researcher Industry Scientific Exchange (RISE) programme and National Technology and Innovation Sandbox (NTIS) programme
• Smart regulator
• Talent projection
• Provide clear policy on rare earth upstream to downstream
• Training of skilled workers at all levels of entry through TVET community colleges
• Review on the export duty
• High income (royalty) for government
• The creation of free trade zone with friendly policies and its adoption at Silver Valley Tech Park in Perak
• Public-private partnership that enables profit-sharing
• Built-to-suit and lease (BTSL)
• Incentives (tax and import duty exemption for downstream processing)</td></tr>
</table>

No	Items	Details
		Downstream industries: ▸ Establishment of downstream IAC-REE ecosystem ▸ Price advantage of locally developed technologies ▸ Logistics/supply chain expansion ▸ Job or employment opportunities ▸ Micro-credentials on job training ▸ Provide upskilling competencies for IAC-REE talents ▸ High-value products (super-magnets, wind turbines) (do not have IP and players for automotive)
5	Customer Relationships	**Federal and state governments:** ▸ G2G (bilateral trade) ▸ Social obligation ▸ Environmental protection (decarbonisation) ▸ Subsidies for end-users and consumers **Downstream industries:** ▸ Global market to supply REE products to ASEAN countries ▸ Establish public-private initiatives ▸ Business-to-business (B2B) partnership of downstream component manufacturer in collaboration with end users (e.g., automotive industry) ▸ Provide services and support to consumers
6	Channels	**Federal government:** ▸ Dialogue for government involving industrial engagement, especially with the state governments, such as *Perbadanan Kemajuan Negeri Perak* (PKNP) ▸ Provide a platform for internationalisation engagement ▸ Market access ▸ One-stop agency for various laws and licenses application **State government:** ▸ One-stop centre ▸ Export port using Lumut port and avoid tax/cut cost in warehousing ▸ Provide land lease of 20–35 years for related industries **Downstream industries:** ▸ Service centres and market outlets

No	Items	Details
7	Cost Structure	**Federal government:** • R&D costs, infrastructure, human capital development (HCD) • Provide international negotiation on trade, tax, and, incentive • Double tax reduction/redemption **State government:** • OPEX • Examples: Investments state: 80 acres, cost RM 181 billion for three phases and infrastructure • Kelantan state: In need for federal grant • Carbon tax • Cost incorporating renewable energy (reduce carbon tax)
8	Revenue Streams	**Federal government:** • Receive income tax **State government:** • Leasing income, royalty, and end-product joint venture (state government-industry partnership) • Federal grant to support the state • Profit-sharing partnership with industry players
9	Customer Segments	Super-magnets and electric motors **Federal and state governments:** • Market promotion and business matching • Upgrade logistics (port facility) for REE export to ease of China and oversea markets **State government:** • Market promotion and business matching **Downstream industries:** • Marketing and promotion • Look for market • Customer feedback and product improvement • Medical and healthcare services • Automotive • Warehousing • Energy • E&E • Mobility

Table 4.15: Detailed business model canvas for the downstream sector of the IAC-REE industry in Malaysia (UMW Analytics, 2022)

The value proposition for the downstream REE business model highlighted the value added offered on the proposed products. A permanent magnet is an essential component in the production of electric motors. Through the use of a super-magnet in an electric motor, it is possible to create a more efficient and durable product. However, in order to achieve this, it is important that the magnet can be manufactured to a high-quality standard. This can be achieved with the use of reliable equipment for the manufacturing of these magnets. One such piece of equipment is the induction furnace used in the production of super-magnets. An induction furnace is a device that uses electricity to produce heat.

The operation of NdFeB magnets involves creating an electromagnetic field between two coils of wire that carry an electric current. Businesses in Malaysia should leverage on the REE available with high Nd content, which are suitable for the NdFeB magnet manufacturing. These so-called super-magnets are effectively necessary for the net zero carbon reduction, especially in so-called "green industries" related to the electric motors for EVs and wind turbines. Other potential use involves MRI scanners. The EV market is expected to reach USD 1.11 trillion by 2030 at forecasted CAGR of 22.5% from 2022 to 2030 (EV Market, Beyond Market Insights, 2021). Since 2000, both USA and China have been engaged in a geopolitical war for control of REE. The conflict has primarily focused on two key REE – Dy and Tb. These two elements are critical to the production of computer hard drives, magnets, lasers, smartphones, and other high-tech products. In 2010, China accounted for more than 97% of the global production of REE. In the same year, USA produced only 3.4% of the world's supply. Since then, China has tightened its stranglehold on the global supply of these critical materials, depriving American businesses and consumers of access to these materials at a fair price. As the world's leading producer of REE, China can use its dominant position in the market to artificially depress prices and enrich itself at the expense of the American businesses.

TABLE 4.16

Country	Export Volume (metric tonnes)	Share (%)	Export Value (millions of USD)	Share (%)
China	407,886.6	42.3	8,112.2	46.3
USA	89,467.1	9.3	953.6	5.4
Malaysia	87,696.1	9.1	942.4	5.4
Austria	87,055.1	9.0	867.8	5.0
Japan	68,412.9	7.1	2,172.6	12.4
Other countries	223,172.7	23.2	4,467.7	25.5

Table 4.16: Breakdown of global rare earth exports (2008–2018) (UN Comtrade Database 2008–2018)

The USA-China trade dispute over REE has also caused dramatic increases in the price of these elements, which have forced manufacturers to seek alternative sources of supply or identify ways to reduce production costs. In the long term, USA must adopt new strategies to address the shortage of REE and regain access to the market. These strategies should include investing in the domestic production of REE and improving the efficiency of these supplies. As tabulated in Table 4.16, Malaysia exported about 9.1% of the total global rare earth exports (behind USA and China).

It would be beneficial for Malaysia to leverage on this situation for the country's economic growth and increasing competitiveness when the demand is strong and on the rise. In order to achieve this, Malaysia should gain advantage by leveraging the vast availability of raw materials from upstream and developing the ecosystem until downstream. Not only that, coupled with the horizontal and vertical integration in the supply chain, high-quality products can be produced at an incredibly competitive price. There are many potential customer segments for rare earth super-magnets as follows:

(i) Manufacturing and manufacturing-related firms: These firms use rare earth super-magnets for a variety of purposes, including holding down manhole covers and grates, holding open industrial gates, and storing small parts or items in bulk bins. Some of the largest manufacturers of this type of product include Magna International Inc., IGUS AG, and Sumitomo Electric Industries Ltd.
(ii) Industrial machinery and automation firms: These firms use super-magnets for heavy equipment used in a wide variety of industries, such as oil and gas exploration, mining, construction, and agricultural equipment. Some of these firms include Caterpillar Inc., General Electric Co., and Deere & Company.
(iii) Aerospace firms: These firms use super-magnets for applications like locking nuts and bolts in place on airplanes, securing windows during flight, and capturing space in wind tunnels. Some aerospace firms that use these products include Boeing, Lockheed Martin Corp., and Pratt & Whitney.
(iv) Marine and marine-related firms: These firms use super-magnets for various sea-faring applications, including anchoring ships to docks and holding window blinds in place during rough weather. Some examples of firms that employ these types of products are Carnival Cruise Lines, Royal Caribbean Cruises Ltd., and Walt Disney Parks and Resorts.
(v) Automotive and related businesses: These businesses use super-magnets in a variety of applications in the automotive market, including holding down door panels, securing hinges, and attaching other parts together. Examples of firms in this field include Ford Motor Company, Honda Motor Co. Ltd., and Volkswagen AG.
(vi) Consumer electronics: These firms use super-magnets in various products, including portable DVD players, cell phone cases, portable speakers, and headphones. A few examples of firms in this field are Apple, Bose Corporation, and Samsung.

Evidently, the applications of these magnets are endless, which can be found in products in about every industry. The demand for these magnets increases as manufacturers explore ways to save money and improve efficiency in their manufacturing processes. However, the increasing demand creates shortages that may lead to the increase of price in the future. In order to keep up with the increasing global demand for these products, new mines have been opened in China, and quotas are placed on the imports of magnets. However, with the increase in the number of mines increases and the supply of magnets, prices are expected to decline over the next few years. This also means that more manufacturers are switching to the use of these materials, instead of the traditional magnets. Using super-magnets for manufacturing purposes has quickly become the new standard, and it is expected that they would replace older magnetic materials used in manufacturing in the coming years. As manufacturing is involved, the delivery of products would be benefitted by the existing logistics firms established in Malaysia. They provide services for the transportation of goods and materials. These firms offer a variety of services like container shipping, bulk shipping, and general cargo shipping. As the use for these products involves wear and tear, one of the opportunities for continuous engagement are through after-sales and service support for servicing and parts replacement for magnets and motors or rotating machineries.

There are several key resources needed to manufacture these products. It is crucial for businesses to use reliable equipment for the manufacturing of magnets. One of the key resources needed to produce these products is human talent. The role of the Ministry of Human Resources (MOHR) is particularly crucial in ensuring that adequate talents with skillsets required by the industries are met. This would be beneficial to increase the number of specialists, especially white-collar workforce that is readily available in the market, such as those who are currently working in Lynas Malaysia, Gebeng.

Nevertheless, for the downstream sector to work, a good business model with the right stakeholders should first be established, preferably involving those with experience in certain industries like mobility, energy, and medical sectors. Technology transfer should also be provided between joint venture partners, so that they can benefit from this collaborative arrangement. Furthermore, there should be a commitment or quota to be met in converting raw materials to the finished products for Malaysia to gain advantage of the ecosystem development. These activities can be established within the existing and new high-tech industrial parks or eco industrial parks, such as through the Northern Corridor Economic Region (NCER) or East Coast Economic Region (ECER). This can promote industrial symbiosis between the integrated supply chains, where firms can benefit from working closer together for improved efficiency and coordination across the supply chains. This may result in better use of resources, increased cost-savings, and improved sustainability.

With the development of the downstream ecosystem, it will not only guarantee access to the ASEAN market but also the global market. Malaysia should strategise for FDIs to develop the downstream ecosystem to be as enduring as the electrical and electronics sector in this country. A leading market research group, IMARC, reported in 2021 that the global markets for magnets reached USD 36.6 billion and forecasted that it would reach USD 47.4 billion by 2027, with CAGR of 4.71% during the period of 2022–2027.

STATISTA statistics (Figure 4.24) displays the demand for permanent magnets in industrial applications worldwide in 2010 and 2015, with projected figures for 2020 and 2025. Back in 2015, the global demand for permanent magnets to be used in industrial applications was at 5,000 metric tonnes. It is projected that this would increase to 7,000 metric tonnes in 2025.

FIGURE 4.24

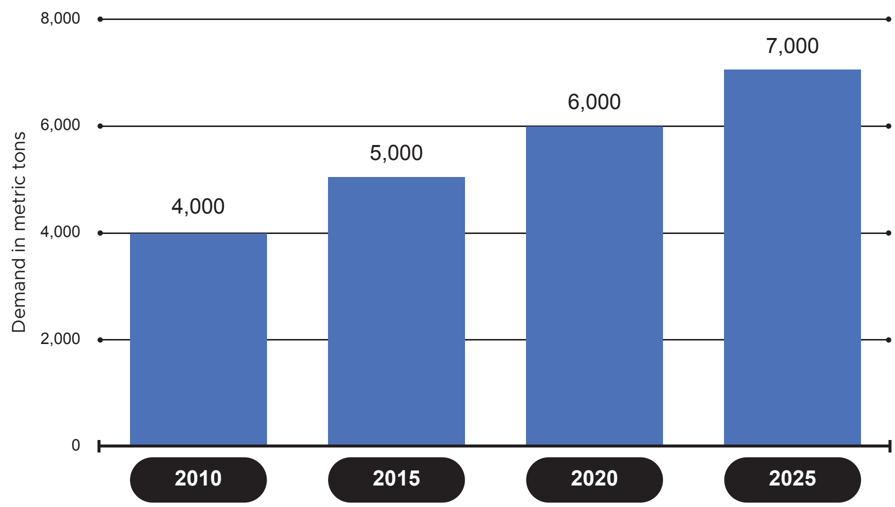


Figure 4.24: Demand for rare earth in industrial permanent magnets worldwide from 2010 to 2025 (in metric tonnes) (Statista Research Department, 2016)

FIGURE 4.25

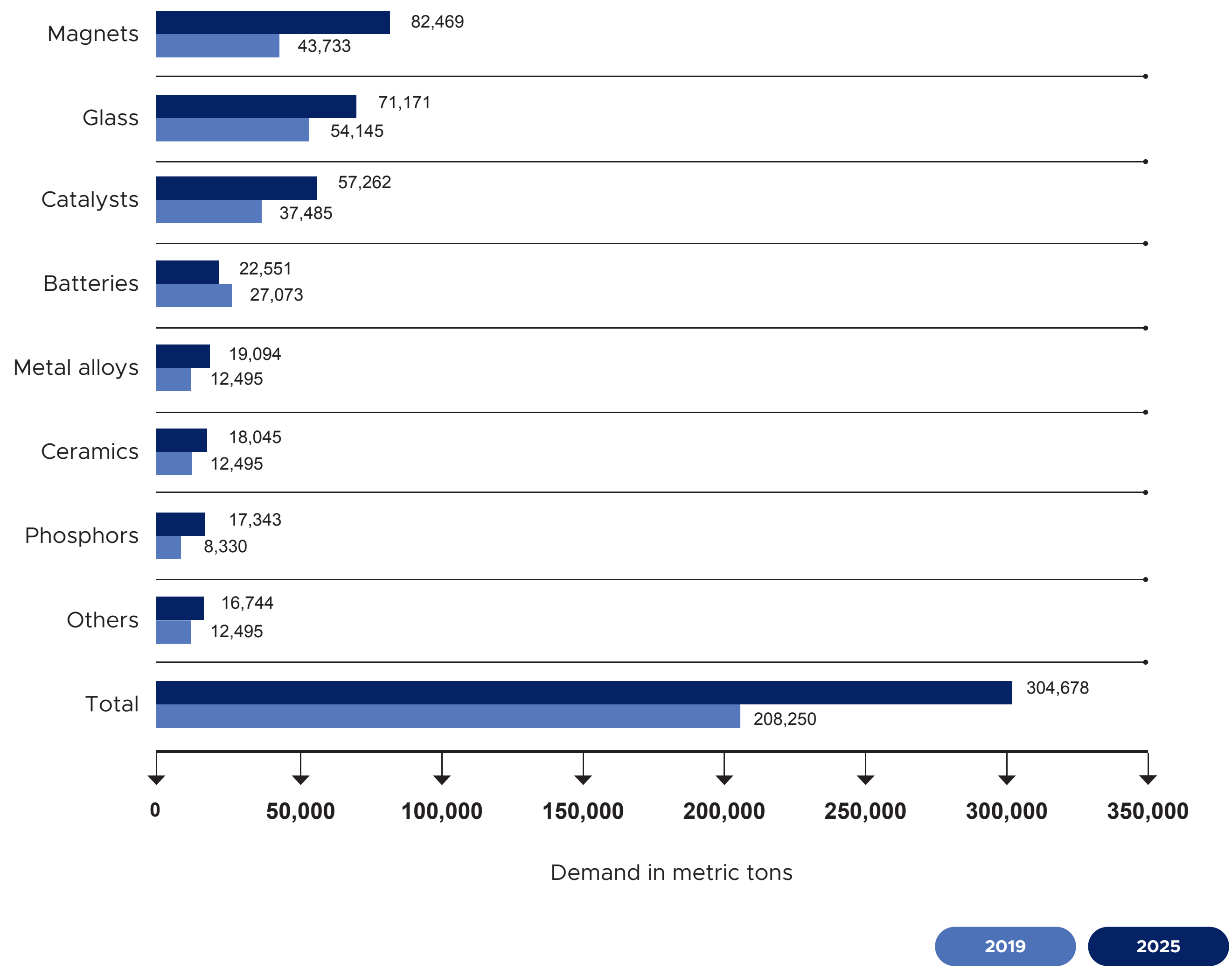


Figure 4.25: Demand for REO worldwide in 2019 and 2025 by end use (in metric tonnes) (Statista Research Department, 2016)

In 2019, the global REO demand (Figure 4.25) to produce magnets amounted to 43,733 tonnes, which was then forecasted to increase nearly double (82,469 tonnes) by 2025 (Statista Research Department, 2016). Malaysia has also set a target on the percentage of EVs at 38% from the total industry volume (TIV) by 2040 with respect to the Low Carbon Nation Aspiration target, as declared in the New Energy Policy (2022–2040). Cooperation among key partners is equally imperative in managing the resources for the delivery of the required activities and subsequently, in establishing customer relationships among the targeted consumers through proper channels, as depicted in the business model canvas (Figure 4.26). Materialising all these activities involve costs. A good business model involving the beneficiaries is needed, especially when high CAPEX and OPEX are involved. The government can provide SMEs monetary assistance in a form of Credit Corporation Guarantee (CCG) and assist the industry in some form of security of cashflow forecasting through the consistency in policies, such as the involvement of salary cap, electricity and water tariffs, or special incentives. Adding to that, regulations and obligations on reporting need to be properly established for clarity and to ensure the sustainability of the downstream sector in Malaysia. This can be established through a higher local percentage on equity, which is already being practised and accepted for certain industrial sectors.

Referring to the business model canvas in Figure 4.26 and Table 4.17, the approach is significantly different from the approach shown in Table 4.16. The previous approach is industry-centric, whereas the approach here is more of a hybrid mode, involving both federal and state governments and the industry. It can be clearly seen that, for a country level, a macro perspective is involved, unlike the previous approach that focuses at a more micro level. From a national perspective, it is evidently more complicated as it involves more than just commercial aims and many stakeholders, as well as the public. This involves providing clear and transparent business-friendly policy interventions related to REE from the upstream sector to the downstream sector, involving manufacturing and services.

In order to promote industrial symbiosis in the rare earth industry, one approach is the creation of free trade zone (FTZ). The second approach is to leverage on the existing technology park models like the Silver Valley Technology Park, Perak High Technology Industrial Park, or those located in Kulim, Kertih, Gua Musang and Gebeng. This would be beneficial for the expansion of the ecosystem and in providing income opportunities for the state and people.

FIGURE 4.26

Key Partners

- Local suppliers for process materials and consumables
- Machinery and equipment suppliers (inspection system), overseas metal bending and fabrication, local computer numerical control
- Factory site near processing plant (buy, rent, or JV)
- Logistics services
- Security company
- Federal government (automation grant – MIDA, Free Trade Zone, customs permit, and approval for imported goods)
- Federal government (MITI, DOE and NRES)
- State government (land, etc.)
- University (R&D support)
- Financial institutions
- Regulatory body (free trade zone, customs permit, and approval for imported goods) and local authority
- Testing services
- Training provider
- Local community
- Product off takers

Key Activities

- Production manufacturing
- Warehouse
- Trading, procurement, and outsourcing
- Business development
- Transportation
- Training and upskilling
- Technology development
- Engineering design and new product introduction development
- Research and development

Key Resources

- Energy resources
- Electricity
- Water supply
- Raw materials process and consumables (3,000 metric tonne annually)
- Manpower
- Talent pool (white and blue collar)
- Customer service
- Machinery and equipment
- Infrastructures and logistics
- IP protection
- Fiscal incentives and financial assistance
- Land
- Operating license

Value Propositions

- Permanent magnet and electric motor production for EV
- Possibilities of price advantage, logistic/supply chain, and geopolitics (tariff war between US and China)
- High product quality at low cost
- Skills and competency talent available in countries (e.g., talent development programme assisted by MOHR)
- Provide competent local JV partner
- Provide mechanism of transfer of technology
- Commit to the percentage of products to local supply versus oversea markets
- Establish eco-industrial park at several economic zone (e.g., NCER/ECER)
- Industrial symbiosis between integrated supply chain
- Access to ASEAN market
- Presence of midstream and local sources at upstream

Customer Relationships

- Pricing competitiveness
- Business and after-sales support
- Visa/working permit policy that encourages family members of experts to reside in Malaysia
- Good governance

Channels

- Federal and state government initiatives (visits)
- Direct negotiations
- Convention/symposium on REE conducted by government agency to promote products/services
- Integrated industrial park to cater for supply chain raw materials
- One stop centre for approval of licenses both at state and federal levels
- Industry engagement

Customer Segments

Magnets and Electric Motors

- B2B (i.e., OEM and system integrators including manufacturers and assemblers of consumer electronics, energy, medical, and automotive) from local and overseas (Japan, US, Korea, and Europe)
- After-sales activities

Cost Structure

- Consistent incentives by the government to ease of cashflow forecast
- Ease of borrowing using DFI fund for SMEs and SMIS
- Clear regulations and obligations on reporting
- Capital government investment
- Salary cap – changes the duration for minimum salary cap (> 5 years once)

Revenue Streams

- Allow higher local percentage on equity
- Product selling (per tonne)

Figure 4.26: Business model canvas of the REE downstream hybrid model for the government and industry (ASM Analytics, 2023)

TABLE 4.17

No	Items	Details
1	Key Partners	▸ Local supplier for process materials and consumables ▸ Machinery and equipment suppliers (inspection system), overseas (metal bending), overseas (fabrication), and local (computer numerical control) ▸ Factory site near processing plant (buy, rent, or JV) ▸ Logistics services ▸ Security company ▸ Federal government (automation grant—MIDA, FTZ, customs permit and approval for imported goods) ▸ Federal government (NRES, MITI, and DOE) ▸ State government (land etc) ▸ University (R&D support) ▸ Financial Institution ▸ Regulatory body (free trade zone, customs permit & approval for imported goods) and local authority ▸ Testing services ▸ Training provider ▸ Local community ▸ Product off takers
2	Key Activities	▸ Production manufacturing ▸ Warehouse ▸ Trading, procurement, and outsourcing ▸ Business development ▸ Transportation ▸ Training and upskilling ▸ Technology development ▸ Engineering design and new product introduction development ▸ R&D
3	Key Resources	▸ Energy resources ▸ Electricity ▸ Water supply ▸ Raw materials process and consumables (3,000 metric tonne annually) ▸ Manpower ▸ Talent pool (white-and blue-collar) ▸ Customer service ▸ Machinery and equipment ▸ Infrastructures and logistics ▸ IP protection ▸ Fiscal incentives and financial assistance ▸ Land ▸ Operating license

No	Items	Details
4	Value Propositions	‣ Production of super-magnets and electric motors for EVs ‣ Possibilities of price advantage, logistics/supply chain, and geopolitics (tariff war between USA and China) ‣ High-quality products at low cost ‣ Skills and competency talents available in countries (talent development programme assisted by MOHR) ‣ Provide competent local joint venture partners ‣ Provide mechanism of technology transfer ‣ Commit on the percentage of products for the local supply versus foreign markets ‣ Establish eco-industrial park at several economic zones like NCER/ECER ‣ Industrial symbiosis between the integrated supply chains ‣ Access to the ASEAN market ‣ Presence of midstream and local source at upstream
5	Customer Relationships	‣ Pricing competitiveness ‣ Business and after-sales support ‣ Visa/working permit policy that encourages the family of experts to reside in Malaysia ‣ Good governance
6	Channels	‣ Federal and state government initiatives (site visits) ‣ Direct negotiations ‣ Convention/symposium on REE conducted by the related government agency to promote products/services ‣ Integrated industrial park to cater for supply chain raw materials ‣ One-stop centre for license approval at both state and federal levels ‣ Industry engagement
7	Cost Structure	‣ Consistent incentives by the government to ease cashflow forecasting ‣ Ease of borrowing using DFI fund for SMEs and SMIS ‣ Clear regulations and obligations on reporting ‣ Capital government investment ‣ Salary cap—change the duration for the minimum salary cap of once every five years
8	Revenue Streams	‣ Allow higher local percentage on equity ‣ Product selling (per tonne)
9	Customer Segments	Magnets and electric motors ‣ B2B (i.e., OEM and system integrators, including manufacturers and assemblers of consumer electronics, energy, medical, and automotive) from local and overseas (Japan, USA, Korea, and Europe) ‣ After-sales activities

Table 4.17: Detailed hybrid business model canvas for the downstream sector of the IAC-REE industry in Malaysia (ASM Analytics, 2023)

The National Technology Innovation Sandbox (NTIS) should be utilised by the industry to test technology- and policy-related matters. Import or export duty exemption and other incentives must be reviewed and improvised to facilitate the fast-tracking of the downstream sector.

As for human capital development, aspects related to the preparation of the right skills and talents are needed for both governmental and industrial sectors. This would involve the strategic synergy between the Ministry of Higher Education (MOHE) and the downstream sector. Given the significance of talent pool, a projection of supply and demand needs to be formulated based on the close linkages of industries, MOHR, and MOHE. Training of skilled blue and white-collar workforce at all levels of entry need to be devised under the TVET and community educational programmes.

Public-private partnership should be demonstrated in providing a sure-win situation for both government and industries. One of the existing programmes that can be leveraged on is the Researcher Industry Scientific Exchange[19] (RISE). Through this platform, expert service providers can relate to parties who need solutions for their problems. Built-to-suit leases[20] (BTSL) is an option that can be considered as a business model for the downstream manufacturing plant, which can help in the development of the downstream ecosystem.

Constant synergy is needed among key partners in managing the key resources for the key activities, as displayed in the business model canvas in Figure 4.26. Apart from the collection of taxes, the government should embark on joint venture and profit-sharing business models with the industries—for instance, in certain cases, some of these taxes can be waived for a certain number of years, such as the investment tax allowance (ITA) provided through MIDA. Innovative business models and incentives need to be crafted in preparation for new forms of taxes, such as the carbon tax, which can impact Malaysia’s future competitiveness. This is imperative to attract business enterprises, FDIs, and DDIs to come and set up in Malaysia and to provide growth opportunities for longer years, providing sustainability not only to the industries but also most importantly, the environment for future generations.

With that, income, such as royalty, to the state governments should be transparent and benefit the local communities, such as improving and providing amenities for improved income and lifestyle. More spillovers can benefit the state government following the establishment of the downstream ecosystem. Competitive advantage pricing can be achieved as the vertical and horizontal integration of supply

[19] Researcher-Industry Scientific Exchange (RISE) is a platform that connects expert service providers with parties who need solutions in the problems faced. This sharing of expertise aims to increase innovation and productivity, as well as capacity building for both parties through research, consultation, technology transfer, or training. (https://rise.mosti.gov.my/)

[20] BTSL is where the landlord develops the facility for clients with specific requirements and manages the entire development process, and clients enjoy the new facility, while retaining financial flexibility (https://www.i-industrial.space/built-to-suit-built-to-lease).

chain is developed and achieved. This can facilitate the advancement of locally developed technologies in producing high-value products (super-magnets and motors) but also the logistics and supply chain ecosystem. This can also create more job opportunities for the people. Besides that, upskilling programmes offered to the public, such as the micro-credentials with on-the-job training programmes can benefit the industries.

The business model for the downstream sector requires support from all parties based on the partnership mode. The targeted short-term investment value required from the industry players (via private financial initiatives) is estimated at RM 300 million for the production of super-magnets, with the production capacity at 3,000 tonnes per year. This can provide job opportunities for 900 people and create potential revenues of RM 708.4 million in the first year. On the other hand, the short-term investment required for the production of electric motors is RM 600 million, with the potential revenue creation of RM 1.065 billion and potential job opportunities for 2,000 people. In order to make it more attractive, the government can consider providing special fiscal incentives, specifically ITA and the pioneer status, in order to promote the downstream sector; thus, creating the needed platform for the local industry consortium. The participation of local firms within the value chain can provide more indirect economic effects on the manufacturing activities.

In addition, fiscal assistance can be introduced for the adoption and application of local content in the product development. The downstream sector requires certain assurance on the feedstock supply. In this case, the government can introduce special quota from the local mining resources through the collaboration with the state governments and the local midstream REPP. For fast-tracking, providing reasonable operating license can be considered for the present midstream players in Malaysia, which can amplify the business connection for the downstream sector. Industry players also need to explore the supply of metals and alloys from foreign players at the most attractive price for more competitive business environment. Government can also strategise the transfer of technology and knowledge via strategic procurement of offset programmes. The export tax to the global supply can be formulated to facilitate the local manufacturing industry in penetrating the global markets. The industry players involved in the downstream sector need to embrace more of the ESG agenda in order to enhance the track records for international businesses.

In general, the recommendations for the hybrid business model are as follows:

(i) Provide fiscal incentives to support the local downstream industry players. This study identified several models of fiscal incentives applied by a few countries, including China, Vietnam, and USA:
- ITA and the pioneer status – In Vietnam, tax incentives may include up to four years of tax exemptions and 50% tax break in the following nine years.
- Tax credits for local content – In USA, it would be USD 20 per kilogram credit (Rare Earth Magnet Manufacturing Production Tax Credit Act of 2021) for American-made NdFeB super-magnets, with the credit growing to USD 30 per kilogram for magnets made with rare earth sourced from American mines.
- Export tax exemption (production quota/export tax) – In China, a refundable 13% VAT is given to Chinese rare earth magnet producers. The Chinese players can enjoy 13% raw material cost advantage over their foreign competitors.
- Import duty – China has introduced 5% import duty to the foreign supplies of oxides, carbonates, and metals, causing foreign players to supply rare earth concentrates of lower value add.
- Import tax exemption for goods and raw materials

(ii) Creation of FTZ for the dedicated MRTP
- The development of FTZ and MRTP based on the model of BTSL
- Structuring the assessment rates and quit rent based on a gradual and successful basis for the first five years of operation

(iii) Smart regulations for the application process of the industrial park and factory establishment and performance monitoring

(iv) Provide REE business-friendly policies to promote the manufacturing of super-magnets and electric motors
- Waste management for chemicals used
- Renewable resources for thermal and electrical energy production
- Feedstock supply from the midstream (local/foreign separation plant)
- Recycling process for used magnets containing end-of-life products to promote circular economy

(v) Create employment for the local people at the state level and provide an upskilling programme

(vi) Talent development (training based on TVET) and designed together with the offset programme for knowledge transfer and strategic technology procurement

(vii) Enhance public awareness of the acceptance and utilisation of rare earth for product application through CEPA

(viii) Safeguarding Malaysia’s resources to ensure integrated supply from the upstream sector and midstream sector to the downstream sector

(ix) Public-private partnership enables a win-win situation for the industry and government – monetary returns/income for the government, and corporate tax to the federal government and royalty payment to the state government for any utilisation of assets/resources/land and logistics expansion
(x) Promote participation of local companies via JV
(xi) Facilitate the access to the global and local markets for high-value-added products (magnets and electric motors)
(xii) Adoption of ESG

i. Scenario planning and critical path mapping

According to the Joint Research Centre (JRC) from the EU Commission, there are two plausible scenarios for the global demand of rare earth product-based application at the downstream level (Figure 4.27): high demand and low demand scenarios. It was forecasted that the REE would be mainly utilised for the end-product of wind energy, EVs, and other sectors, such as electrical and electronic appliances and catalysts.

In addition, the future downstream sector of various plausible scenarios are shaped by the following key drivers:

(i) Knowledge and acceptance of local community are among the key drivers that determine the level of rare earth utilisation in the end-products for consumer.
(ii) An established policy for the manufacturing of rare earth-based products can promote the development of the downstream sector.
(iii) A clear regulatory process can provide a business-friendly environment for this competitive industry in Malaysia. Automation and Industry 4.0 would enhance the productivity of the downstream sector for the manufacturing of rare earth-based products, promoting high-quality production in meeting the market demand.
(iv) The adoption of sustainable technology, such as EVs, plays a critical role as this determines the economics of scale on the demand side. The increase in the demand for EVs drives the production of rare-earth-based super-magnets and electric motors. In addition, a few countries have set their net zero pledge, which drive the interest in EVs.

FIGURE 4.27

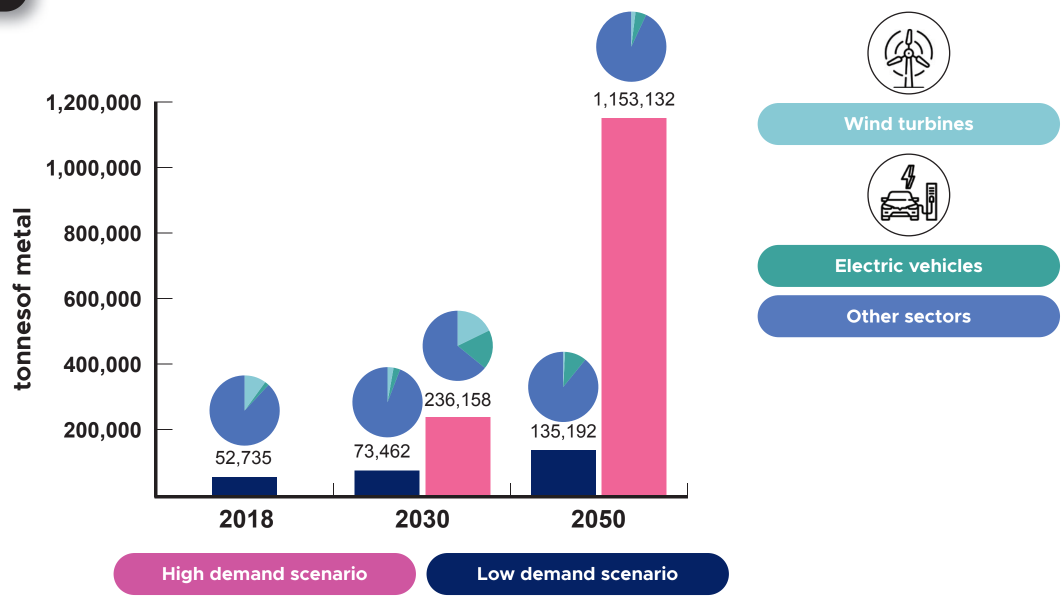


Figure 4.27: Estimated global demand of rare earth element for product applications based on two plausible scenarios (Alves Dias et al., 2021)

However, there are plausible risks that need to be factored in. These future risks may disrupt the growth of the downstream sector. There is claim on new discoveries for alternative materials to replace REE in applications, such as tetrataenite, an iron-nickel alloy with an ordered atomic structure to replace these super-magnets. The emergence of alternative materials would substitute the usage of rare earth materials in the end-products. The disruption on the supply of materials, from upstream or midstream, can affect the downstream sector in meeting up the production demand. The disruption of supply can be caused by several factors like pandemic, conflict of war, deficit of materials, and price factor.

The emergence of high technologies for specific functions can provide risks and disruption to the downstream sector – for example, a new type of mobility that is green and not totally independent from electric-based vehicles. The defence and renewable energy sectors also undergo the revolution of technologies, which would provide imbalance for the demand and supply. The health and safety on the usage of REE have always been a major concern due to their long-term effects on the human body and environment. The negative effects on the health and safety of humans, if provided with strong evidence, can cause a low uptake of rare earth-based product at the consumer level.

High demand scenario

There are several factors that can drive the high demand scenario – for example, the migration of each country towards decarbonisation through the establishment of a friendly policy and market instruments to stimulate the growth of green mobility and renewable energy. Malaysia is set to achieve net zero GHG emissions by 2050, as set out in the National Energy Policy 2022–2040. The policy is equipped with the selected targets, such as the targeted percentage of EV share at 38% and the targeted total installed capacity of renewable energy at 18,431 MW. This strong presence from the demand side creates the need of the supply chain in the regional market. The introduction of carbon tax forces the industry players to opt for green and sustainable technologies with lower emission. Automotive makers would then be more focused on the manufacturing of low-emission vehicles, such as EVs. Energy industry players would be prompted to explore options to enhance the renewable energy generation from various sources, including wind energy and batteries, which would stimulate the manufacturing activities of wind turbines, motors, and parts.

The exponential growth of urbanisation would cause other sectors like telecommunications, petrochemical industries, and electrical and electronic appliances to drive the high demand for REE. The high demand scenario is also supported with the stable rare earth supply from the upstream and midstream sectors, along with the sustainable production and operation. Technology improvements in the downstream sector for product manufacturing can lead to innovations from multiple levels of the industry players and sectors. The introduction of the extended producer responsibility (EPR) can boost the recycling activities by the manufacturers.

Low demand scenario

As for the case of low demand scenario, supply can only keep up with the demand due to several factors, which may cause uncertainties to the downstream sector. Any pandemic outbreak can cause a slowdown in the economic growth; thus, resulting in low manufacturing productivity due to the low uptake. A pandemic also causes difficulties in the operation and global trading. The limited supply of resources from the upstream and midstream sectors would drive the industry players to explore for other types of materials and technology improvement. For instance, as of now, the focus lies in the R&D activities on alternative materials for super-magnets in various applications, such as multipolar synchronous and superconductor-based generators. Hybrid drive generators also introduce smaller super-magnets, as compared to the original standards.

Most of the options are still in their immature stage, which may not be viable. However, the latest development in electric motors introduced by BMW can power up the BMW iX M60 without the use of rare earth metals. The invented products apply a special design to generate the torque via contactless power transmission. This can be a game changer for the low demand scenario, particularly if BMW were to provide technology licensing to the players, resulting in the production of electric motors without rare earth-based magnets. The emergence of new alternative fuel vehicles and renewable energy systems with lower emission may result in low utilisation of rare earth-based products. The disruption of rare earth supply can cause crisis, resulting in price fluctuations and unstable supply (Figure 4.28).

FIGURE 4.28

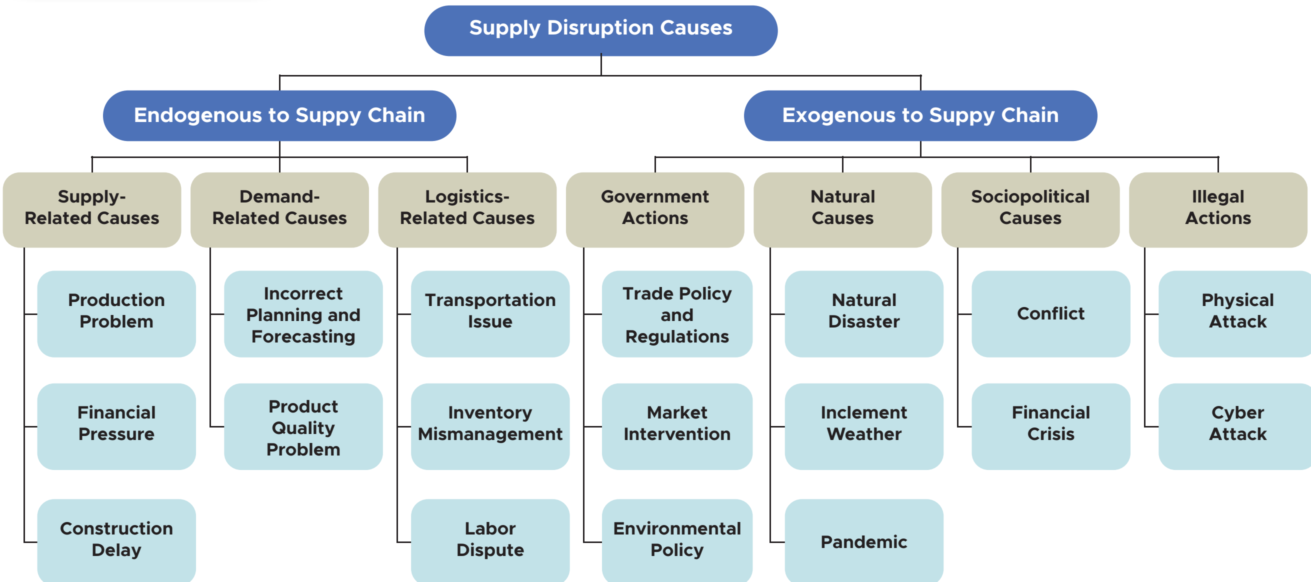


Figure 4.28: Potential causes of supply disruption (Riddle et al., 2021)

ii. Strategies and recommendations

The proposed strategies and recommendations (Table 4.18 until Table 4.20) for the rare earth downstream sector are based on the 8i ecosystem for the industry development to promote high value-added activities.

iii. KPIs

The downstream sector requires a set of measurable targets at the national level to ensure that all stakeholders pursue a common goal in developing the downstream sector of the rare earth industry. Several national targets have been proposed, such as the number of job employment, the contribution of GDP, the participation of local firms, magnet manufacturing capacity, revenues, and local content. Those set targets are expected to complement the existing national targets from various strategic documents, such as the number of EVs, the percentage of renewable energy generation, the capacity of energy storage systems, and the net zero carbon by 2050. The set of these national KPIs is interrelated to the target of production capacity at the national level.

In 2014, Shin-Etsu[21] invested in manufacturing in Vietnam, with the capacity of super-magnet production at 2,000 tonnes per year. With the same capacity of production, an estimated supply of NdPr at one-third from the targeted production, equivalent to 700 tonnes per year, is required. In order to produce high-performance super-magnets, additional supplies of Dy and Tb materials are required. As decided at the FGD, Malaysia aims to be ready at the production capacity of 3,000 tonnes per year in 2025. This sets the basis for Malaysia to go forward to achieve long-term KPIs by phases, which are further elaborated in Table 4.19.

TABLE 4.18

	Proposed National Targets
1	Manufacturing production capacity
2	Participation of local company
3	Job employment
4	Revenue
5	Local content
6	Investment

Table 4.18: List of proposed national targets

KPIs for the national target are expected to be achieved by 2025 (short-term), 2030 (mid-term), and 2050 (long-term) considering the ongoing initiatives taken by the stakeholders and interested parties. KPIs are developed for the downstream sector to embark on two product applications, namely super-magnets and electric motors (Table 4.20 and Table 4.21).

[21] Shin-Etsu Chemical Co. Ltd. is the Group's parent company for S.E.H. Malaysia Sdn. Bhd., which is an innovative company specialising in the development and production of specialty chemicals and high-tech materials. (https://www.sehmy.com/index.htm)

TABLE 4.19

No	Items	Details
1	Institutions	i. Develop a national strategic policy to promote the downstream sector of the IAC-REE industry and drive the ecosystem growth ii. Strengthen institutional support by establishing a one-stop centre (OSC) and empowering the government agency or National Advanced Material Consortium (NAMC) to facilitate the development of the downstream sector of the IAC-REE industry and to avoid the overlapping of roles and responsibilities. NAMC can be leveraged: ▸ To identify a champion across the industry value chain and to be positioned in the consortium ▸ To optimise the national resources, market instruments, and fiscal incentives to drive the downstream sector ▸ To assess the risks associated with the IAC-REE downstream ▸ To identify the needs for R&D to develop collaboration models for product development and improvement ▸ To provide grants based on thematic development involving key partners ▸ To develop the industry ecosystem for the IAC-REE downstream ▸ To perform industry insights in the monitoring of the performance of the downstream sector iii. Create a dedicated GLC or empower the existing GLC as an industry champion for the IAC-REE downstream to spearhead the industry; business collaborations involving the GLC and potential end-users to penetrate and stimulate the local market and global business opportunities iv. Establish the Critical Material Institute as a Centre of Excellence for R&D, focusing on IAC-REE-based products
2	Internationalisation	i. Commit to long-term G2G collaboration for the localisation of high-tech manufacturing technology for IAC-REE based products via any government scheme, such as Industrial Collaboration Programme (ICP) ii. Promote the involvement of local Malaysian experts in IAC-REE international associations iii. Implement a strategic approach at the World Economic Forum or global platform to demonstrate the IAC-REE country's ecosystem in order to attract FDIs iv. Revise and review the export quota of rare earth carbonate from upstream and rare earth metal products from midstream to ensure adequate supply for the local downstream – for example, 30% for export and 70% for the domestic manufacturing market v. Create spillover effect for trade commodities between countries

No	Items	Details
3	Intellectual Capacity	i. Forge the collaboration between industry and academia by strategizing the research activities driven by industrial problems, focusing on process improvement and new product innovation ii. The role of the government in coordinating the partnerships involving private sectors (foreign or local firms) and universities to form a collaboration model in the forms of licensing, royalty basis, co-innovation and co-sharing, and multilateral patent pool iii. National upskilling programme for the manufacturing of IAC-REE-based products by leveraging on the existing talent pool for the manufacturing activities—to formulate the mechanism to retain the talent chain and incorporate the knowledge for the undergraduate students; to enhance and introduce the knowledge of IAC-REE industry via TVET iv. Exchange programme for human resource development and transfer of knowledge among universities and industry players—to uplift the visibility of local rare earth experts for knowledge sharing v. Review talent policy to balance between building talents or to attract talents (especially foreign talents) considering that the transfer of technology and knowledge from international experts at this stage is critical vi. Encourage policy for work permits to hire foreign talents and build local talents—need a balanced approach for local and international talents vii. Promote a talent-friendly policy to ensure foreign experts' contributions towards human capital development programmes for short- and long-term measures
4	Incentives	i. Introduce special fiscal incentives to promote investments for the IAC-REE downstream sector and accelerate the take up from local end-users ▸ Optimise the existing incentives offered by the government on GITA and GITE (green technology), industrial automation, and etc. ▸ Performance-based incentive mechanisms and time-based incentives ▸ Soft loan with a specified grace period for the IAC-REE industry ▸ Incentives for patent applicants in protecting the ideas for new product invention and manufacturing process for the super-magnets and electric motors as home-grown product and technology ▸ Adoption of local content ▸ Application of locally produced rare earth metals ii. Develop equity conditions between the local and joint venture partners iii. Import and export activities: Impose export duties for rare earth materials to ensure adequate supply for local downstream sectors iv. Incentives to intensify circular economy, such as urban mining or utilising the by-products as value-added products (currently by-products are considered as waste materials) v. Allocate and strategize the targeted funding and grant for R&D and C&I downstream activities based on TRL vi. Adopt industrial collaboration programme (ICP) as an offset programme or any government scheme for the technology transfer and procurement for the manufacturing machinery and equipment.

No	Items	Details
5	Integrity	i. Introduce a business-friendly environment for midstream operating license based on the duration of at least 10 years, instead of the annual/periodical renewal application, in order to exert positive impact on businesses in the downstream sector ii. Reclassification of chemicals used in the manufacturing activities for scheduled waste management iii. Develop industrial standards and guidelines for the manufacturing of IAC-REE based products iv. Protective clause on the percentage of rare earth resources specified for domestic use (safeguarding resources) as part of the policy and enforcement during the first five years of the national downstream industry rollout v. Establish national testing and certification to uphold the quality and reliability of the Malaysian IAC-RE based products vi. Establish regulatory framework and governance on the ESG reporting for IAC-REE downstream ecosystem to comply with the sustainability agenda vii. Uplift the IAC-REE downstream sector for the reporting under 12MP mid-term review (Chapter 3: Propelling Growth of Strategic and High-Impact Industries as well as Micro, Small, and Medium Enterprises)
6	Interaction	i. Quantify the potential contributions of the IAC-REE industry on sustainability and ESG towards achieving Malaysia's decarbonisation trajectory by 2050 ii. Empower the industries' association network or consortium for the development of the industry ecosystem and facilitate the demand and supply of the IAC-REE downstream iii. Adopt the quadruple helix model for the society involvement in every decision-making stage through targeted public engagements for full support, especially from local communities iv. Establish a strategic partnership with ASEAN and neighbouring countries to promote technology transfer and knowledge exchange for IAC-REE-based products—for examples, Malaysia and Thailand establish technology transfer partnership for the battery manufacturing industry; Malaysia and Vietnam establish a partnership for the magnet production industry. v. Collaboration with the state government and regional economic corridor authority to drive the IAC-REE downstream activities, such as super-magnet production at the targeted industrial park zone based on the cluster model

No	Items	Details
7	Infrastructure	i. Access the industry needs and gaps to optimise the existing infrastructure and encourage shared facility services ii. Establish local testing and services for downstream manufacturing activities and uplift the existing capability of related institutions, such as SIRIM and UMPSA iii. Establish linkage to the centre of interest (COI) (i.e., InvestPerak) iv. Align with the state government to develop a specific high-tech eco-industrial park for the downstream manufacturing activities with integrated infrastructures in order to showcase the advanced industry cluster zone
8	Infostructure	i. Establish CEPA under *Unit Komunikasi Korporat* (UKK) for each related ministry ii. Digital database of local and global industry supply chains and ecosystems on IAC-REE for the targeted users from the government, industry, academia, and public iii. Platform for virtual industrial networks to access information on the policies and best practices, availability of infrastructures, regulations, skills, and technology applications

Table 4.19: List of strategies and recommendations for the downstream sector (ASM Analytics, 2023)

TABLE 4.20

No.	Proposed National Targets	KPI by 2025 (Short-Term)	KPI by 2030 (Mid-Term)	KPI by 2050 (Long-Term)
1	**Manufacturing production capacity**	3,000 tonnes/year	35,000 tonnes/year	100,000 tonnes/year
2	**Participation of local company**	15%	50%	90%
3	**Job employment (direct)**	900	10,500	30,000
4	**Revenue**	RM 708.40 million	RM 8.27 billion	RM 23.63 billion
5	**Local content**	20%	70%	90%
6	**Investment**	RM 300 million	RM 3.5 billion	RM 10 billion

* The calculated revenue is based on the Shanghai Metal Market at an average price of NdFeb magnet of USD 53,770/tonne. The production capacity of 10,000 tonnes/year requires investment of RM 1 billion and contributes 3,000 jobs.

Table 4.20: Proposed KPIs for the super-magnet production

TABLE 4.21

No.	Proposed National Targets	KPI by 2025 (Short-Term)	KPI by 2030 (Mid-Term)	KPI by 2050 (Long-Term)
1	**Manufacturing production capacity**	1 million/year	5 million/year	30 million/year
2	**Participation of local company**	15%	50%	90%
3	**Job employment (direct)**	2,000	10,000	60,000
4	**Revenue**	RM 1.06 billion	RM 5.32 billion	RM 31.94 billion
5	**Local content**	20%	70%	90%
6	**Investment**	RM 600 million	RM 3 billion	RM 18 billion

* The calculated revenue is based on the average price of USD 242.16/unit for the interior permanent magnet motor made by NdFeB, according to the Study by Newcastle University and Nidec Corporation on Electric Vehicle Traction Motors Without Rare Earth Magnets[22]

Table 4.21: Proposed KPIs for the electric motor production

22 Shanghai Metal Market https://www.metal.com/price/Rare%20Earth/Rare-Earth-Oxides 2023.
Widmer, James, & Martin, Richard, & Kimiabeigi, Mohammad. (2015). Electric vehicle traction motors without rare earth magnets. Sustainable Materials and Technologies. 29.10.1016/j.susmat.2015.02.001.

4.5 Chain of Custody

Chain of custody is the process by which inputs and outputs and the associated information are transferred, monitored, and controlled as they move through each step in the relevant supply chain. One useful certification body that monitors the chain of custody involves the International Sustainability Carbon Certification (ISCC), which ensures the compliance with the established requirements. Understanding the origin of input materials, product components, product outputs, and the conditions under which they are produced has become increasingly important. Manufacturers need to demonstrate their compliance with the requirements regarding health and safety, as well as environmental, social, and quality-related aspects, while consumers and other end-users need to be able to trust these claims made for the products (ISO 22095:2020).

4.5.1 Three Models of Chain of Custody

Figure 4.29 presents the three models of chain of custody, with the identity preservation model having the highest score in consumer confidence.

(i) Chain of custody models

(a) Module A – Identity preserved
The identity preserved supply chain model assures that the rare earth-based products delivered to the end users are uniquely identifiable to a single ISCC certified separation plant (REPP). REPP must ensure that ISCC-certified REC feed materials are kept physically isolated from other ISCC-certified REE sources throughout the supply chain. The preservation model records the highest score in consumer confidence.

(b) Module B – Segregated
The segregated supply chain model assures that rare earth-based products delivered to the end-users come only from an ISCC-certified REPP. It permits the mixing of ISCC-certified REC products from a variety of ISCC certified mines.

(c) Module C – Mass balance
The mass balance system allows the mixing of ISCC-certified REC and non-certified REC at any stage in the supply chain provided that the overall site quantities are controlled. Certified REE products delivered to the end-users under the mass balance supply chain model are traceable to a list of ISCC-certified and uncertified mines.

(ii) Competitive advantage of a complete IAC-REE supply chain

Malaysia can take advantage of its unique single source, traceable IAC-REE products to claim the highly regarded identity preservation status for the country’s REE products. This can be implemented by controlling the upstream mines with strict SOP and ISCC certification and the processing through a central REPP with ISCC-certified operation. Malaysia’s identity preservation or segregated model for REE products would provide the needed competitive marketing advantage over other products from uncertified sources.

FIGURE 4.29

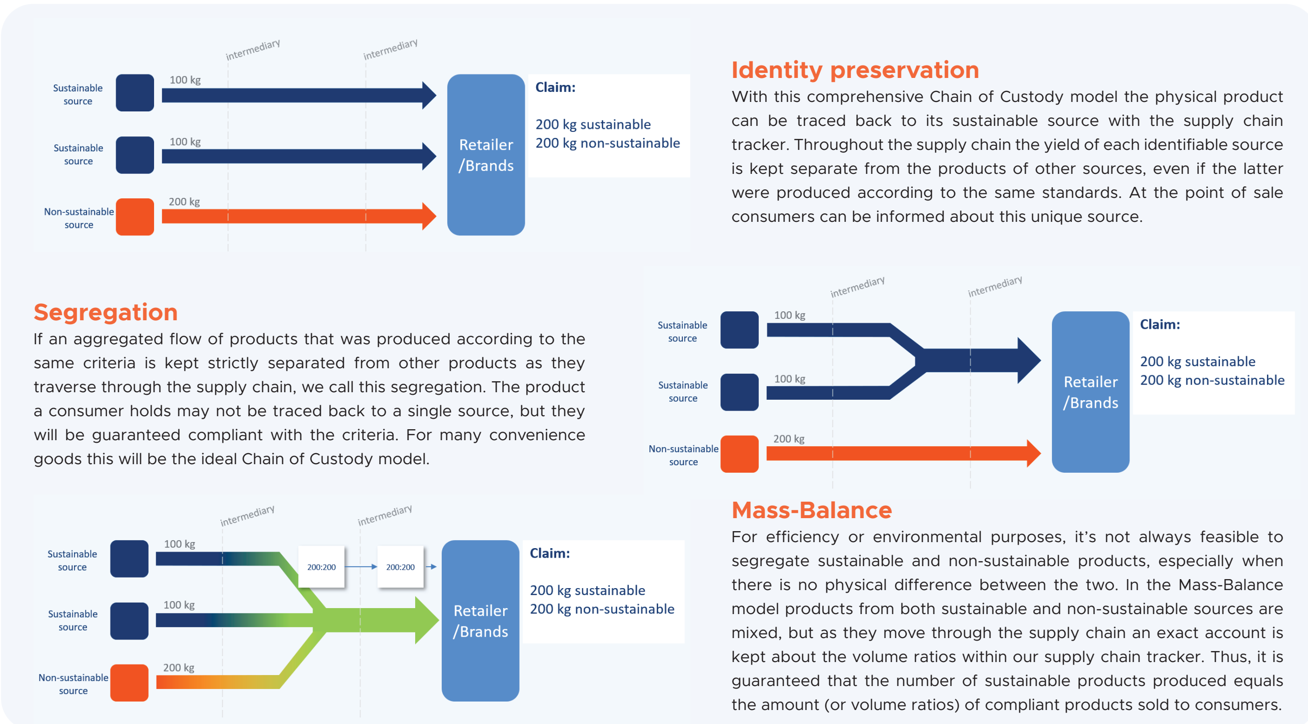


Figure 4.29: Three models of chain of custody suitable for midstream IAC-REE (Chainpoint, n.d.)

Figure 4.30 shows an idealised chain of custody for the Malaysian IAC-REE industry. Rare earth products from the Malaysian IAC-REE industry can be claimed for identity preservation by ensuring that every step of the supply chain conforms to the ISCC standard. With that, this claim would place Malaysian REE products in a high position.

(iii) Set up a radio-frequency identification (RFID) tracking system for product tracking from upstream to downstream

It is proposed that an RFID tracking system is set for:

(i) REC from the mines;
(ii) Separated REO products from the REPP;
(iii) Rare earth metal and product from the midstream; and
(iv) Magnet products from the downstream.

The RFID tracking system on the mined REC products should contain information on the origin of the products, mining tenement locations, ESG-compliant mining methods, and the estimated quantity and quality of the product batch. The information would be readable while in transit, as well as at the discharge destination at the REPP. The information would be used by the REPP to input the corresponding quantity and purity of the REO in the REC and to calculate the market value and the corresponding royalties to the states. In addition, the information can be shared online with the authorities, including the state authorities, in real time. This would eliminate potential leakages/thefts/under-declaration for royalty payments.

As for the separated REO products, the RFID tracking system would have the information regarding the chemical constituents, purity, and weight of purified REO products. Besides that, information of the source of raw materials can be incorporated into the RFID tracking system. Such arrangement complies with the chain of custody models.

Similar RFID coding is proposed to be incorporated in the downstream products for the completion of product tracing.

FIGURE 4.30

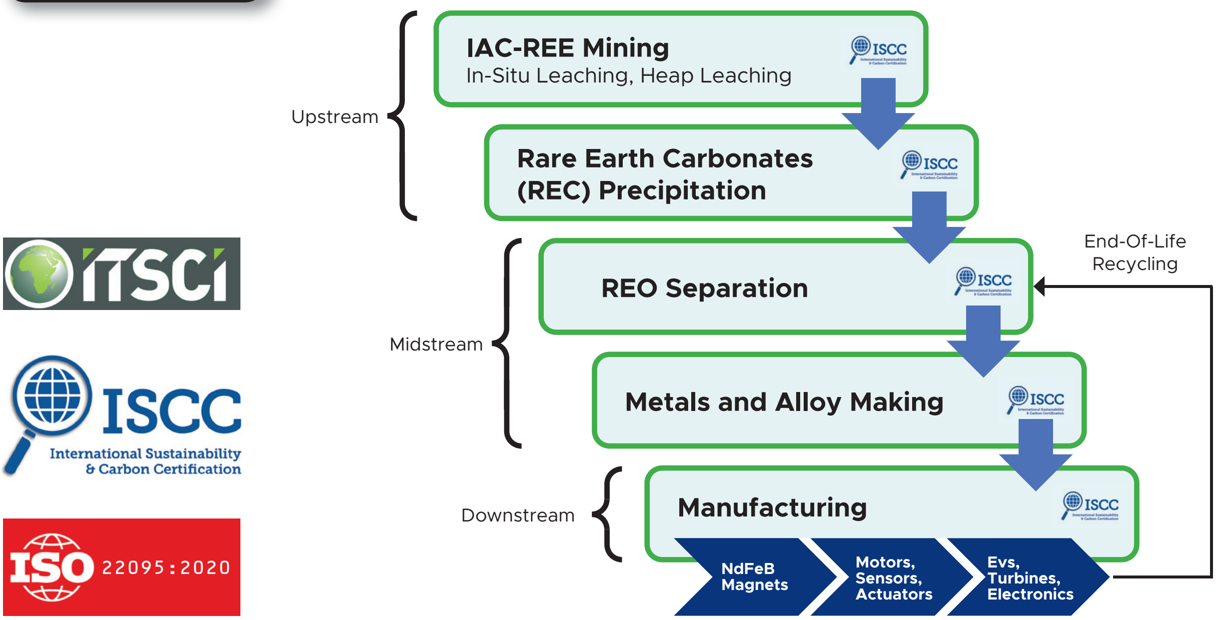


Figure 4.30: Optimised chain of custody for the Malaysian IAC-REE industry

4.5.2 Chain of Custody over Resource–Upstream Sector

The chain of custody for the upstream sector is depicted in Figure 4.31.

i. Ownership

Minerals in the ground belong to the state, as provided for in the federal constitution. The state government holds the authority to issue the rights to mine by way of an ML or proprietary mining lease (PML) under the provisions of the State Mineral Enactment (SME). The ML holder undertakes the mining in accordance with the SME, Act 525, and other relevant laws and regulations. The leaseholder takes custody of the minerals that are extracted from the ground (mined) and processed them into mineral ores, concentrates, and products. Upon the sales of the products, the leaseholder has to pay royalty on minerals to the state before passing the custody of the mineral products to the buyer.

Basically, all matters pertaining to the SME would be under the responsibility of the state government, the authority being the State Director of Lands and Mines. These include the issuance of the mineral tenements and the collection of royalties and any such payments due to the state government. All matters pertaining to the MDA would be under the purview of JMG, the authority being the Director General of Mines at the federal level and the Director of Mines at the state level. These include matters pertaining to the safety and, to some extent, the environment. With reference to the export of REC, it comes under the ambit of NRES, as an export permit is required. Matters pertaining to the environment are under the purview of the Department of Environment, which acts under the authority provided in Act 127.

ii. Material traceability

In the current legal framework for mineral resource development in Malaysia, there are laws and regulations that adequately address the issues of material traceability in the upstream sector of the IAC-REE industry. Nevertheless, in view of the recent developments in the global mineral supply chain, especially in regards to ESG compliance, conflict minerals, and climate change agenda, consumers may require product traceability certification from independent internationally accredited bodies when they source their supplies.

As far IAC-REE resources are concerned, there are several options for the local producers of REC. Firstly, the International Tin Supply Chain Initiative (ITSCI) approach (ITSCI, 2023) be considered for adoption. This programme for responsible mineral supply chains has been successfully implemented in the Democratic Republic of Congo for tins and associated minerals. Under the development and management of the International Tin Association, ITSCI has been recognised to be in compliance with the Organisation for Economic Cooperation and Development (OECD) Due Diligence Guidance and accepted into the list of Responsible Mining Initiative (RMI). Another useful certification body includes the ISCC for the certification of products. Material traceability can be achieved by controlling the upstream mines with strict SOPs and applying one of the three models recommended for ISCC certification. Accordingly, ISCC is an international certification system that covers all kinds of bio-based feedstocks and renewables catering to energy, food, feed, and chemical sectors.

FIGURE 4.31

	Minerals in the ground **(IAC-REE deposit)**		Mineral ores, concentrates, Products **(REC)**		Mineral ores, concentrates, Products **(REC)**
Primary Legislation	• Federal constitution • SME & regulations • MDA & regulations • All other relevant laws and regulations	• SME & regulations • MDA & regulations • All other relevant laws and regulations – such as EQA & regulations	• SME & regulations • MDA & regulations • All other relevant laws and regulations	• SME & regulations • MDA & regulations • All other relevant laws and regulations – such as Custom Act 1967	• MDA & regulations • All other relevant laws and regulations – such as Custom Act 1967
Ownership	State Government (State Land/Forest Reserve Area) Land Proprietor (Alienated Land)	ML Holder PML Holder Appointed Operator	ML Holder PML Holder Appointed Operator		Buyer
Payments/Revenue	Licence fees	License fees, premiums, land rents, tributes	Tributes	Royalty to State, sales tax, other taxes	
Material Traceability	Location audit by independent accredited party (e.g., ITSCI, ISCC,etc)	Process audit by independent accredited party (e.g., ITSCI, ISCC,etc)	Material audit and tagging by independent accredited party (e.g., ITSCI, ISCC,etc)	Certification & declaration of compliance by independent accredited party as per customer requirement	

Figure 4.31: Chain of custody over resource–upstream sector of the IAC-REE industry

4.5.3 **Chain of Custody for the Midstream and Downstream Sectors**

According to ISO 22095:2020, the purpose of the chain of custody is to provide guidelines on the transparency of the materials and originality of the products. The chain of custody describes the process by which inputs, outputs, and associated information are transferred, monitored, and controlled as they move through each step in the relevant supply chain. It is essential to ensure the proper functioning of the downstream manufacturing, as all materials and products are not to be tampered with and should not be moved illegally or without the necessary permission. There are a few models on the development of the chain of custody, such as the identity-preserved model, segregated model, controlled blending model, mass balance model, and book and claim model. The chain of custody for the downstream sector is developed and proposed based on the mass balance model in order to describe the input and output material flow at the manufacturing level, as illustrated in the Figure 4.32. Manufacturers need to document the details of each item supplied to the factory. The input supply chain consists of rare earth as the raw materials that can be supplied from the local REPP. Processing materials, such as fuels, industrial gases, and utilities, including consumable materials, are also supplied to the manufacturing as it comprises key processes like raw material preparation, melting, milling, pressing, machining, coating, magnetisation, and packaging.

FIGURE 4.32

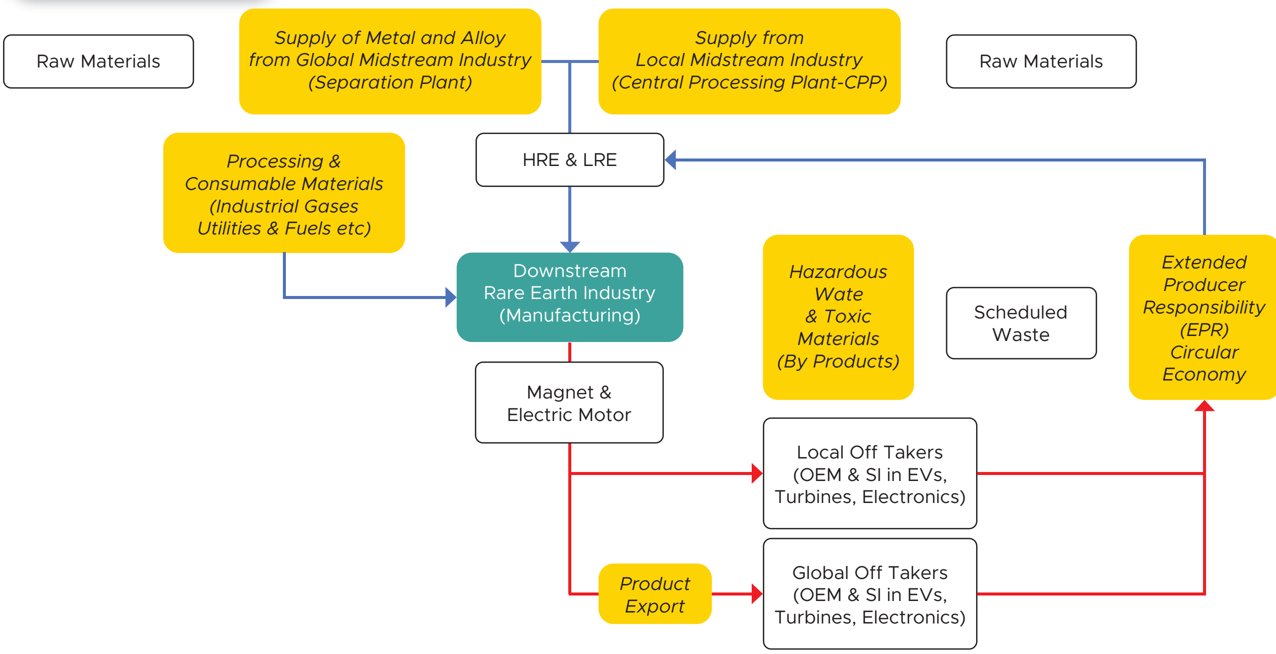


Figure 4.32: Chain of custody for midstream and downstream sectors based on the mass balance module (MIGHT, 2023)

The main raw materials required to produce super-magnets consist of Nd, Fe, and B. With the production capacity of 10,000 tonnes per year, an estimated supply of 35% NdPr from 10,000 tonnes, which is equivalent to 3,500 tonnes NdPr, is expected. The remaining volume supply of iron and boron would require around 6,500 tonnes, depending on the formula and specifications of super-magnet production, which are typically classified information. As for high-performance super-magnets, additional supplies of HREE, such as Dy and Tb, are needed to improve the magnet's resistance to demagnetisation at high temperature. The REO, either in the form of HREE or LREE, supplied to the manufacturing firm can be traced using RFID or blockchain technology.

RFID product tracking involves the use of the RFID tag attached to the products with certain information. The RFID tag transmits the pulsating radio waves, and the RFID reader toll captures the information. The product outputs, such as super-magnets, motors, sensors, or actuators supplied to the OEM and SI from the global market or local market, need to be tracked in, which provide the needed information on the source of the products being manufactured. The tracking of the products by OEM and SI until the end-of-life stage can enable the circular economy initiative. Several global industry players, such as REEcycle, Heraues Remloy, and Vamalog, are all involved in the recycling activities through the use of their patented recycling process. The chain of custody concept can enhance the tracking activities from the input level to the output level and optimise the resources.

Blockchain is an emerging technology that can be used for tracking activity. It provides visibility and transparency on the movement of raw materials and products in manufacturing, warehousing, transporting, and trading activities within the supply chain based on individual serial numbers. Nestle adopts the same approach using blockchain application for the tracking exercise within the supply chain.

4.6 Environment, Social, and Governance Sector

4.6.1 **Introduction**

i. Background

In September 2015, the United Nations (UN) adopted "Transforming Our World: The 2030 Agenda for Sustainable Development", which includes a set of SDGs for 2015–2030. SDGs represent the world's comprehensive plan of action for social inclusion, environmental sustainability, and economic development.

There is a growing demand among the quadruple helix partners, which include the government, consumers and investors, the community, and society, on the role of businesses to move beyond the pursuit of profits alone and to be aligned with the sustainability agenda. Responsible and ethical businesses need to fulfil their sustainability journey not only through their adherence to the regulatory requirements but also be seen to act accordingly through other non-regulatory initiatives, including CSR efforts.

Meanwhile, ESG refers to environmental social and governance and relates three key factors when it comes to measuring the sustainability and ethical impacts of a business. The term "ESG" was first coined in 2005 in a landmark study, entitled "Who Cares Wins", which included guidelines on the integration of ESG factors into businesses. ESG became the first sustainability scoring concept, which has been adopted by large index providers and promulgated by the UN Principles for Responsible Investing (PRI). More investors have started to use ESG to evaluate the behaviours of businesses to determine their future financial performance. ESG factors are a subset of non-financial performance indicators, which include ethical, sustainable, and corporate governance issues, such as ensuring that the systems are in place for accountability and managing the firms' sustainability performance.

The increasing demand for transparency and accountability on the firms' social and environmental impacts drives the need for ESG disclosures in the minerals supply chain. ESG disclosures also address the effectiveness of CSR efforts in achieving SDGs, as shown by the linkages in Figure 4.33. The common global consensus on ESG disclosures is based on the global reporting initiative (GRI). These disclosures should follow internationally recognised ESG standards that consider all materiality topics for both internal and external stakeholders. A government plays an important role in enhancing sustainability and transparency—for examples, through the requirements of sustainability reporting (or ESG disclosures), collaborative initiatives, voluntary sustainability initiatives in policies, enhanced use of EIA to pinpoint key areas in the reporting, and the linkages between EIAs and ESG disclosures.

FIGURE 4.33

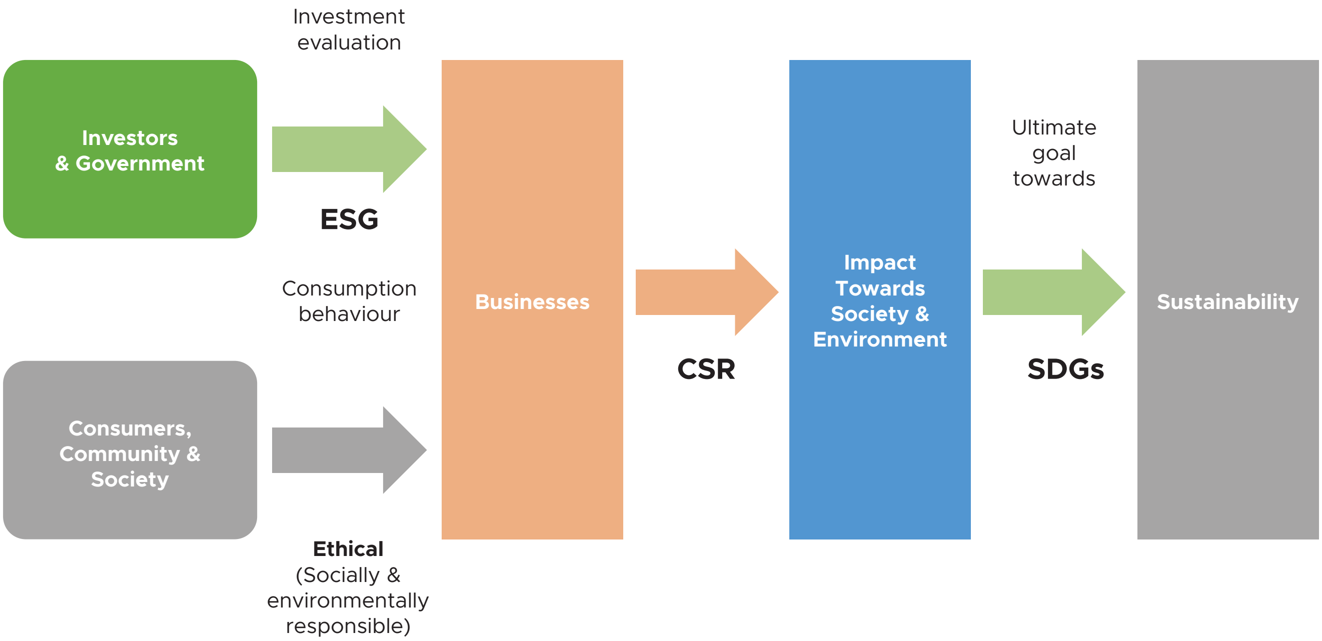


Figure 4.33: Relationships of SDGs, CSR, and ESG (Raja Ehsan Shah, 2023)

The extraction and processing of minerals exert both positive and negative effects across the SDGs. The industry can foster economic development by providing opportunities for employment, business development, increased fiscal revenues, and infrastructure linkages. Metals and minerals are at the core of economic and technological developments. Many of the minerals, including REE, are also essential building blocks to technologies, infrastructures, energy, and agriculture. Accordingly, REE value chain can be discussed in three sequential sectors. When it comes to the upstream sector, REE can be extracted from monazite, bastnasite, or eudialyte, where physical ore goes through a beneficiation process. Alternatively, REE can also be extracted from IAC through ISL and precipitation processes. Subsequently, as for the midstream sector, REE are extracted and purified before REO and metals can be produced. As for the downstream sector, rare earth metals and alloys make up critical parts in the clean energy transition to meet the urgent climate challenge through the production of batteries for cars, solar panels, super-magnets, cellular phones, and wind turbines. The demand for REE has increased significantly to cater to the technological shift towards decarbonisation, which is driven by the shifts towards the electrification of industrial processes.

Historically, however, the extraction and processing of minerals have contributed to many challenges that SDGs intend to address—environmental degradation, displacement of populations, worsening economic and social inequality, armed conflicts, gender-based violence, tax evasion and corruption, increased health risks, and the violation of human rights. In these recent decades, the industry has made significant advances in mitigating and managing these impacts and risks by improving how businesses manage their environmental and social impacts, protect the health of the workforce, achieve energy efficiency, report on financial flows, and respect and support human rights. Further consideration of these impacts and risks is required to address the inevitable increase in the entire REE value chain in order to meet the growing demands for REE.

Hence, ESG provides a comprehensive framework that enables firms within the entire extraction and processing of minerals supply chain to make the right choices for the balance of benefits to the environment, economy, and the people. New standards and frameworks on mineral-related investments should be measured, even at the global level. This can address the challenges faced by the entire minerals supply chain in determining the appropriate priorities and how reporting should be done. Businesses that are involved in the extraction and processing of minerals must deliberate the risks associated with ESGs, such that their needs to attract investments, obtain licensing rights, and good working relationships with the civil society can be successfully achieved. This study report also covers the status of ESG disclosures with a specific focus on how related stakeholders can further support the efforts of the industry in advancing its sustainability practices and disclosures.

4.6.2 Current Status on ESG Disclosures

Generally, ESG consists of three main components: principles and targets, disclosure and reporting, and ratings. Some of the key catalysts that drive ESG disclosure include international and national regulations and investors' growing demands for sustainability information. The increasing pressure from communities and NGOs for transparency are among the key drivers of ESG for the mainstream. Furthermore, the global stock exchanges have made it compulsory for Public Listed Companies (PLCs) to provide ESG disclosures (or sometimes known as Sustainability Report), either as independent documents or as part of their annual financial reporting.

4.6.3 Way Forward

i. Materiality model

The overall business model approach would enhance the contributions of the rare earth industry to the country's socioeconomic development, backed by the projected increase in ROV without compromising the sustainability requirements. The materiality model was developed to support the business model developed for the upstream, midstream, and downstream sectors of the rare earth industry through the efficient, responsible, and sustainable development of the rare earth resources and their value-added products by recommending the appropriate minimum approach for inclusion in ESG disclosures involving this industry.

ii. Development of materiality model

Materiality, in the context of ESG, refers to the effectiveness and financial significance of a specific measure as part of a firm's overall ESG analysis. Material factors are financial elements that are deemed fundamental to the long-term success of a firm's ESG strategy. ESG materiality analysis serves as the basis to map out the IAC-REE business value chain in Malaysia, concerning the associated risks and opportunities in each component within the supply chain. The materiality model (Figure 4.34 and Figure 4.35) was intended to provide an overview of the relationships of key components considered in a materiality analysis in relation to the sectors within the IAC-REE industry.

FIGURE 4.34

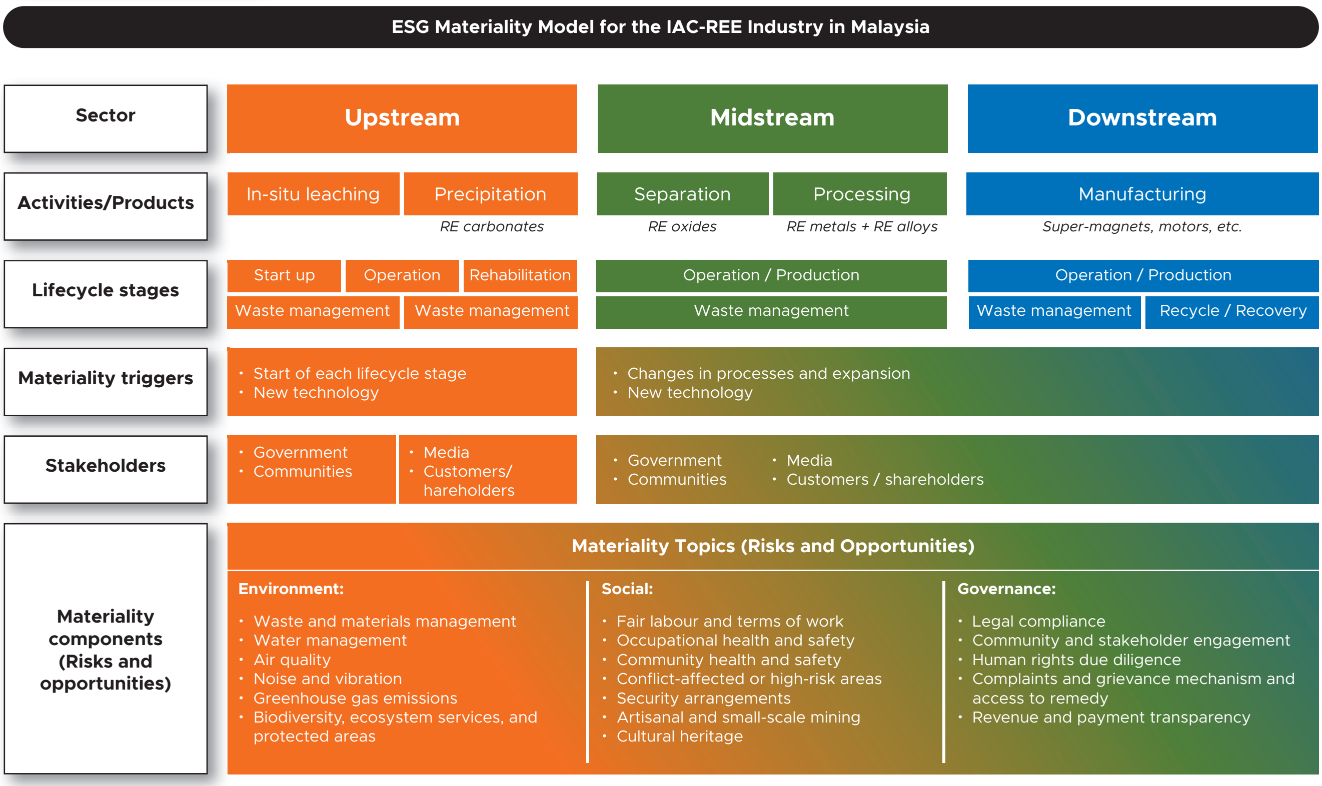


Figure 4.34: ESG materiality model

iii. ESG materiality topics for IAC-REE resources

❶ Environmental Topics	i.	**Waste and materials management**	Refers to the management of risks associated with wastes generated, including hazardous and non-hazardous wastes from the upstream, midstream, and downstream sectors.
	ii.	**Water management**	Refers to the impacts associated with water management, which may include higher costs, liabilities, and lost revenues due to curtailment or suspension of operations; the severity of these risks varies according to the region's water availability and the regulatory environment.
	iii.	**Air quality**	Refers to GHG emissions from the industry, which include hazardous air pollutants, criteria air pollutants, and volatile organic compounds (VOCs) from activities within the upstream, midstream, and downstream sectors.
	iv.	**Noise and vibration**	Refers to the risks associated with the workforce, communities, and ecosystems affected by noise and vibration generated by the activities within the upstream, midstream, and downstream sectors.
	v.	**Greenhouse gas emissions**	Refers to the generation of direct and indirect GHG emissions, including carbon dioxide from fuel use and other activities throughout the IAC-REE ecosystem.
	vi.	**Biodiversity, ecosystem services, and protected areas**	Refers to the range of impacts on biodiversity, such as alterations of landscape, vegetation removal, and impacts to wildlife habitats, from the activities within the upstream, midstream, and downstream sectors, as well as the regulatory or reputational barriers to accessing reserves in ecologically sensitive areas.
❷ Social Topics	i.	**Fair labour and terms of work**	Refers to the inherent tension between the needs to lower the labour cost to remain price competitive and to manage human resources to ensure long-term performance; working conditions in industrial operations may be physically demanding and hazardous.
	ii.	**Occupational health and safety**	Refers to a firm's abilities to protect the health and safety of its employees and to create the culture of safety and well-being among employees at all levels in order to help prevent accidents, mitigate costs and operational downtime, and enhance workforce productivity.

iii.	**Community health and safety**	Refers to activities that are perceived as engaging in community's resources motivated by feelings of unjust distribution of benefits to the communities or loss of value due to destruction of nature.
iv.	**Conflict-affected and high-risk areas**	Refers to the presence of armed conflicts, widespread violence, or other risks of harm to people. Armed conflicts may take a variety of forms, such as the conflict of international or non-international characters, which may involve two or more states or may consist of wars of liberation, or insurgencies, civil wars, and etc. High-risk areas may include areas of political instability or repression, institutional weakness, insecurity, collapse of civil infrastructures, and widespread violence. Such areas are often characterised by widespread human rights abuses and violations of national or international laws.
v.	**Security arrangements**	Refers to community-related risks when operating in conflict zones and in areas with weak or absent governance institutions, rules of law, and legislations to protect human rights, as well as risks when operating in areas with vulnerable communities, such as indigenous people.
vi.	**Artisanal and small-scale mining**	Refers to the uncertainty of activities from sectors that are informal and outside of the legal frameworks with unknown numbers of participants in the sector. Artisanal and small-scale mining has long been recognised as an important phenomenon with complex social, economic, environmental, and governance dimensions, which need to be addressed in an inclusive manner.
vii.	**Cultural heritage**	Relates to the impacts of activities within the ecosystem that affect artefacts, monuments, a group of buildings and sites, and museums, which have a diversity of values, including symbolic, historic, artistic, aesthetic, ethnological, or anthropological, scientific, and/or social significance.

3 Governance Topics	i.	**Legal compliance**	Relates to a firm's adherence to business code of ethics and compliance with the international laws and regulations, as well as local laws and regulations of operating bases.
	ii.	**Community and stakeholder engagement**	Refers to the adoption of various community engagement strategies in the global operations of managing risks and opportunities associated with the community rights and interests. Strategies are often underpinned by the integration of community engagement into different phases of the project cycle.
	iii.	**Human rights due diligence**	Refers to activities perceived as contributing to the violations of human rights or failing to account for human rights that may be affected following the protests, riots, or suspension of permits. Substantial costs related to compensation or settlement payments, and write-downs in the value of reserves in such areas would be incurred. There are also risks when operating in areas with vulnerable communities, such as indigenous people.
	iv.	**Complaints and grievance mechanisms and access to remedy**	Refers to grievance mechanisms and other processes to provide remedy in such situations. This is not new to firms; the existing systems are typically for people within the firm, primarily employees, while the responsibility to respect human rights applies to all stakeholders who are negatively affected by the firm's activities or business relationships.
	v.	**Revenue and payments transparency**	Refers to business ethics and maintaining an appropriate level of transparency in payment to governments or individuals. The emergence of several anti-corruption, anti-bribery, and payment transparency laws and initiatives creates regulatory mechanisms to reduce these risks.
	vi.	**Chain of custody**	Chain of custody and traceability are key concepts of ensuring responsible sourcing practices and to be embodied within the ESG practices in the entire IAC-REE ecosystem. The chain of custody refers to the documentation and tracking of a product from its origin to the final destination, while traceability involves the ability to trace a product back to its source through the supply chain.

FIGURE 4.35

ESG Materiality Component Mapping for IAC-REE Industry in Malaysia

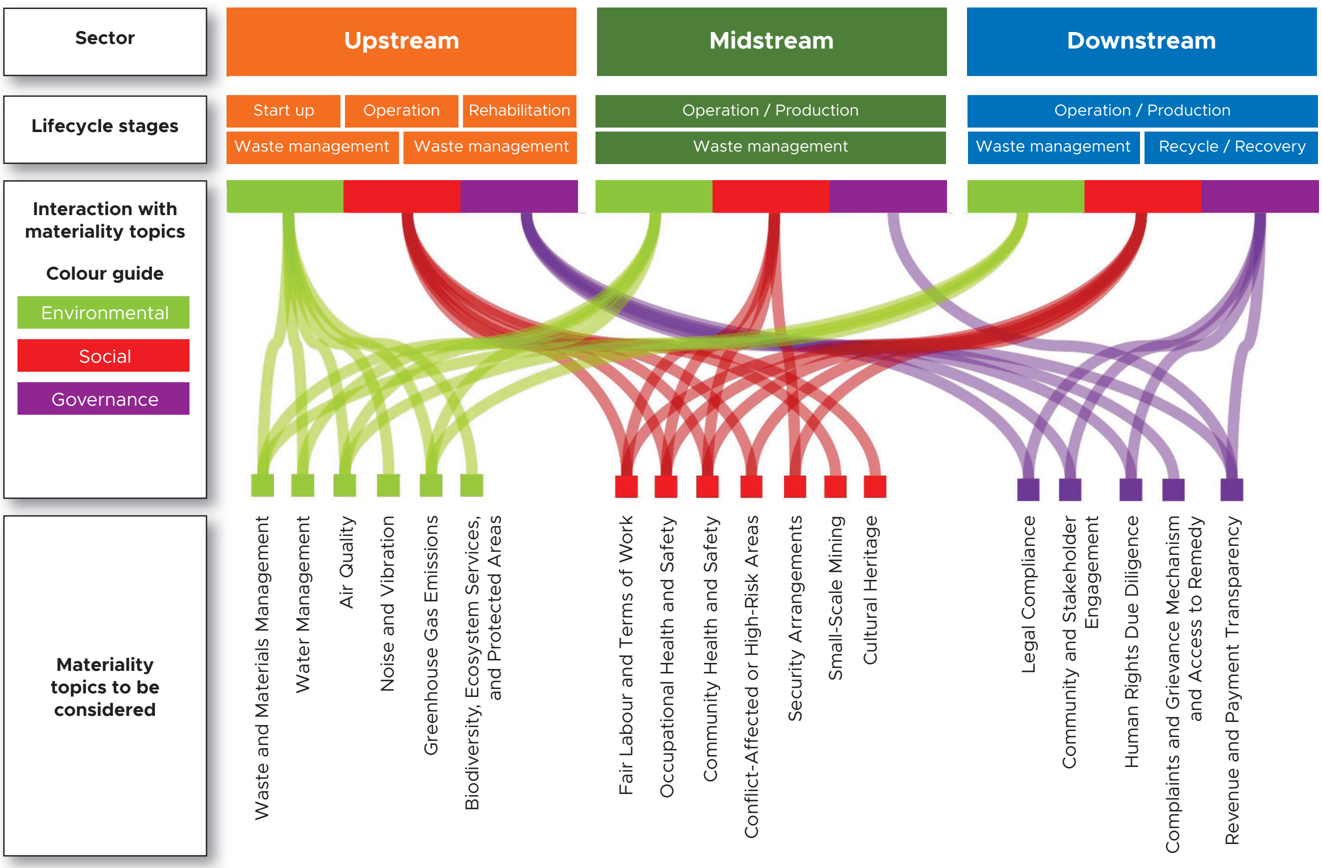


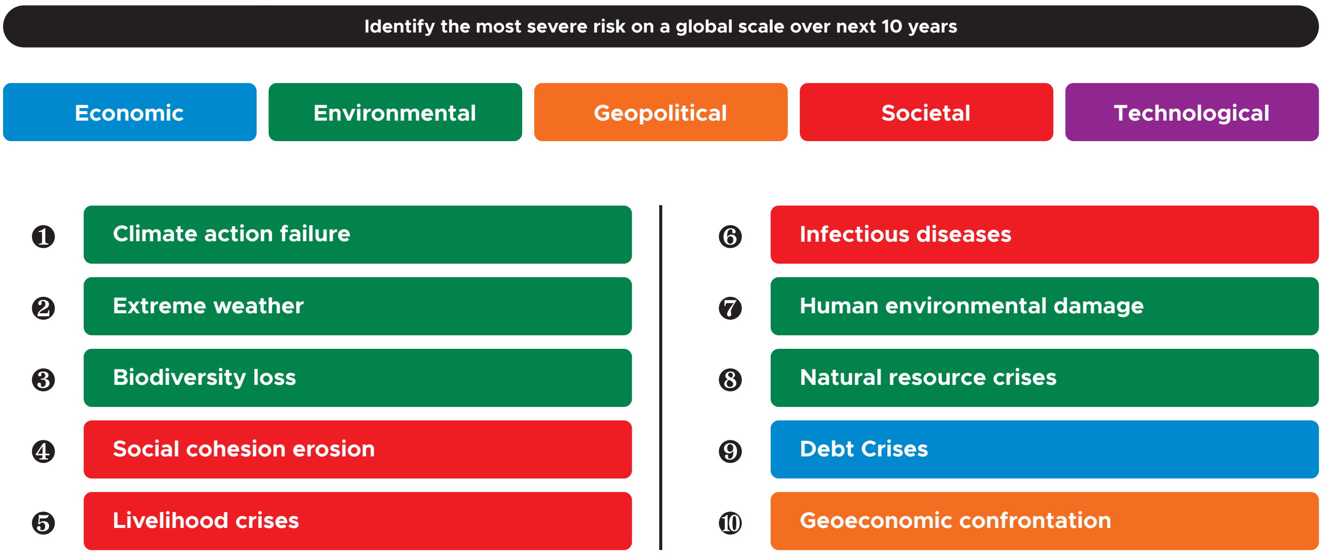
Figure 4.35: ESG materiality component mapping of the IAC-REE industry in Malaysia

4.6.4 **Scenario Planning for ESG Practices in the IAC-REE Industry**

ESG commitments are not made easy, even for firms with financial room to manoeuvre. The delivery of ESG disclosures can be difficult due to the technological changes and inconsistent policy signals, while conflicting rhetoric, regulations, and incentives may generate discontent among businesses. In order to address these challenges, the use of scenario planning is suggested to identify and put systems in place to manage risks that can potentially disrupt businesses and ensure resilience. One generally insightful method for identifying risks as perceived by various stakeholders is through a survey, as reported by the World Economic Forum.

The Global Risks Report 2022 presented the results of the latest Global Risk Perception Survey (GRPS) based on the samples of 124 countries (Figure 4.36). The World Economic Forum defines global risk perception as "the possibility of the occurrence of an event or condition that, if it occurs, could cause significant negative impact on several countries or industries". It may cover risks related to economy, environment, geopolitical, society, and technology. The scope, as reported by the annual Global Risks Report, covered a period of 10 years: short-term (1–2 years), mid-term (2–5 years), and long-term (> 5 years).

FIGURE 4.36



Source: World Economic Forum Global Risk Perception Servey 2021-2022

Figure 4.36: The most severe risks on a global scale over the next 10 years (World Economic Forum, 2022)

The results showed that, for the short-term (two years), societal risks – in the forms of "social cohesion erosion", "livelihood crises", and "mental health deterioration" – have deteriorated the most since the pandemic began. As for the mid-term (five years), the respondents perceived societal and environmental risks as the top-most concern. However, over a 10-year horizon, planetary health remained dominant, where environmental risks were perceived to be the most damaging for people and the planet. In particular, "climate action failure", "extreme weather", and "biodiversity loss" were ranked as the three most severe risks. In addition, the respondents suggested that "debt crises" and "geoeconomic confrontations" as among the most severe risks over the next decade.

The Global Risk Report (World Economic Forum, 2022) highlighted the following concerns, as reported by Malaysian respondents:

(i) Human-made environmental damage
(ii) Employment and livelihood crises
(iii) Prolonged economic stagnation
(iv) Geopoliticalisation of strategic resources
(v) Debt crises in large economies

As for the current study on the development of IAC-REE in Malaysia, it is proposed that the ESG-related concerns (Figure 4.37) would be based on the following concerns:

(i) Geopoliticalisation of strategic resources
(ii) Human-made environmental damage
(iii) Climate action failure

i. Geopoliticalisation of strategic resources

The IAC-REE industry is subject to a number of challenges in terms of achieving sustainable and environmentally-friendly practices. Geopolitical tensions and rising competition over climate-friendly raw materials, particularly between China and USA, can undermine international cooperation on green transition progress. In addition, it can be expected that various stakeholders within the IAC-REE industry may prioritise nationally important industries and shift to national security concerns in the face of increased global tensions.

According to the Global Risks Report 2022, government finances in many countries, including USA and Europe, have been under pressure, which can lead to insufficient incentives for households and businesses to invest in net zero technologies and a few penalties for failing to do so. This can result in the slow uptake of new technologies, such as low-carbon energy generation and carbon capture and storage, continuous household overconsumption of carbon-intensive products and services, and failure to grasp the seriousness of climate threats.

In addition, new innovations that require high amounts of energy during production and use, such as crypto-mining or crypto-trading, often rely on fossil fuel energy sources, which can offset efforts to reduce ecological footprints. These challenges can slow down the transition to sustainable and environmentally-friendly practices within the IAC-REE industry. As the largest producer and exporter of REE, China may also contribute significant impact on the industry’s ability to transition towards sustainable practices due to its domestic policies and regulatory frameworks.

FIGURE 4.37

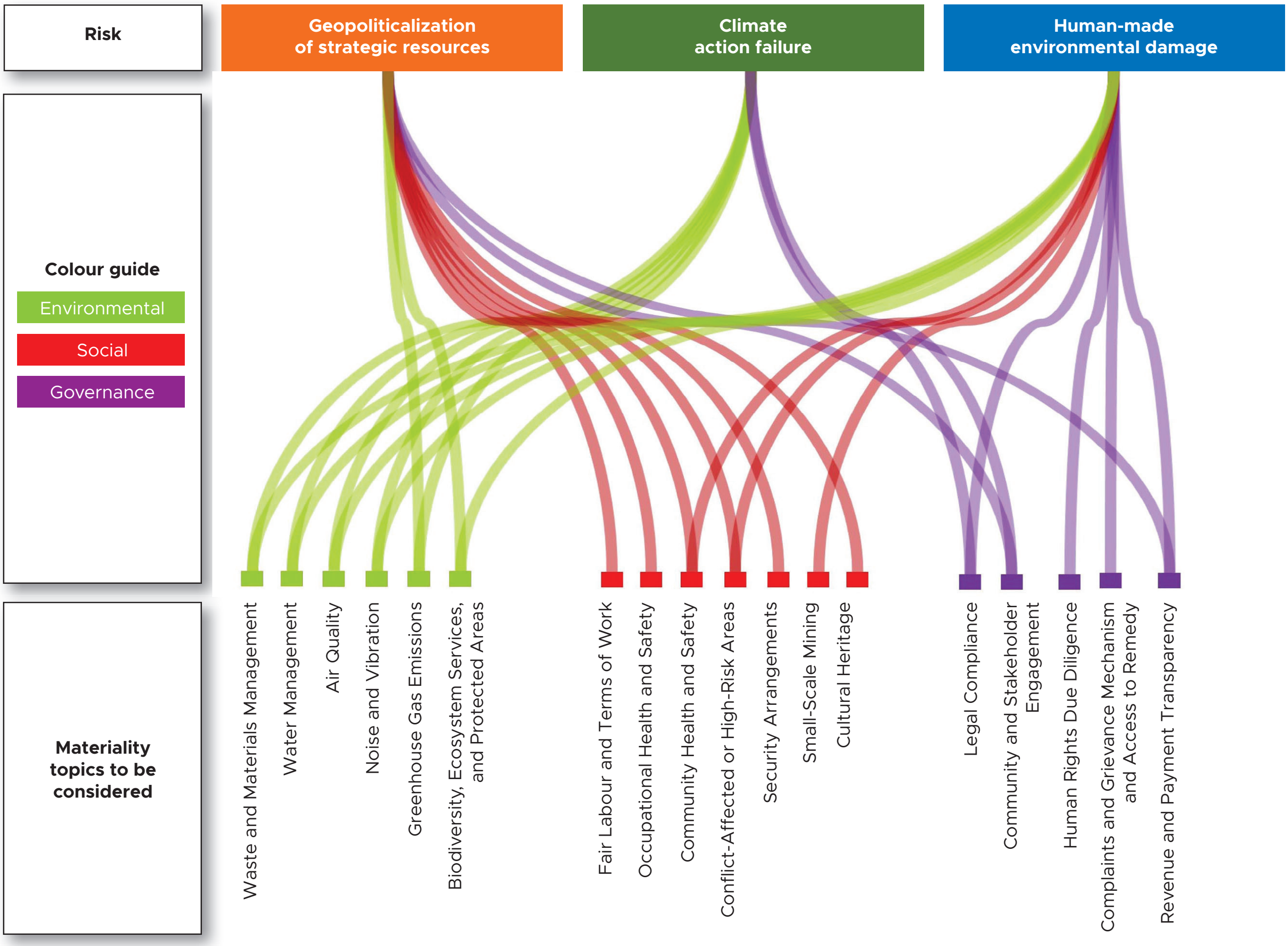


Figure 4.37: The mapping of recommended ESG materiality topics against selected global risks

This situation creates an opportunity for ASEAN countries to venture aggressively into the IAC-REE industry. In this respect, Malaysia, in particular, should incentivise the development of the entire IAC-REE ecosystem through the ESG adoption within the eco-system to move up the global innovation value chain. Poor regulation of new green markets may create unwanted monopoly in geopolitically contested industries, such as REE extraction. Furthermore, the ESG materiality assessment incorporates traceability of rare earth minerals and their derivatives with respect to the concept of chain of custody.

ii. Human-made environmental damage

The IAC-REE industry plays a crucial role in promoting sustainable development through the use of REE in various low-carbon technologies, such as wind turbines, EVs, and efficient lighting. However, the speed and degree of transition in the production of REE can result in significant impacts on natural ecosystems and contribute to human-made environmental damage.

The extraction and processing of REE have negative environmental and social impacts, particularly in emerging economies, where REE mines are often located. The rush to extract REE for decarbonisation efforts can result in additional negative impacts on the ecosystems and indigenous societies, including habitat destruction, biodiversity loss, water pollution, and soil contamination. In view of the potential environmental impacts, emphasis should be given to the prevention and mitigation measures in environmental management plans.

Poorly sited REE mines or processing plants can affect ecosystems and wildlife at a large scale and present societal risks, such as forced relocation of local residents. The continued degradation of nature would add stress on the local residents, public health, businesses, and ultimately, the stability of the society. The IAC-REE industry needs to be aware of these consequences and take the necessary steps to mitigate these impacts.

It is important to note that scientific analysis in many parts of the world points to environmental adjustments and feedback loops that would push ecosystems beyond the tipping points. However, at that point, decarbonisation efforts would be rendered useless. Therefore, it is crucial for Malaysia to develop and implement frameworks through the adoption of ESG to balance the need for REE, promoting sustainable development.

iii. Climate action failure

The use of REE in various low-carbon technologies, such as wind turbines, EVs, and efficient lighting, is critical. However, the industry also faces significant transition risks as the world shifts towards a low-carbon economy following the rapid shifts in policies and regulations, as well as the changes in consumer behaviour and investors' preferences. It is a positive point to note that, in the midst of this shift, the rise of stakeholder capitalism, shareholder activism, and increased awareness by firms to employ ESG targets and metrics, coupled with ESG-based investments, have reshaped the financial and economic landscapes.

4.6.5 Implications and Pathways

The development and implementation of an industry-specific framework in regard to ESG are of paramount importance in addressing various risks associated with the IAC-REE industry. The identified key areas of concern include geopoliticalisation of strategic resources, human-made environmental damage, and climate action failure. It is deemed imperative that an analysis is conducted to identify potential strategies that can address these concerns and promote the adoption of ESG practices within the industry.

In order to effectively address these risks, a comprehensive and scientifically sound framework is necessary. A risk-based approach is recommended for the specific case of the development of the IAC-REE industry in Malaysia. This approach should consider the potentials of unexpected paths and blind spots, triggers, and shocks that may result in a wide range of outcomes, with varying likelihoods and impacts.

Minimum materiality components should be identified and selected for organisational ESG disclosures within the IAC-REE ecosystem. These materiality components should be chosen based on their ability to effectively address all three identified main risks and enhance traceability throughout the entire IAC-REE ecosystem.

In addition, it is important to consider the behaviours and actions of specific stakeholders and the potential consequences of a range of risk outcomes, from probable to improbable and from manageable to severe. This would ensure that the ESG framework in the IAC-REE industry is comprehensive and scientifically sound to effectively address various risks and challenges associated with the industry.

4.7 An Integrated IAC-REE Sustainable Business Value Chain Model

4.7.1 Introduction

The following subsections outline an integrated IAC-REE business value chain, which is aligned with global best practices related to planetary health and ESG considerations. The proposed framework provides a comprehensive assessment of the IAC-REE business value chain. The framework also explains how well these three sectors are seamlessly integrated to create network externalities and multiplier effects, creating better economies of scale, economies of scope, and ROV from rare earth resources. The later subsections will discuss the key strengths and weaknesses of the local IAC-REE business value chain and propose strategies to enable it to move up the global innovation and economic value chain.

4.7.2 Characterising the IAC-REE Business Value Chain

The IAC-REE business value chain consists of interactions between the three sectors within the domestic economy, as well as with relevant sectors in foreign markets. Additionally, the model includes the global market for the downstream sector (products and services) and markets for the repurposing and recycling of products from the industry. The inclusion of the latter market highlights the importance of incorporating a circular economic model aligned with the 8R values-based development philosophy, as outlined in Chapter 2.

A key feature of the proposed model lies in the formation of strategic partnerships between players in local and foreign markets. These partnerships support the creation of network externalities that enable local firms leverage foreign markets for improved access to the supply of raw materials, expertise, technology, financing, and markets. This, in turn, has important spillover impact on local players through the richness in their products and services rendered to the domestic and global markets. The strategic partnerships between the domestic and foreign sectors can be in the form of JVs, G2G agreements for knowledge and technology transfer, B2B commercial arrangements on mining, processing, and product development, R&D collaborations, the transfer of materials, technologies, and knowledge, and other partnerships. These arrangements have the potential to increase FDI in the domestic IAC-REE industry.

It is postulated that the holistic development of the entire IAC-REE value chain contributes significantly to the Malaysian economy. This entails the development of strong upstream and midstream sectors, which would provide a strong foundation for the development of the downstream sector. A strong upstream sector entails the adoption of state-of-the-art, responsible mining methods towards ensuring an adequate supply of REE resources for the domestic midstream and downstream sectors. Increasing investments in developing the 8R-8i ecosystem enablers in the rare earth ecosystem of all three sectors and the recycling/repurposing market can lead to strong dynamic capabilities in all these sectors. This will have a “knock-on” impact on the ROV of the sectors, enhancing the global competitiveness of the domestic IAC-REE industry and its contributions to the Malaysian economy. The framework also shows that the value chain will derive ROV from all three sectors, including the recycling/repurposing sector. It is postulated that the ROV from a strongly integrated sector would be higher than the sum of the ROVs of the individual sectors.

4.7.3 Assessment of the Enabling Environment 8R–8i Values-Based IAC-REE Business Value Chain

The integrated IAC-REE business value chain shown in Figure 4.38 presents the state of the business models for the upstream, midstream, and downstream sectors.

FIGURE 4.38

Integrated IAC-REE Business Model

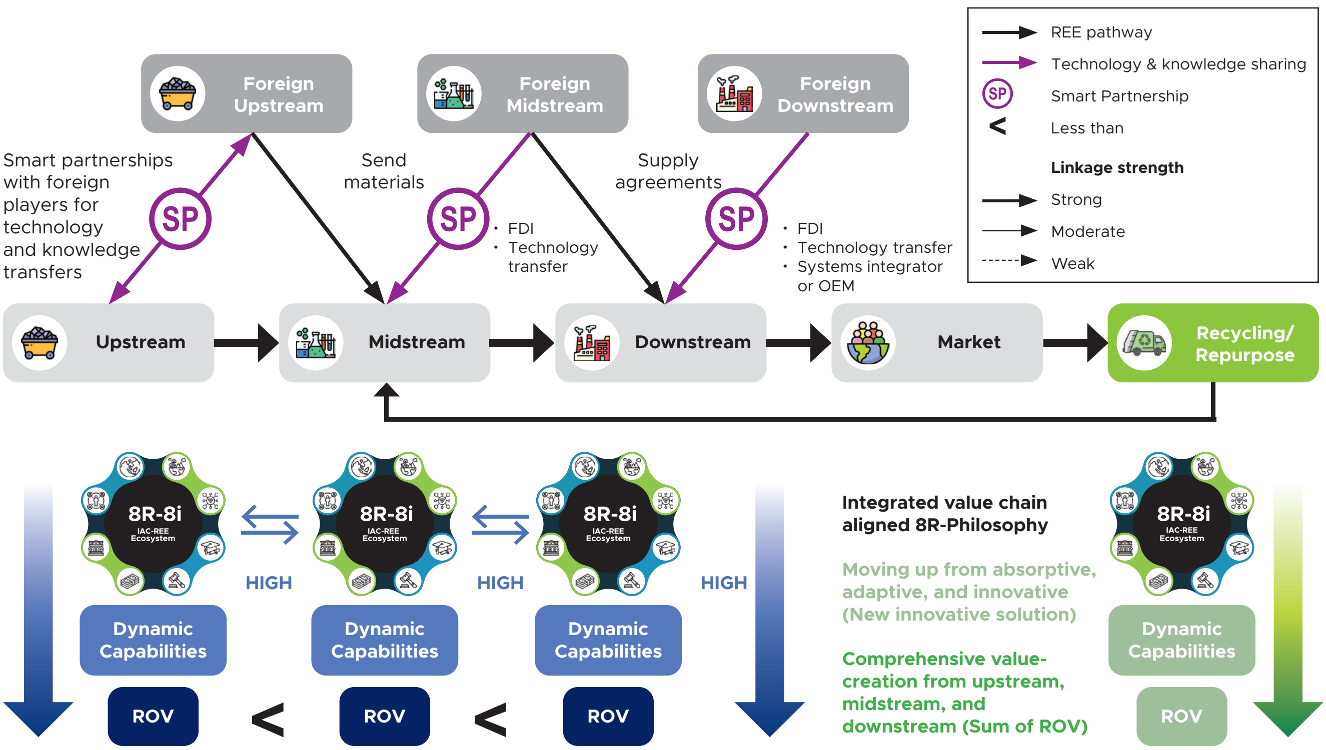


Figure 4.38: An integrated IAC-REE business model

Note: Analytics by Sunway Institute for Global Strategy and Competitiveness

4.7.4 State of the Business Model for the Upstream Sector

Based on both secondary and primary data collected, the study team obtained the following information pertaining to the issues and challenges faced by the upstream sector of the industry:

(i) Lack of local experts/talent stock in ISL mining and on-site processing – shortage of skilled geologists, mining engineers, metallurgists, chemists, and chemical engineers in Malaysia and globally.

(ii) Insufficient research on sustainable, smart, and responsible mining to minimise or mitigate the environmental impacts of ISL mining and for the rehabilitation of mining zones.

(iii) Lack of information on the full impact of IAC-REE extraction on the environment and human health, resulting in a lack of trust and increased suspicion among the public.

(iv) Resource estimation is in Malaysia in the preliminary stage; figures are, at best, Inferred Resources.
(v) Policies on the banning of mining in PFR and ESA that essentially sterilise a large proportion of the country's resources.
(vi) The federal government was not consulted on the details of partnerships involving foreign players and state governments.
(vii) Government incentives for exploration and mining, are generally, are almost non-existent.
(viii) With a lack of knowledge on IAC-REE among authorities and NGOs, poor community engagement process has led to immense public distrust of environmental regulations and enforcement.
(ix) Information and data are not easily accessible as they are not fully digitalised and are kept within their respective agencies.

The participating stakeholders in the study also provided information to strengthen the business model for the upstream sector:

(i) The NRES annual budgets should focus more on reconnaissance and follow-up investigations of REE areas nationwide.
(ii) Populate JMG's digitalised national mineral inventory (i.e. MyGEMS) to store data contributed by state governments and industry players. The database should allow access to all interested parties.
(iii) A separate study to formulate incentives for the exploration and mining of IAC-REE and to attract investments (such a study has been done by the government of Western Australia and can be used as a guide).
(iv) NRES should be the lead agency for the formulation and management of such incentives, especially for green mining.
(v) Review the definition of "minerals" in the State Mineral Enactments with respect to REE (as parts of the State Mineral Enactments do not cater for the mining of IAC-REE).
(vi) CEPA exercises should be conducted with the local communities surrounding the exploration and mining site(s), so as to avoid misinformation.

The state of the 8R-8i ecosystem enablers of the upstream ecosystem is summarised in Figure 4.39. The gaps and way forward are highlighted to bridge the gaps in the enablers of the ecosystem.

The ecosystem analysis for the upstream sector shows the presence of systemic gaps in the ecosystem, which have resulted in low dynamic capabilities within the sector. There is a high dependence on foreign players to mine valuable REE for the industry in Malaysia. If the gaps in the ecosystem are closed, as previously outlined, the potential to enhance the dynamic capabilities is high (Figure 4.40). This would increase the competitiveness of the domestic downstream sector. Conversely, weakness in the dynamic capabilities would result in lower ROV from the domestic IAC-REE sector, as outlined in Figure 4.41. If the enablers of the ecosystem and dynamic capabilities of the industry are improved, as detailed above, the ROV for this sector would certainly increase.

Using the building-blocks of the IAC-REE business value chain for the upstream sector, the current and future states are outlined in Figure 4.42. The business model for the current upstream sector was found to be fragmented due to the weak state of the enablers of the ecosystem. Referring to the Kenering Pilot Project site, REC have been exported to China. If this trend continues, this may result in the midstream and downstream sectors being unable to build strong dynamic capabilities and achieve higher ROV from the domestic REE. The proposed state of strengthening the 8R-8i ecosystem enablers of the upstream sector would not only raise the dynamic capabilities and ROV of the upstream sector but also provide a solid foundation for the midstream and downstream sectors.

FIGURE 4.39

Internationalisation

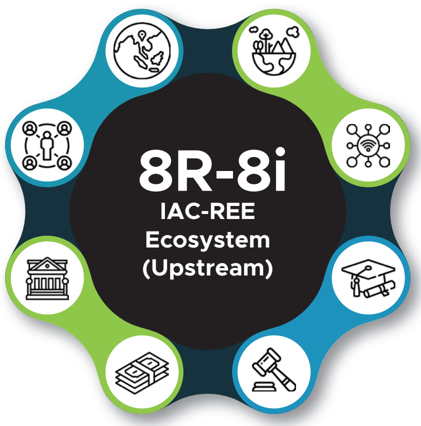
i. Limited global benchmarks, best practices, and standards for ISL of IACs.
ii. Weak international linkages for two-way knowledge and technology sharing.

i. International linkages/JV to increase influx of foreign talent and companies specialised in responsible mining to move up the technology chain.
ii. Horizon scanning for best practices, standards, trends, and technologies.

Infrastructures

i. Insufficient detailed information on resources and reserves of IAC-REE in Malaysia.
ii. Limited analytical facilities resulting in high cost of analyses and long delays.

i. Fast track detailed geological surveys with increased government funding.
ii. Facilitate private sector investments into feasibility studies to enlarge mineable reserves.
iii. Facilitate establishment of more accredited REE analytical laboratories.
iv. Open up more areas for exploration and mining and review the ban on mining in PRFs and ESAs.



Interaction

i. Poor interaction between and among stakeholders.
ii. Fragmented collaboration: ad-hoc basis.
iii. Lack of CEPA programmes and avenues for intellectual discourse.

i. Formal platform for stakeholder engagement.
ii. Citizen participation for policy design and decision-making
iii. Early and continuous CEPA.

Infostructure

i. Limited availability of and accessibility to digitalised REE resources information.
ii. Weak supporting digital infrastructure (e.g., 5G and high-speed Internet).

i. Fast track data digitalisation process.
ii. National database for seamless sharing subject to conditions.
iii. Expedite 5G/Internet initiatives and policies.

Institutions

i. Non-cohesive institutional framework .
ii. Weak institutional leadership for the mining sector.
iii. Lack of “Champion with Clout”.

i. Whole-of-Government and Whole-of-Society approaches
ii. Review national and state policies, and ensure they are comprehensive with follow-through.
iii. National committee as “Champion with Clout” to lead.

Intellectual Capital

i. Mismatch in industry needs for HIL talents and programmes.
ii. Steep learning curve due to limited availability of IAC-REE related technology outside of China.

i. Industry-academia partnership for industry-relevant programmes, internships, and smart and responsible mining.
ii. Create more opportunities for on-the-job training through issuance of ELs and MLs to more companies in the private sector.

Incentives

i. Lack of incentives to promote exploration and mining of minerals, including IAC-REE.
ii. Low priority given to the mineral sector.
iii. Lack of a government entity responsible for incentives for the mining sector.
iv. Excessive taxes imposed by the states act as disincentives to investors.
v. Limited avenues for fund (venture capital) raising.

i. Designate REE as a strategic industry to be given priority for fund allocation.
ii. JMG/NRES to be appointed by MoF as agency responsible for establishing and managing incentives for the mining sector.
iii. Incentives to attract investments and to promote responsible mining, ESG embracement, R&D, talent development, etc.

Integrity

i. Current legal framework, standards, and guidelines sufficient but need to be fine-tuned to cater for IAC-REE ISL-based mining (presence of governance issues).
ii. Low awareness and adoption of ESG.
iii. Policy inconsistencies between state and federal governments.
iv. Lack of responsible mining initiatives.

i. Review legal framework and ensure strict enforcement.
ii. Compulsory ESG adoption, compliance, and monitoring.
iii. Improve governance, especially fair and transparent evaluation and approval for tenements.

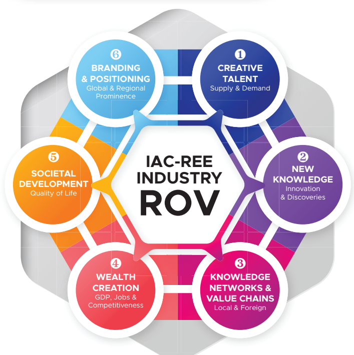
Figure 4.39: Gaps and way forward of the upstream ecosystem (Adapted from Nair et al., 2022)

FIGURE 4.40

CURRENT STATE		PROPOSED WAY FORWARD	
INNOVATIVE CAPABILITY (LOW)	i. Despite its maturity in the foreign markets, the IAC-REE industry is still in its infancy globally, including Malaysia (nascent stage). Domestic players have to rely heavily on foreign technology to move forward.	i. Instilling a creative mindset among local talents to move away from reliance on foreign technology. ii. Leap-frogging/pace-setting industry creating and exporting innovative sustainable and smart mining technologies for domestic and regional consumption. iii. Sustainable satellite mines (regional and global) for domestic midstream consumption.	INNOVATIVE CAPABILITY (HIGH)
ADAPTIVE CAPABILITY (LOW)	i. Steep learning curve due to a lack of international collaboration for the sharing of technologies, processes, and knowledge. ii. Limited local indigenous R&D. iii. Little to no domestic players capable of extracting IAC-REE using the ISL mining method.	i. Indigenous R&D to contextualise sustainable mining techniques and technologies to tropical climate (ASEAN region) and terrain to minimise/eliminate damage to forest, soil, and water sources> ii. Domestic players deploying techniques and technologies for sustainable extraction of REE that adheres to ESG and clear traceability documentation (blockchain).	ADAPTIVE CAPABILITY (HIGH)
ABSORPTIVE CAPABILITY (LOW)	i. Weak international linkages for two-way knowledge and technology sharing limits domestic adoption of foreign technologies and processes for sustainable mining. ii. Limited ability to attract foreign players, talents, and researchers to conduct R&D on sustainable mining domestically. iii. Limited indigenous R&D into sustainable mining techniques and technologies. iv. Lack of domestic talent with required expertise and skills.	i. International linkages to attract/joint venture (JV) with leading responsible mining experts (players and researchers) through mutually beneficial terms (domestic IP and shared mined resource). ii. Produce specialised experts (foreign industry training and bonded). iii. Industry-academia/academia-academia R&D collaboration (domestic-foreign) for sustainable and smart mining. iv. Open-access national database containing digitalised public REE data. v. MRTP (responsible mining technology).	ABSORPTIVE CAPABILITY (HIGH)

Figure 4.40: Current and proposed dynamic capabilities of the upstream sector (Adapted from Nair et al., 2022)

FIGURE 4.41



1. **Creative Talent**
2. **New Knowledge**
3. **Knowledge Networks and Value Chains**
4. **Wealth Creation**
5. **Societal Development**
6. **Branding and Positioning**

CURRENT STATE

1. Nascent sector suffers weak supply of talent specialised in IAC extraction and poor public perception.
2. Weak international linkages and indigenous R&D for responsible mining of REE, resulting in REE extraction issues by the ISL method due to potential environmental impact from current mining practices.
3. Weak global networks for absorptive capability building and lagging indigenous research in responsible mining (involves steep learning curve).
4. Sector operating at lower end of value chain (export raw materials), low-income jobs, and lower GDP contribution, along with the potential risk of pollution spillover due to low technology and lack of ESG awareness and compliance.
5. Operations running legacy/unsustainable techniques that require low STI products and services, with minimal spillover onto other industries for product and service innovations.
6. Domestic and FDI focusing on low-cost REE extraction and export of REC, along with weak knowledge transfer for local talent development.

PROPOSED STATE

1. Specialised talents and experts in sustainable mining, industry-academia for industry ready and relevant training programmes, including specialists in ESG technology awareness and regulations.
2. Indigenous innovations in responsible, smart mining that simultaneously raise environmental and societal capital.
3. Domestic and international collaborations for cross-pollination (multidisciplinary) to develop new innovations in responsible mining.
4. Creation of high-income jobs spawned from new areas of technology and innovation in relation to/resulting from responsible mining.
5. Improved efficiency, safety, and sustainability of mining, creating greater demand for green mining technologies.
6. Regional and global partnerships for the export of technologies and expertise in responsible mining.

Figure 4.41: Current and proposed ROV of the upstream sector (Adapted from Nair et al., 2022)

FIGURE 4.42

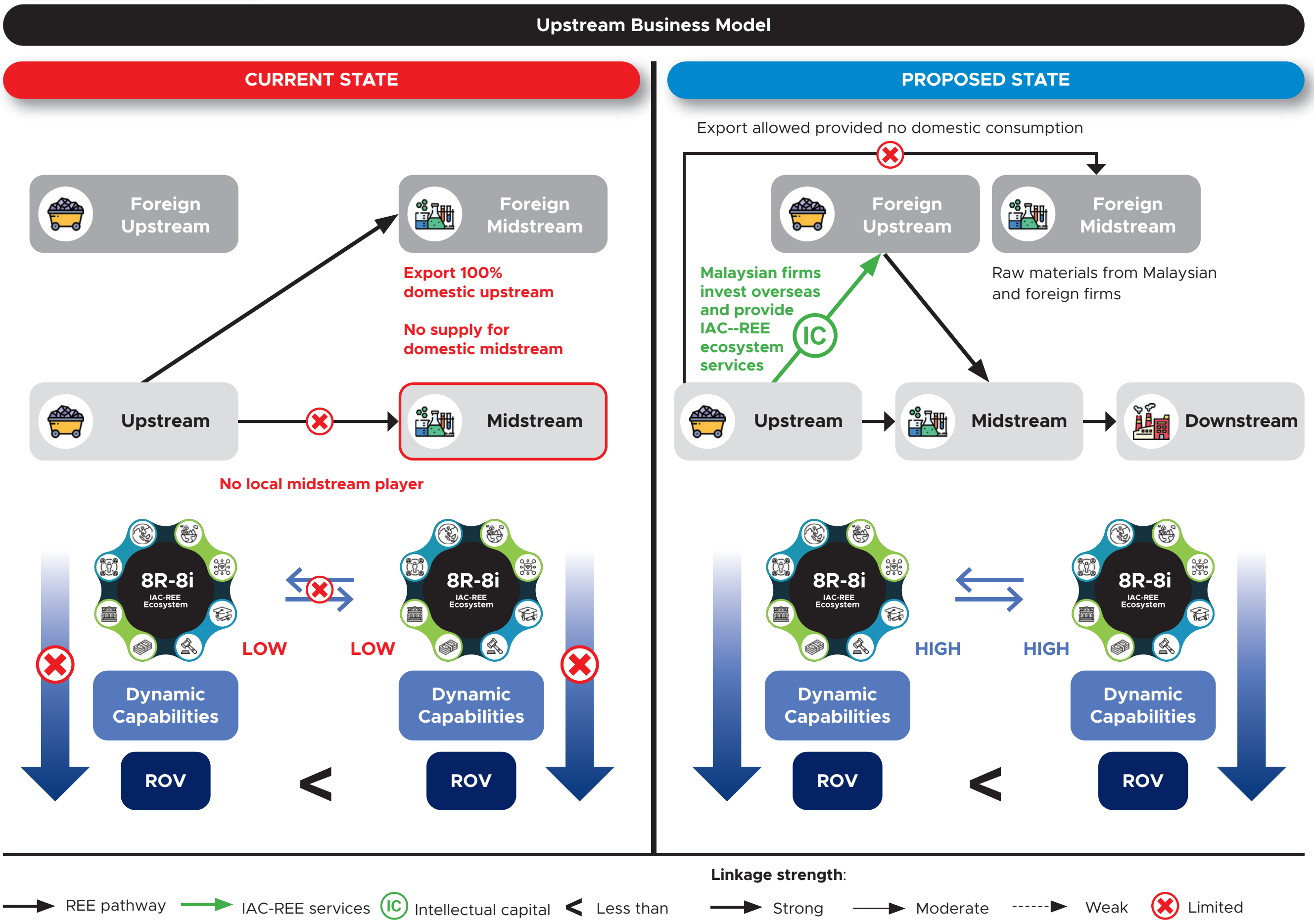


Figure 4.42: Current and proposed business models of the upstream sector (Adapted from Nair et al., 2022)

Note: Analytics by Sunway Institute for Global Strategy and Competitiveness

4.7.5 State of the Business Model for the Midstream Sector

The state of the business model for the midstream sector was ascertained from the study's various FGDs and site visits. The following challenges were identified:

(i) Policy inconsistency and lack of consensus on the direction of the REE processing industry.
(ii) Policy inconsistency perpetuates the fragmentation of the supply chain among the upstream, midstream, and downstream sectors.
(iii) Lack of human capital/experts to support the midstream sector.

(iv) Lack of understanding of the necessary legal requirements for the industry causes significant delays in the issuance of licenses (Act 127 requires certain activities to conduct EIA or Detailed EIA (DEIA) before the issuance of relevant licenses).
(v) Infrastructure in the midstream sector is still in the development stage, but it is driven by REE of mineral origin, producing radioactive thorium as a by-product. However, this segment is currently dominated by a foreign player (i.e., Lynas Malaysia). Meanwhile, the midstream sector has yet to take off due to the weak upstream supply and absence of a strong local player.
(vi) High costs of the separation and purification processes due to the high costs required to train experts and talents to run the processing facility.
(vii) Insufficient financing schemes to overcome the high capital entry barrier into the midstream sector.
(viii) Lack of strong government support and a short licensing period, resulting in firms unwilling to fully invest in the processing infrastructure (requires high capital investment).

To enhance the competitiveness of the local midstream sector's business model, the following information was identified from the FGDs:

(i) The upstream and midstream sectors must be integrated to ensure the production of purified Malaysian REOs for the downstream sector – to retain 20% of REC from the local IAC-REE plant at the market price for the local REPP for testing/process development during the initial stage and for R&D.
(ii) MOSTI should place high priority in supporting R&D in rare earth green processing as this would be a sought-after technique globally in the near future.
(iii) Industry players in the midstream sector should be given a suitable period of tenureship to assure foreign investors who plan to invest in Malaysia that there is a secure guaranteed supply of vital resources for the manufacturing of REE metals and alloys, as well as super-magnets.
(iv) There is a need for stronger government support to develop the midstream sector, such as high-tech infrastructures, R&D, and innovations in next-generation processing and midstream activities, according to ESG requirements, which often require high capital investment.
(v) The high capital investment must be "dove-tailed" with strong investments in human capital development that can create better ROV for the midstream sector and also those from the upstream and downstream sectors. These investments must enable the entire IAC-REE ecosystem to move up the global innovation value chain.
(vi) There is also a need to establish business-friendly policies for more local players in the midstream sector and enhance the competitiveness of the local players; a strong local midstream sector can attract investment into upstream and downstream sectors.

A summary of the 8R-8i ecosystem enablers of the midstream ecosystem, including the gaps and measures to bridge the identified gaps, is presented in Figure 4.43. Dynamic capabilities of firms in the midstream sector were assessed, and the obtained results are summarised in Figure 4.44. The results showed that the gaps in the ecosystem perpetuate low dynamic capabilities in local players who are seeking to process IAC REE. Similar to the upstream sector, the midstream sector was also found to be highly dependent on foreign players. Weaknesses in the components of the dynamics capabilities potentially result in a break in the transmission from absorptive and adaptive capabilities to innovative capabilities in this sector. The study's findings also highlighted that, if measures were taken to close the challenges in the ecosystem, this sector would then have the potential to build strong dynamic capabilities.

FIGURE 4.43

Internationalisation

i. Weak international linkages for two-way knowledge and technology sharing.
ii. Weak adoption of global best practices and standards for a sustainable supply chain.

i. International linkages/JV to increase influx of foreign talent and companies specialised in REE processing and purification.
ii. Horizon scanning for best practices, standards, trends, and technologies.

Infrastructures

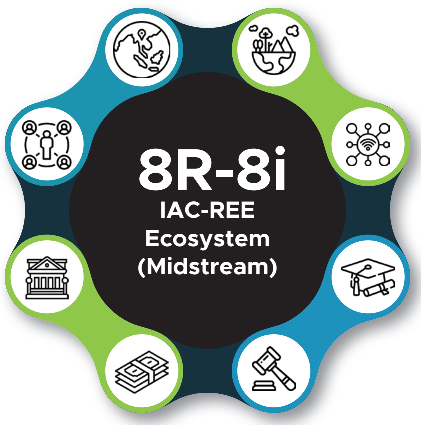
i. Lack of/unstable REO supply (domestic and foreign upstream).
ii. Limited facilities and high-cost of lab analysis and equipment for REE.
iii. Developing domestic sector but lack of strong local players (foreign dominated).

i. Secure 20% local REC as stock up inventory and establishment of REC central buying house
ii. Sustainable smart factories.
iii. MRTP with satellite centres and facilities for R&D services and collaboration.

Interaction

i. Poor coordination and collaboration between stakeholders (supply chain).
ii. Ad-hoc community engagement and weak citizen participation.
iii. Lack of CEPA programmes.

i. Formal platform for stakeholder engagement as core to the REE manufacturing industry.
ii. Citizen participation for policy design and decision-making (early and continuous CEPA).



Infostructure

i. Limited availability, accessibility, and sharing of digitalised REE resources.
ii. Weak supporting digital infrastructure (e.g., 5G and high-speed Internet).

i. National database for public data.
ii. Open-data and data sharing policies
iii. Expedite 5G/Internet initiatives and policies.
iv. Smart manufacturing (IoT, AI, big data, traceability, and block chain).

Institutions

i. Weak state-federal consensus, as well as gaps and overlapping of jurisdiction.
ii. Poor policy coverage and cohesion. Patchy, lack follow-through, and inconsistent.
iii. Weak institutional leadership for REE processing.

i. Whole-of-Government and Whole-of-Society approaches.
ii. Review national and state policies, and ensure they are comprehensive with follow-through.
iii. National committee as "Champion with Clout" to lead.
iv. Should be core to the nation's manufacturing strategic plan.

Intellectual Capital

i. Nascent industry leads to low awareness, scepticism, and negative perception regarding the sector.
ii. Insufficient indigenous research for REE processing and experts with related specialised skill sets.
iii. "Lock-in" to foreign technology.

i. Industry-academia partnership for industry-relevant programmes, internships, and research.
ii. Increase R&D in sustainable and smart REE processing and by-product recovery.
iii. Development of local processing technology.

Incentives

i. Lack targeted fiscal/non-fiscal incentives and limited financing for adoption, innovation, and R&D for sustainable REE processing and supply chain.
ii. High cost of entry, green tech, and OPEX/CAPEX.
iii. Limited financial products and services for REE processing (e.g., insurance).

i. Core R&D and infrastructure funding for the IAC-REE industry.
ii. Financing schemes tied to measurable targets (sustainability and research).
iii. Comprehensive economic and financial scheme for the midstream sector.

Integrity

i. Weak legal framework, standards, guidelines, and enforcement specific to IAC-REE.
ii. Low awareness and adoption of ESG.
iii. Information asymmetry, and low transparency, traceability, and accountability.

i. Digital systems for tracking and traceability (blockchain).
ii. Review legal framework and ensure strict enforcement.
iii. ESG adoption, compliance, and monitoring (measurable targets).

Figure 4.43: Gaps and way forward of the IAC-REE midstream ecosystem (Adapted from Nair et al., 2022)

The assessment of the ROV of the midstream sector revealed that the sector did not attain its full ROV (Figure 4.45). The lower levels of ROV appeared to be attributed to the significant gaps in the 8R-8i enablers of the ecosystem and low dynamic capabilities among the local players in the industry. If the enablers of the ecosystem are strengthened, both dynamic capabilities and ROV generated from the local players in the sector would increase.

Based on the above analysis, the current and proposed IAC-REE business value chain for the midstream sector are shown in Figure 4.46. The current midstream sector is plagued by several challenges – major fragmentation of the sector and the lack of local midstream players. Currently, the local rare earth processing sector is led by a foreign player, creating the knock-on impact on the local players in the downstream market and the recycling/repurposing market. Due to the lack of integration of the midstream ecosystem with that of the upstream and downstream ecosystems, locally mined REE make their way to the foreign midstream market instead. This causes local downstream players to be dependent on foreign players for processed REE. Weaknesses in the enablers of the midstream ecosystem and fragmentation among all three sectors' ecosystems have resulted in all of them having lower dynamic capabilities and ROVs. Significant improvement in the enablers in the midstream sector, as discussed above, would strengthen the value-add to the upstream and downstream ecosystems.

FIGURE 4.44

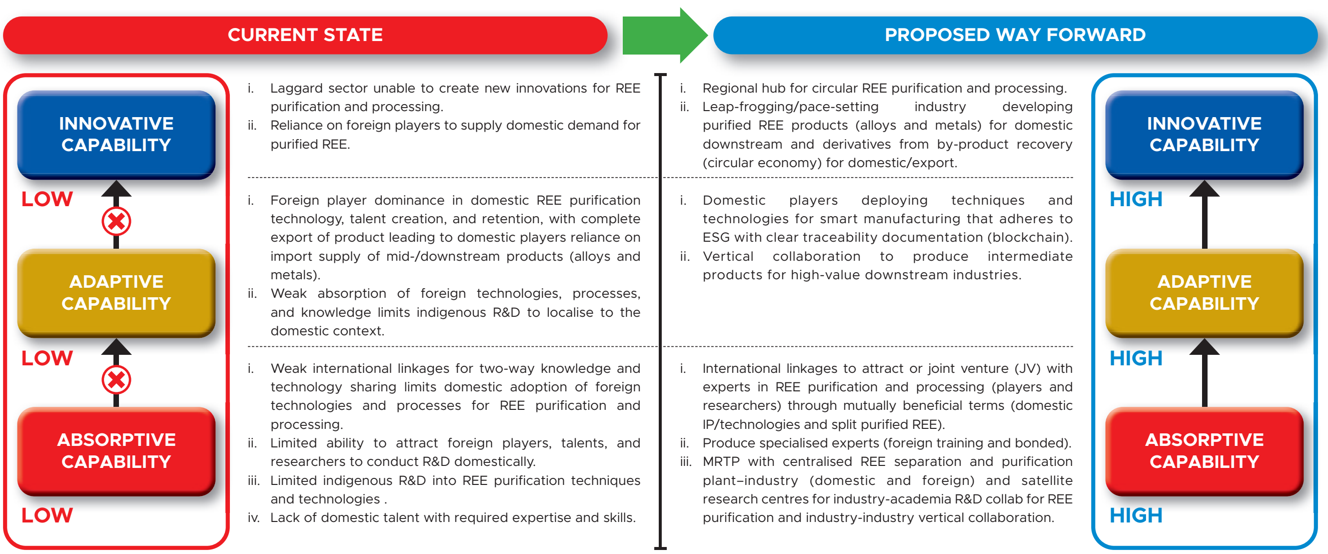
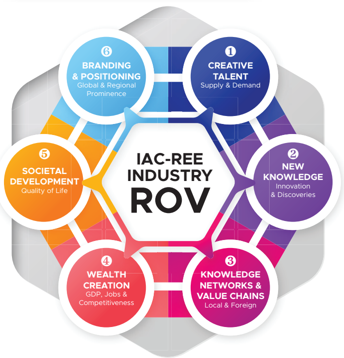


Figure 4.44: Current and proposed dynamic capabilities of the midstream sector (Adapted from Nair et al., 2022)

FIGURE 4.45



1. **Creative Talent**
2. **New Knowledge**
3. **Knowledge Networks and Value Chains**
4. **Wealth Creation**
5. **Societal Development**
6. **Branding and Positioning**

CURRENT STATE	PROPOSED STATE
1 Nascent sector suffers weak supply of talent specialised in REE processing and poor public perception.	1 Specialised talents and experts in sustainable manufacture. Industry-academia for industry ready and relevant training programmes.
2 Few local players and weak international linkages and indigenous R&D for REE processing. Potential company-community conflict due to negative perception and the lack of communication strategy and CEPA programme.	2 Innovations in sustainable REE processing and traceability (blockchain) for products and services that adhere to ESG.
3 Weak global networks for absorptive capability building and lagging indigenous research in REE processing, along with low adoption of global best practices in domestic supply chain.	3 Domestic and international collaboration for cross-pollination (multidisciplinary) to develop new innovations in REE purification and processing.
4 Sector operating at lower end of value chain (export purified REE) reliant on purely extractive resource, along with the creation of low-income jobs and lower GDP contribution.	4 Creation of high-income jobs spawned from new areas of technology and innovation in REE processing and alloy/metal production, recycling, and spillover industries.
5 Operations running legacy/unsustainable techniques that require low STI products and services.	5 Improved efficiency, safety, and sustainability of REE processing creating demand for STI-driven downstream services and products (EVs and renewable energy generation).
6 Domestic and FDI focusing on processing and exporting purified REE due to the lack of high-value downstream industries	6 Regional and global partnerships for R&D and innovations in domestic REE purification technologies.

Figure 4.45: Current and proposed ROV of the midstream sector (Adapted from Nair et al., 2022)

4.7.6 **State of the Business Model for the Downstream Sector**

This subsection focuses on the state of the business model for the local downstream sector. The following challenges were identified to have hindered the development and competitiveness of this sector:

(i) The absence of dedicated research interest groups, consisting of relevant stakeholders for more targeted planning of the IAC-REE industry, especially for the midstream and downstream sectors

(ii) The absence of joint-IP between countries that are well-developed in this rare earth industry and local players in the domestic ecosystem

(iii) A lack of experts focused on the IAC-REE industry, especially TVET and undergraduates, as well as a lack of material science, metallurgy, and manufacturing engineering programmes. This is further exacerbated by a lack of know-how on using REE in the manufacturing of products and technologies. There is also insufficient expertise in developing technologies to enable the industry's adherence to the 8R-8i values-based development philosophy and ESG requirements.

FIGURE 4.46

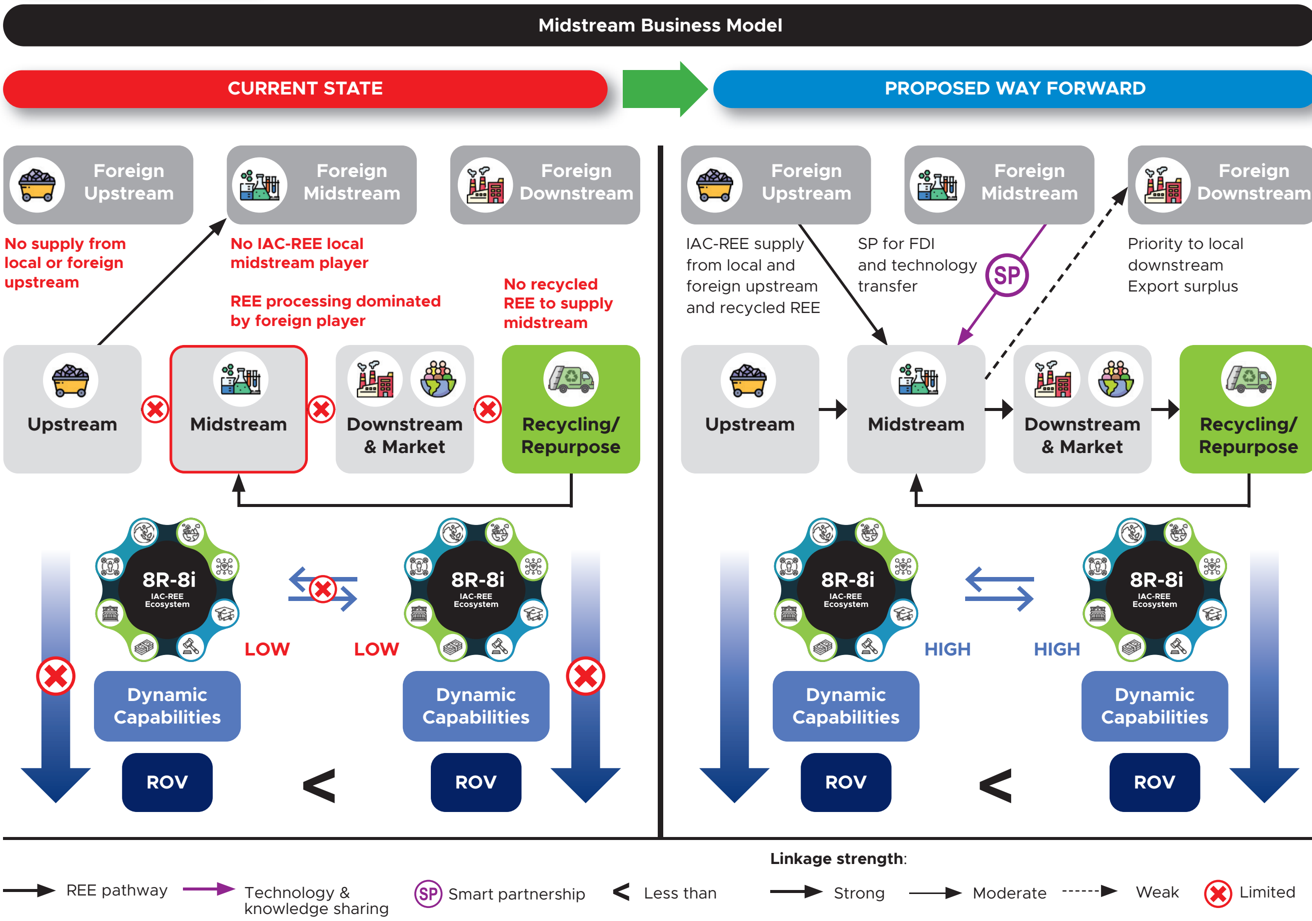


Figure 4.46: Current and proposed business models of the midstream sector (Adapted from Nair et al., 2022)

Note: Analytics by Sunway Institute for Global Strategy and Competitiveness

(iv) Lack of major research facilities and equipment, which are open for access to relevant industries and universities is further compounded by a lack of government research fundings allocated for R&D on advanced and critical materials and environmentally friendly technologies related to the IAC-REE industry.

(v) Lack of knowledge transfer on the manufacturing of magnets and batteries among international organisations, local firms, and related agencies – local players do not have access to state-of-the-art technologies due to the lack of a strong R&D ecosystem in the industry.

(vi) Lack of high-quality processing facilities and supply of purified REE and REE metals and alloys for the local downstream sector – the lack of financial resources in this industry to establish the facilities and operations from end-to-end value chain (upstream to downstream). There is heavy dependence on foreign players to supply materials for their operations with many local players at the lower end of the value chain

(vii) The difficulties in managing the quality of the finished products and product quality consistency according to international standards, which includes the difficulties in matching the required high purity needed by the market (depending on buyers' specifications)

(viii) Limited engagement and communication with all stakeholders, including the public, on the importance of the IAC-REE industry for future technologies, that contributes to cleaner technologies and high-income job opportunities, transforming Malaysia into a high-tech country. There is a lack of CEPA programmes on safety and sustainable measures to be taken by the industry and the authorities to mitigate risks associated with environmental degradation, while preserving the biodiversity of natural ecosystems

The downstream sector derives the highest value in the value chain. At present, the industry is primarily driven by foreign players. To enhance the competitiveness of the local players in this segment of the value chain, concerted efforts to increase the number of players are necessary, and they must have the necessary resources to move up the global innovation and economic value chain. The following measures are proposed to ensure that the local industry nurtures strong downstream players:

(i) Since the midstream and downstream sectors are categorised as promoted industries by MITI and MIDA, these agencies should undertake Foreign Investor Trade Missions to attract investments into the country for the manufacturing of rare earth metals and alloys, super-magnets, electric motors, and other rare earth-based products.

(ii) The downstream sector involves advanced technologies. This requires significant investment in R&D infrastructures and commercialisation ecosystems to translate the R&D undertaken by universities and research centres to the market. In this context, it is proposed to allocate government research funding for R&D on advanced and critical materials. Fundings should be made available and managed by a proposed Institute of Critical Materials Technology Malaysia (ICMTM)[23] .

[23] Proposed under the Blueprint for the Establishment of Rare Earth-Based Industries in Malaysia (2014)

(iii) In partnership with the private sector, the government should allocate adequate funding for the establishment of a MRTP that is aligned to the 8R-8i values-based development philosophy and ESG requirements. The technology park can play a key role in fostering strong partnership between research institutions and local industries to spearhead fundamental and translational R&D that can lead to next-generation mining, processing, and relevant products and services in the industry, including enhanced demand-oriented research through university-industry collaboration.

(iv) MRTP can play a key role in fostering international collaboration with leading international centres of excellence and multinational industry players, both within the IAC-REE industry and with other relevant industrial sectors.

(v) Incentives in the forms of tax deduction and access to R&D infrastructure and support systems should be extended to foreign collaborators that can undertake R&D and higher value-added activities in Malaysia and foster the transfer of technology and knowledge to local firms within the value chain.

A summary of the 8R-8i ecosystem enablers of the downstream sector is given in Figure 4.47. In this figure, the key gaps in each enabler of the ecosystem are summarised, and measures to close the gaps are outlined.

The dynamic capabilities of firms in the downstream sector are summarised in Figure 4.48. All three components of the dynamic capabilities for local firms in the downstream sector were found to be low. The low absorptive capabilities of new technologies in the industry have curtailed local firms' adaptive and innovative capabilities. Many of these firms are highly dependent on foreign players for new technologies and know-how. If local players intensify the development of the local ecosystem (8R-8i ecosystem enablers), there is potential for the increase in local firm dynamic capabilities, enabling them to move up the global innovation value chain.

Based on the current state of the downstream ecosystem and the dynamic capabilities of the downstream sector, ROV was found to be low, suggesting an inability to attain their full ROV potential (Figure 4.49). If the industry can intensify the development of the enablers of the ecosystem and raise its dynamic capabilities, there is a high likelihood of the industry raising its ROV and overall contribution to the Malaysian economy.

As shown in Figure 4.50, the study found that the business value chain of the local downstream sector to be fragmented and operating at the lower end of the global value chain. The downstream sector is dominated by foreign players, with most of the rare earth products from the midstream sector exported overseas. Limitations in the upstream and midstream sectors are magnified at the downstream sector, especially when there are no major local players in the latter. The majority of downstream sector players are from countries like China, Japan, and USA. Meanwhile, many local manufacturers of products related to the IAC-REE industry are involved in the assembly of industrial magnet applications or disk-drive manufacturing, both of which operating at the lower-end of the value chain. Additionally, there is little presence of recycling/repurposing of REE, which inhibits not only an alternative source to virgin REE but also the ability to close the loop for a sustainable and circular IAC-REE industry.

Strengthening the business model of the downstream sector through the proposed measures can enable the local downstream sector players to "pipe-into" to the global value chain and build strong dynamic capabilities; all of which would increase the ROV contributions of the downstream sector to the Malaysian economy.

FIGURE 4.47

Internationalisation

i. Weak international linkages for two-way knowledge and technology sharing.
ii. Weak adoption of global best practices and standards for sustainable supply chain.

i. International linkages/JV to increase influx of foreign talent and companies specialised in REE products and spillover industries (e.g., renewable energy and smartphone).
ii. Horizon scanning for best practices, standards, trends, and technologies.

Infrastructures

i. Lack of/unstable REE metal supply (domestic and foreign upstream).
ii. Limited facilities and high-cost of lab analysis, equipment, and research for REE.
iii. Limited domestic know-how and technology for REE product manufacture.

i. Establish MRTP which the REO and REE alloy can be supplied from midstream REPP.
ii. MRTP with satellite centres and facilities for R&D services and collaborations.

Interaction

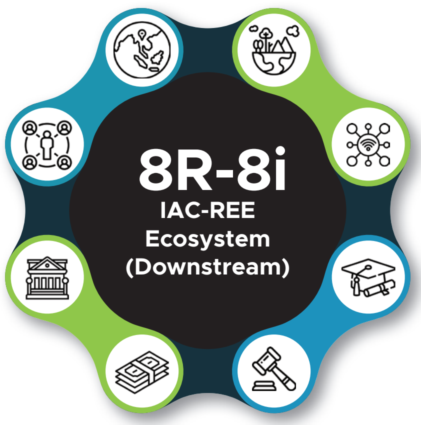
i. Poor coordination and collaboration between stakeholders (supply chain).
ii. Ad-hoc community engagement.
iii. Weak citizen participation.

i. Formal platform for stakeholder engagement.
ii. Citizen participation for policy design and decision-making (early and continuous CEPA).
iii. Set up MRTP.

Institutions

i. Poor policy coverage and cohesion. Patchy, lack follow-through, and inconsistent.
ii. Weak institutional leadership for REE-based products, services, and manufacturing.

i. Whole-of-Government and Whole-of-Society approaches.
ii. Review national and state policies, and ensure they are comprehensive with follow-through (direct and spillover industries) – strengthening of the manufacturing sector in REE.
iii. National committee as "Champion with Clout" to lead.



Infostructure

i. Limited availability and accessibility to digitalised REE resources.
ii. Weak supporting digital infrastructure (e.g., 5G and high-speed Internet).

i. National database for public data.
ii. Open-data and data sharing policies.
iii. Expedite 5G/Internet initiatives and policies.
iv. Smart manufacturing (IoT, AI, and big data).

Intellectual Capital

i. Nascent industry leads to low awareness and scepticism regarding sector.
ii. Industry experiencing insufficient experts and specialised talents.
iii. Insufficient indigenous research for REE-based IPs, technologies, and services.

i. Industry-academia partnership for industry-relevant programmes, internships, and research.
ii. Increase R&D in sustainable, smart REE-based IPs, technologies, and services (magnet, automotive, EV, smartphone, and recycling).

Incentives

i. Lack fiscal/non-fiscal incentives and limited financing for adoption, innovation, and R&D for sustainable supply chain (REE and spillover industries).

i. Fiscal/non-fiscal incentives and financing schemes tied to measurable targets (sustainability and research).
ii. Increased research funding for REE -based high-value industries (EV and renewable energy).

Integrity

i. Weak legal framework, standards, guidelines, and enforcement.
ii. Low awareness and adoption of ESG.
iii. Information asymmetry; low transparency, traceability, and accountability.

i. Digital systems for tracking and traceability (blockchain).
ii. Review legal framework and ensure strict enforcement.
iii. ESG adoption, compliance, and monitoring (measurable targets).

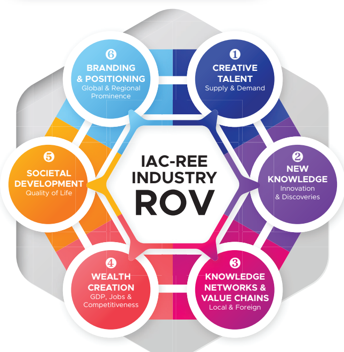
Figure 4.47: Gaps and way forward of the downstream ecosystem (Adapted from Nair et al., 2022)

FIGURE 4.48

Current state		Proposed way forward	
INNOVATIVE CAPABILITY (LOW)	i. Laggard sector unable to create new innovations for REE-based components and products. ii. Reliance on foreign players/import to supply domestic demand for REE-based products and technologies.	i. Partnering with global leaders in R&D and manufacture of REE-based high-value products (EV, renewable energy, and smartphone components). ii. Leap-frogging/pace-setting industry developing REE-based technologies and derivatives from by-product recovery for domestic/export and recycling of RE products.	INNOVATIVE CAPABILITY (HIGH)
ADAPTIVE CAPABILITY (LOW)	i. Foreign player dominance in domestic REE technology and talent creation and retention. Reliance on import supply of mid-/downstream product (alloys and metals). ii. Weak indigenous R&D to modify foreign technologies for domestic production.	i. Contextualised indigenous R&D for REE products and applications suitable for domestic and regional consumption. ii. Domestic players deploying techniques and technologies for smart manufacturing that adhere to ESG with clear traceability documentation (blockchain). iii. Vertical collaboration with midstream/end-of-life for high-value downstream industries.	ADAPTIVE CAPABILITY (HIGH)
ABSORPTIVE CAPABILITY (LOW)	i. Weak international linkages for two-way knowledge and technology sharing limits domestic adoption of foreign technologies and processes for REE magnet manufacture. ii. Limited ability to attract foreign players, talents, and researchers to conduct R&D domestically iii. Limited indigenous R&D into REE products and applications. iv. Lack of domestic talents with required expertise and skills.	i. International linkages to attract/joint venture (JV) with experts in REE magnet and application (players and researchers) through mutually beneficial terms. ii. Produce specialised experts (foreign training and bonded). iii. MRTP via cluster model–industry (domestic and foreign) and satellite research centres for industry-academia R&D collaboration and industry-industry vertical collaboration.	ABSORPTIVE CAPABILITY (HIGH)

Figure 4.48: Current and proposed dynamic capabilities of the downstream sector (Adapted from Nair et al., 2022)

FIGURE 4.49



1. **Creative Talent**
2. **New Knowledge**
3. **Knowledge Networks and Value Chains**
4. **Wealth Creation**
5. **Societal Development**
6. **Branding and Positioning**

CURRENT STATE	PROPOSED STATE
1. Nascent sector suffers weak supply of talent specialised in REE processing and poor public perception.	1. Specialised talents and experts in sustainable manufacture, as well as industry-academia for industry ready and relevant training programmes.
2. Sector reliance on foreign technology and players, along with limited indigenous research and innovation for REE-based products and applications.	2. Innovations in REE products, applications, and adoption of smart manufacturing (automation and IoT), and strategising G2G technology transfer and technology leasing programme for downstream activities.
3. Weak global networks for absorptive and adaptive capability building, as well as low adoption of smart manufacturing.	3. Domestic and international collaborations for cross-pollination (multidisciplinary) to develop new innovations in REE products, applications, and advanced materials. Established local downstream industry consortium comprising anchor company and SMEs.
4. Sector reliance on foreign players and purely extractive resource (no alternative REE supply), as well as weak supply limiting the sector and spillover industry development.	4. Creation of high-income jobs spawned from new areas in REE products, advanced materials, green technologies, and recycling, as well as blockchain-enabled, ESG-compliant traceable supply chains.
5. Labour-intensive manufacturing and local operators at the lower-end of the value chain of final products and services.	5. Application and growth of spillover industries creating demand for STI-driven, REE-based products and services (EVs and renewable energy generation).
6. Domestic and FDI focusing on downstream assembly that relies on imported REE-based components due to the lack of stable RE supply and indigenous high-value downstream industries (EV and renewable energy).	6. Regional and global partnerships for R&D, innovation, and export of domestic REE-based products and services.

Figure 4.49: Current and proposed ROV of the downstream sector (Adapted from Nair et al., 2022)

FIGURE 4.50

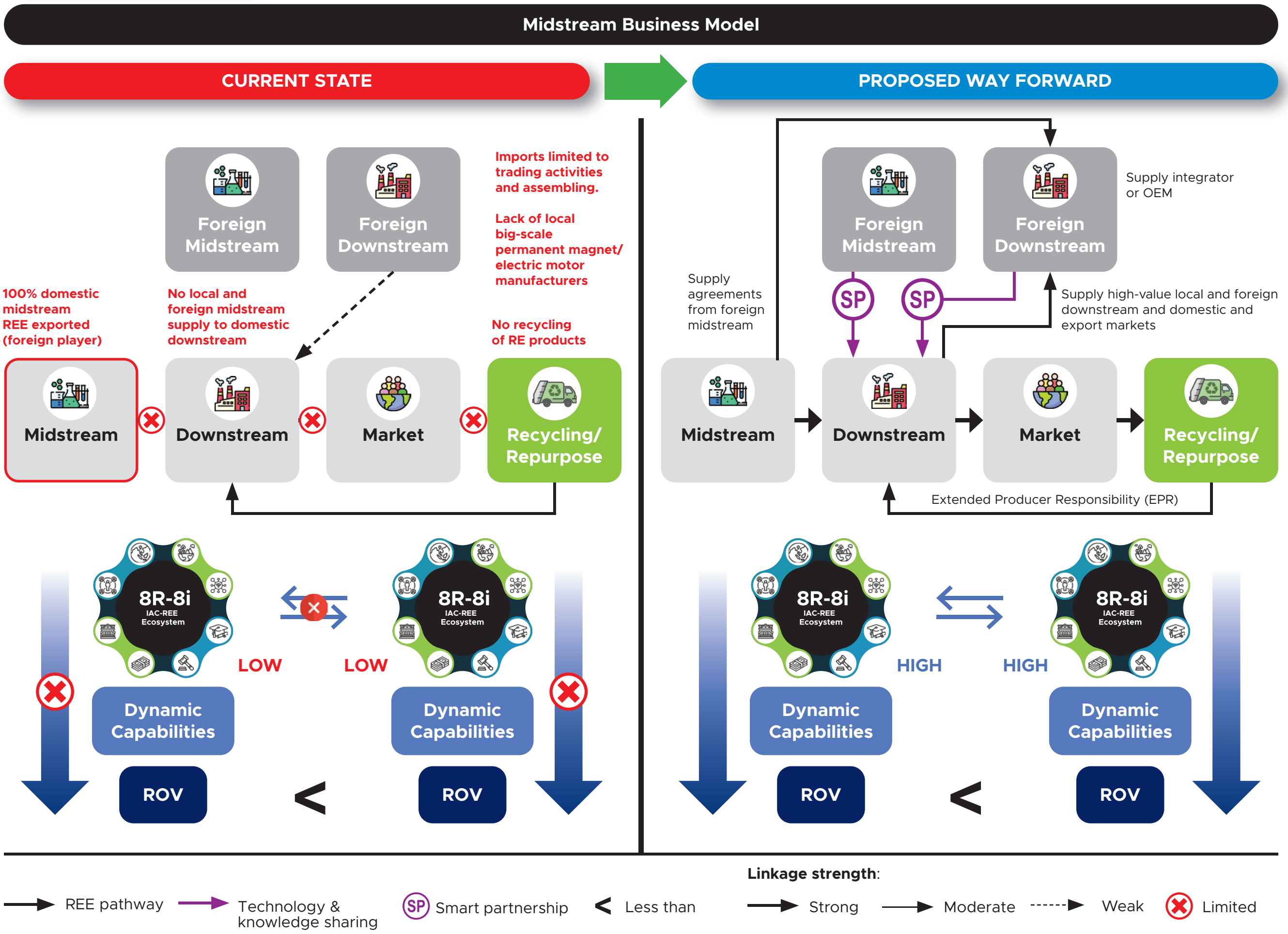


Figure 4.50: Current and proposed business models of the downstream sector a(Adapted from Nair et al., 2022)

Note: Analytics by Sunway Institute for Global Strategy and Competitiveness

4.7.7 Way Forward for the Malaysian IAC-REE Ecosystem – The Integrated Business Model

The previous subsection examined the current business models for all three sectors of the IAC-REE industry. This study also highlighted the gaps in these ecosystems and ways to strengthen and raise competitiveness and economic contributions. The objective of key stakeholders in the industry is to develop a seamless integrated IAC-REE business value chain, as shown earlier in Figure 4.38. There are inherent challenges faced by local players in the current ecosystem, which are summarised below:

(i) *Infrastructure:* To date, a detailed evaluation of REE deposits to determine the economic viability of deposits has not been conducted. Minerals are not classified as forest products; hence, REE in forest reserves cannot be removed. Limited lab service providers and the high cost of lab equipment and analysis are barriers to the industry. This is further exacerbated by the non-availability of major research facilities and equipment for industry and university access. The lack of technology use also hinders the seamless integration of these three sectors in the IAC-REE industry. There is also the low utilisation of environmental technologies that enable the tracking and traceability of best practices of mining, processing, and development of IAC-REE materials, products, and services across all three sectors. This has raised concerns among the public and civil society on the negative spillover effects of the industry on natural ecosystems and society.

ii) *Infostructure:* Weak digital infrastructure, poor data collection and data sharing among stakeholders within and across the sectors lead to low usage and adoption of data-driven solutions and technologies (a critical barrier to digital solutions for environmental management and protection). The lack of open data and data sharing policies results in poor access to information and data by industries, agencies, and the general public. This prevents the enhancement of the “chain of custody” (efficiency, transparency, accountability, and traceability) of the operations across all three sectors.

(iii) *Intellectual capital:* The industry faces difficulties in attracting skilled and expert talents in a wide range of areas across all three sectors, including recycling/repurposing activities. There is also a lack of technical experts, researchers, and educational programmes on sustainable and smart mining methods that are aligned with the 8R values-based development philosophy and ESG requirements. This has resulted in a significant shortage of employees with inter-operability and interdisciplinary skillsets that can transcend various sectors in the IAC-REE industry. Due to the lack of expertise, indigenous research, and innovation in wide-ranging areas, most of the processing, product development, and applications are championed by foreign players. Additionally, a lack of education and awareness on the industry has heightened anxiety among the public and civil society groups on the potential impact of the IAC-REE industry, particularly environmental degradation and lowered quality of life for the people living near mining sites. This situation is further compounded by a lack of experts in educating the public on the role of the IAC-REE industry in the transition towards high technology for the country’s migration towards a circular economic model.

(iv) *Integrity systems:* The limitations in digital architecture across different sectors result in the lack of integration and harmonisation of governance and practices, which tend to perpetuate the weak enforcement of laws and regulations in the industry. Poor transparency and asymmetric information among the stakeholders also lead to a lack of trust and eventually, suspicion of industry operators and government authorities. Furthermore, ESG and sustainability reporting are only mandatory for publicly listed firms. Hence, many operators are not compelled to adhere to the ESG standards.

(v) *Incentives programmes:* Although the IAC-REE industry is seen as a strategic industry for the country, limited fiscal and non-fiscal incentives are allocated to research and innovation in the areas of smart IAC-REE mining practices, purification, and, manufacturing of high-value products and applications. High costs associated with high initial capital and environmental protection are key barriers to entry for local players – for example, costs associated with the initial plant setup and waste management associated with IAC-REE extraction and purification. These issues are further compounded by the nascent nature of the industry (i.e., lack of technologies) and insufficient financing schemes.

(vi) *Institutions and institutional leadership:* There is no “champion with clout” for the systematic development of the IAC-REE industry, albeit it being a strategic sector for many high-tech industries. The absence of Whole-of-Government and Whole-of-Society approach has perpetuated weak coordination among key players within and across the sectors, resulting in fragmentation in governance – gaps and overlaps between the agencies and ministries overseeing the development of the IAC-REE industry. Conflicts and a lack of consensus between the federal and state governments over land use policy and jurisdiction further add to the bureaucratic red tape faced by business operators. Furthermore, weak governance within the sector curtails development and competitiveness among the local players in all three sectors of the IAC-REE industry.

(vii) *Interaction:* Weak institutional governance perpetuates a lack of trust among key players in the industry. This has led to firms in each sector optimising their own outcomes but at the expense of building strong dynamic capabilities for the entire IAC-REE value chain. Weak cooperation and collaboration within and across these three sectors have led to lower dynamic capabilities and ROV among the local players in the IAC-REE industry. The lack of strong dynamic capabilities has led to firms being unable to compete with foreign competitors who posess a more sophisticated and deeper value chain. Additionally, there is a disconnect among the local indigenous population, civil society, NGO groups, and firms operating these mining sites, stemming from the lack of cooperation and collaboration among these stakeholders. This disconnect is further exacerbated by the weak inclusion of local communities and civil societies in policy-making, planning, management, monitoring, and decision-making processes in IAC-REE operations and awareness campaigns. The result is a major societal pushback towards the mining and processing of rare earths in general.

(viii) *Internationalisation:* Local firms and research institutions in all three sectors lack global reach and mechanisms to foster the global transfer of technology and knowledge between local and foreign players. There is a high dependence on foreign players for technology and innovation, as well as a lack of robust incentives and dynamic local players that can build strong dynamic capabilities. Hence, the presence of local players in the midstream sector is non-existent, and many local firms in the downstream sector operate at the lower end of the value chain.

The 8R-8i ecosystem analysis of the IAC-REE business value chain highlights several major weaknesses and fragmentation in the value chain (Figure 4.51). Key features of the current business value chain suggest the export of most of the raw IAC-REE to foreign midstream sectors. The current midstream sector is foreign-dominated and exports its output to foreign downstream manufacturers. The downstream sector is primarily dominated by foreign players, with most local downstream firms operating at the lower end of the value chain. Furthermore, the recycling and repurposing market segments in Malaysia are generally underdeveloped. The fragmentation of the local IAC-REE industry does not enable the industry to build dynamic capabilities in all sectors. Hence, the ROV from these sectors is low, and the contributions of IAC-REE are not fully realised.

To address the highlighted limitations and to build a strong IAC-REE industry, it is important to consider best practices from other countries. Canada is a prime example; having recently entered the IAC-REE industry with a strong 8R-8i ecosystem built on carefully co-developed policies and strategies and strong investments into research and innovation. The industry is expected to play a major role in the country's goals for net zero carbon emissions. Canada's strategy to tackle both supply and demand of REE can serve as a model for other countries, including Malaysia, to secure the position of the IAC-REE industry in the country's strategies to achieve net zero emissions (Figure 4.52).

FIGURE 4.51

IAC-REE Business Model – Current State

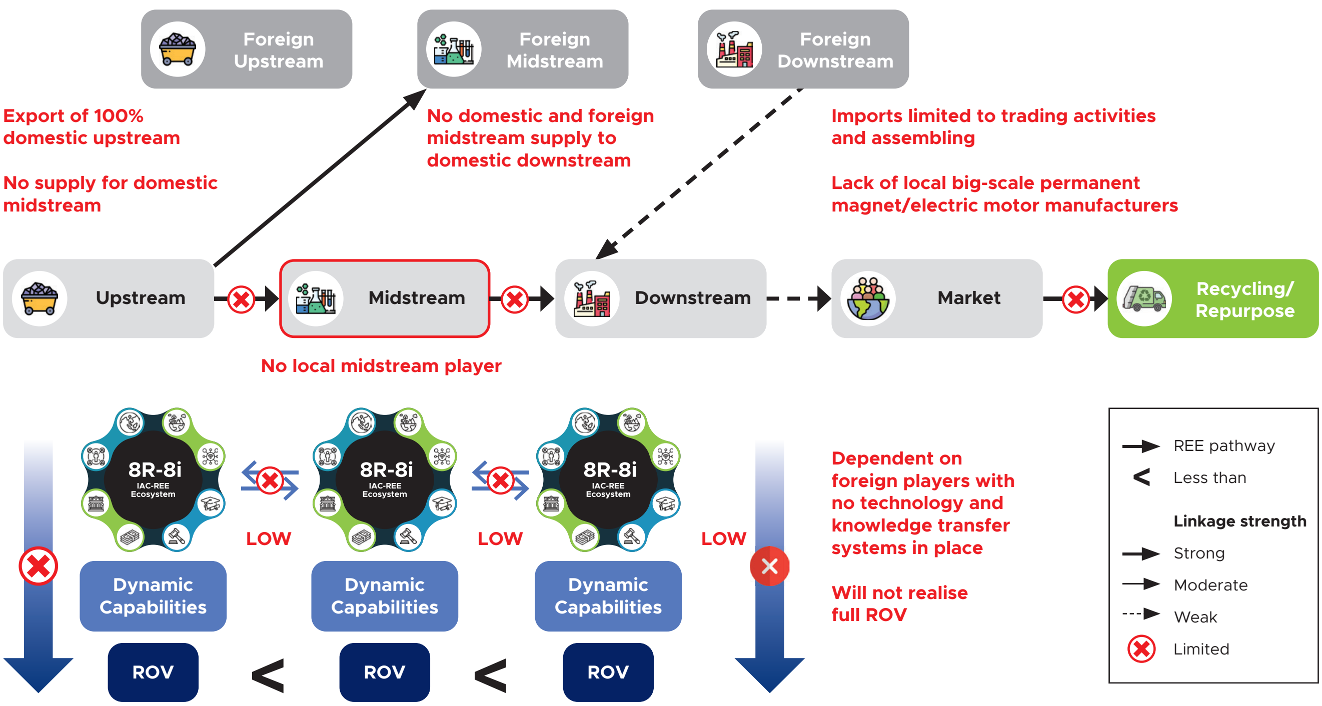


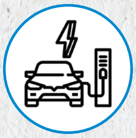
Figure 4.51: Current state of the IAC-REE business value chain (Adapted from Nair et al., 2022)

Note: Analytics by Sunway Institute for Global Strategy and Competitiveness

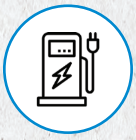
FIGURE 4.52

Canada Rare Earth (RE) Ecosystem

Creating a conducive ecosystem for research, innovation, and smart partnerships to develop the REE industry



$ 1.7 billion is allocated to extend **ZEV purchase incentive programme** until March 2025. Over 150,000 Canadians and Canadian businesses have taken advantage of the incentive (Natural Resources Canada, 2023).



Currently, there are nearly 20,000 **charging stations** at 8,249 charging sites. Additional $ 900 million is allocated to achieve 50,000 EV charges by 2027 (Natural Resources Canada, 2023).

Smart partnerships for EV-related manufacturing:

- Battery plant (JV between LG Energy Solution and Stellantis N.V.)
- Cathode plant (JV between General Motors Co., POSCO Chemical Co. and BASF SE)
- EV plant (General Motors Canada)

Institutions, Integrity, and Incentives

- **Whole-of-Society** approach
- **Government-driven sustainability policies** for energy transition, zero emission vehicles, etc. that drive REE demand
- Foreign investments into state-owned enterprises subject to **intense inspection** and outcomes are made **publicly available** for **transparency** (Science and Economic Development Canada Innovation, 2022)
- **Allocation of $ 3.8 billion** for **Critical Minerals Strategy** for infrastructure, exploration, tax credits, and R&D into responsible extraction and processing, and new innovations through Strategic Innovation Fund (Transport Canada, 2022)

Infrastructure and Infostructure

- Two **REE plants** in Saskatchewan with sustainability targets (private and GLC, respectively) (Messecar, 2022)
- Allocation of **$ 1.5 billion infrastructure** investment for over eight-year period for critical minerals (Transport Canada, 2022)
- **26 R&T parks** housing 1,400 companies and 65,000 knowledge-based workers (AURP Canada, 2017)
- Online directory platform of **800 publicly funded research facilities** open to industry, academia, and government for expertise and services (Research Facilities Navigator, n.d.)

Interaction and Internationalisation

- **Public participation** mechanisms (e.g., citizen assemblies) to allow citizens to understand, deliberate, and decide key recommendations for public policy (Public Service Commission of Canada, n.d.)
- Pledge to UNDRIP to respect and recognise **indigenous peoples' rights** (i.e., indigenous mining agreements, indigenous co-ownership, and impact assessment) (Kung et al., 2022; Natural Resources Canada Government of Canada, 2020)
- Multilateral agreements to build **global research networks** for critical minerals with USA, EU, and Australia (AURP Canada, 2017; Kelly, 2020; Natural Resources Canada, 2020, 2021)

Intellectual Capital

- **BERD** and **HERD** make up a large proportion of GERD (total of $ 40.6 billion), 51.6% and 39.3% respectively, in 2019 (OECD. Stat, 2020)
- **Saskatchewan Research Council** (GLC) is Canada's second-largest R&D organisation, serving 1,400 clients globally. It operates one of two REE mines in Canada (SRC, 2022)
- Four **universities** in top 100 globally (Times Higher rankings)

Figure 4.52: Canada's RE Ecosystem

Note: Analytics by Sunway Institute for Global Strategy and Competitiveness

(AURP Canada, 2017; Kelly, 2020; Kung et al., 2022; Messecar, 2022; Natural Resources Canada, 2020, 2023; OECD Stat., 2020; Public Service Commission of Canada, n.d.; Research Facilities Navigator, n.d.; Science and Economic Development Canada Innovation, 2022; SRC, 2022; Transport Canada, 2022)

In order to migrate from the fragmented IAC-REE business value chain (Figure 4.51) to a more integrated business value chain, as outlined earlier in Figure 4.38, efforts must be undertaken to strengthen the 8R-8i ecosystem enablers for all three sectors and the repurposing/recycling sector. The development of a robust IAC-REE business value chain cannot be left to chance; it has to be developed by design, to ensure that the ecosystem enablers are seamlessly integrated with one another to build strong dynamic capabilities and multiplier effects. The key way forward to developing an integrated IAC-REE business value chain include the following recommendations.

Recommendation 1:

Strengthening institutional governance to ensure the development of seamless integration of the IAC-REE ecosystems

Institutional governance of the entire value chain can be strengthened by incorporating the "Whole-of-Government" and "Whole-of-Society" approach to ensure the buy-in of all stakeholders in the development of the entire IAC-REE ecosystem. There is a need for a dedicated agency[24] with "clout" to provide oversight on the development of the IAC-REE industry. The agency needs to foster strong cooperation and collaboration between the federal government, state governments, industry players (upstream, midstream, and downstream sectors), learning institutions, and community groups to create a conducive environment for the local IAC-REE industry to build strong dynamic capabilities and become globally competitive. This includes ensuring that policies and incentive systems at the state and federal levels are streamlined, harmonised, forward looking, and business- and investor-friendly. Additionally, the agency needs to facilitate high-level coordination between institutional firms to ensure proper implementation of policies and initiatives. A formal citizen participation platform should be established to allow stakeholders the opportunity to understand, deliberate, and co-design policies to improve public trust and support. This should also come in tandem with the strengthening of environmental and social performance of government and industry projects through strict enforcement of environmental regulations and ESG performance metrics.

Recommendation 2:

STIE-driven solutions to foster strong collaborative partnerships among all stakeholders in the IAC-REE ecosystem (chain of custody)

Putting in place a sound STIE strategy, particularly the adoption of the 10-10MySTIE framework, is recommended to develop a chain of custody that can seamlessly integrate, monitor, implement, and refine policies and strategies with respect to the 8R-8i values-based framework and ESG requirements. The previous sections introduced several approaches to chain of custody for the upstream, midstream, and downstream sectors. Moving forward, the 10-10 MySTIE framework was considered due to its holistic

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[24] Refer to the proposed Board of Minerals Development Malaysia (LPMM) in the Blueprint for the Establishment of Rare Earth-Based Industries in Malaysia (2014)

approach that can cover several key technologies, in addition to blockchain technology, to support the use of traceability and accountability systems. Furthermore, MOSTI has already invested resources into implementing initiatives that incorporate the 10-10 MySTIE framework, which include fundings like MOHE grants and MOSTI's Malaysia Grand Challenges. It remains crucial that investment be made to all relevant 10-10 technologies, as blockchain technology requires these necessary auxiliary technologies to perform optimally. An example of a chain of custody framework leveraging the 10-10 MySTIE is shown in Figure 4.53. The chain of custody plays a key role in fostering a strong collaborative platform for all stakeholders across various sectors of the IAC-REE industry and ensuring their adherence to the 8R-8i values-based framework and ESG standards.

The proposed integrated IAC-REE business value chain can be the key catalyst for the country's aspiration of developing a vibrant IAC-REE "circular economy" industry. In this context, the STIE framework contributes the following:

(i) Durable design of technologies derived from rare earth-based products, which can be reused safely and recycled in a way that allows easy removal/treatment of harmful substances.
(ii) Reintegration of end-of-life rare earth-based products and their reintroduction into new components within the value chain.
(iii) Repair and refurbishment of rare earth-based products to provide them multiple lifecycles and for the creation of second-hand markets.
(iv) Introduction of incentives and policies to encourage consumers to recycle end-of-life rare earth-based products, instead of disposing them at waste dumpsites.
(v) Invest in advanced recycling technologies and increase incentives for the integration of recycled rare earth-based products into new products.
(vi) Invest in advanced recycling technologies that extract high-value minerals from end-of-life rare earth-based products and maintains them at high quality.
(vii) Improve existing recycling programmes and facilities (e.g., BuyBack centres and e-waste collection centres).
(viii) Introduce and incentivise extended producer responsibility (EPR) and design for recycling to include producers in recycling efforts.
(ix) Strengthen the enforcement of Act 672 that mandates every household and business to segregate waste at source.

FIGURE 4.53

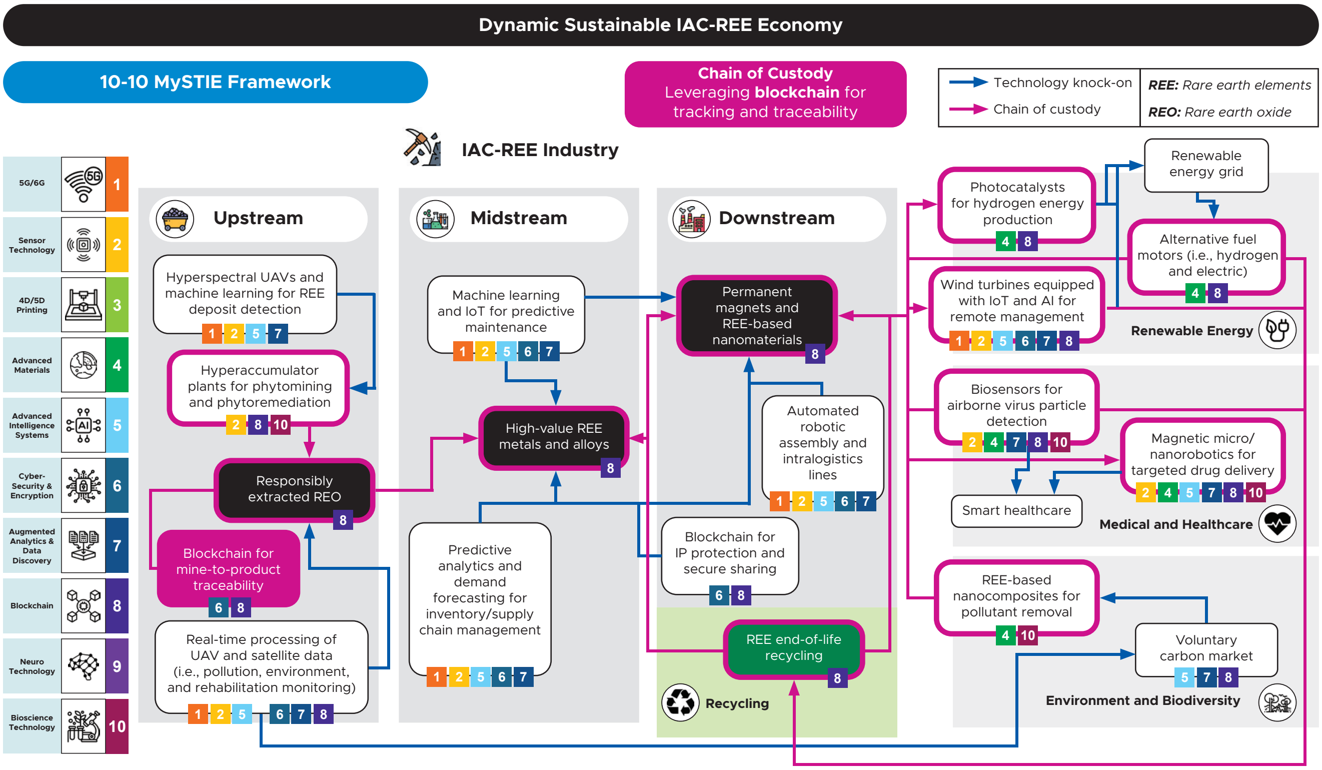


Figure 4.53: Chain of custody aligned to the 10-10MySTIE framework

Recommendation 3:

Economic and financial resources to develop an integrated IAC-REE business value chain

Adequate resources are critical as support for the firms and other stakeholders to enhance the enablers of the ecosystem in building strong dynamic capabilities and improving their ROVs. In this context, comprehensive economic and financial resources should be introduced for the sectors within the IAC-REE industry, which include the following:

(i) *Infrastructure and logistics support:* More investments are allocated to develop seamlessly integrated transportation infrastructure and logistics support system for efficient transportation of IAC-REE materials from mining sites and processing facilities to manufacturing centres, including their integration with advanced technologies, such as Industry 4.0 technology.

(ii) *Investment in talents, capability development, and CEPA programmes:* The creative workforce across all sectors of the IAC-REE ecosystem is critical for the successful development of an integrated IAC-REE business value chain. There is a need to increase investment in technical expertise (TVET and STEM areas) for all three sectors, as well as to nurture talents with multidisciplinary skill sets that can operate across different sectors. These skill sets are critical to ensure seamless integration of operations across the three sectors. Additionally, these investments should be channelled into non-STEM areas, particularly in business development, entrepreneurial skillsets, community development, and cross-cultural competence. Talents in these areas are critical to ensure firms operating in the local ecosystem have the cultural savviness to engage with local communities in the design and development of local projects, such as developing CEPA programmes to minimise conflicts with the indigenous population and address concerns from NGOs and civil society.

(iii) *Investment risk management systems:* Financial institutions should ensure mandatory and voluntary risk management meet ESG requirements when assessing investments related to the IAC-REE industry. This will play a key role in firms incorporating environmentally friendly technologies, practices, and business models for the mining, processing, and production of IAC-REE products and services. The government can play a key role by mandating financial institutions to put ESG compliance requirements in place for major IAC-REE investment plans.

(iv) *Biodiversity and environmental offsets:* These schemes should be introduced to compensate unavoidable IAC-REE development projects that contribute to the degradation of the environment. These offsets can be a key instrument for raising financing in rehabilitating mining sites that have had adverse effects on the biodiversity of the ecosystem. The offsets should be incorporated in all IAC-REE development projects; so that adequate funding is available for revitalising the environment long after the IAC-REE development project is completed.

(v) Strategic R&D funding: Given how critical the IAC-REE industry for the development of major technologies and other economic sectors, the government should prioritise this industry's receipt of national R&D funding. These investments should be directed to the development of innovative mining and processing of IAC-REE materials that are environmentally friendly and meet ESG standards, such as advanced recycling technologies that can create a vibrant “circular economy” within the IAC-REE industry.

(vi) *ESG compliance support for SMEs*: Financial support (e.g., tech financing, R&D grants, and tax incentives) is allocated to firms, especially SMEs in the industry, that comply with the ESG requirements.

(vii) *Attract high-end FDIs:* The government and industry should work closely to develop strategies to attract high-end FDIs into the IAC-REE industry, especially foreign technology-intensive players, to use Malaysia as a “test-bed” for the development of advanced technologies in the mining of IAC-REEs, recycling, processing plants, and development of products like magnets, batteries, and other applications derived from IAC-REE. In this context, government agencies, such as MIDA, should intensify and focus on the incentives for the IAC-REE industry, incorporating the strong elements of knowledge and technology transfer to local players in the ecosystem.

(viii) *Sustainable supply chain support:* The sustainability of the IAC-REE industry is dependent on the incorporation of ESG standards across the entire value chain (chain of custody). This involves major financial investments in technology, regulatory architecture, development of standards and certifications, innovative financial support systems and architecture, and capability development programmes. Investments should be channelled not only into technologies but also a wide range of expertise within the sectors of the IAC-REE industry, involving inter-operability skillsets that can seamlessly integrate operations across the entire value chain.

4.7.8 Scenario Planning and Critical Path Mapping – Staged Development of the Local IAC-REE Business Value Chain

This subsection presents the scenario planning and critical path mapping on the staged development of the integrated business value chain for the IAC-REE industry. The development is segmented into two periods: a short- to medium-term horizon from 2024 to 2030, and a long-term horizon from 2031 to 2050.

i. Short-to medium-term horizon (2024 to 2030) – Building the foundation conditions (regional hub):

The development for this time horizon primarily focuses on establishing the foundational conditions to build strong dynamic capabilities and position Malaysia as a regional hub for the IAC-REE industry. To achieve this, the focus lies on the following proposed initiatives (Figure 4.54):

(a) Introduce comprehensive incentive and government support systems (as outlined in Recommendation 3) to increase the number of local players in all sectors within the IAC-REE business value chain.

(b) Strengthen the 8R-8i enablers of all sectors of the IAC-REE industry for local firms in all sectors to build strong dynamic capabilities that enable the generation of higher ROVs.

(c) Strengthen cross-linkages between the sectors to create network externalities and strong multiplier effects.

(d) Provide incentives and support to the local upstream sector to ensure a large portion of the generated raw minerals are channelled to the local midstream sector to create viable supply systems for the local midstream and downstream sectors. These incentives are to develop larger and more dominant local players that horizontally and vertically integrate both upstream and midstream operations.

(e) Put in place globally competitive investment (FDI) schemes to attract leading international players to use Malaysia as a "test bed" for the development of next-generation solutions and technologies in all sectors of the IAC-REE industry – a strong push towards the transfer of technology and knowledge to local players and supply chain through relevant schemes.

(f) Improve the domestic recycling and repurposing supply chain for a circular IAC-REE industry, including improving the existing recycling network (e.g., facilities, programmes, logistics, and awareness) and increasing research and innovation on recycling technologies for improved efficiency and cost-effectiveness.

FIGURE 4.54

IAC-REE Business Model, 2024–2030 (Proposed)

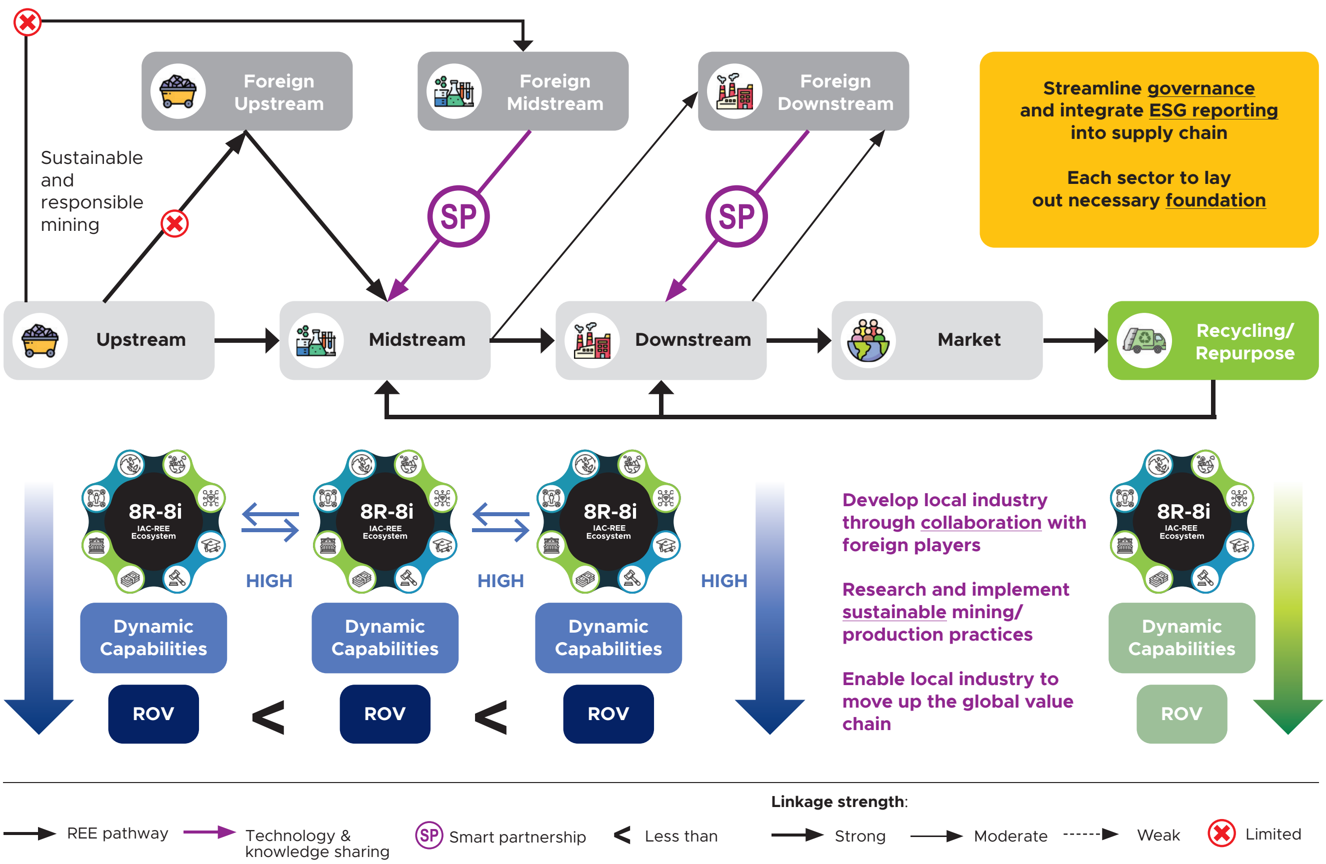


Figure 4.54: Short- to medium-term (2024–2030) development of the IAC-REE business value chain (Building the foundation conditions – regional hub)

Note: Analytics by Sunway Institute for Global Strategy and Competitiveness

ii. **Long-term horizon (2031 to 2050) – Moving up the global value chain:**

In this time horizon, the focus lies in the development of the IAC-REE industry as a key enabler of a world of net zero (decarbonised economy). In this context, the local IAC-REE industry becomes a major source for the IAC-REE ecosystem services, process manufacturing, and new product development. In order to continuously move up the global innovation value chain, the following initiatives should be undertaken (Figure 4.55):

(i) Expand the pool of REE resources; by encouraging Malaysian firms to invest in other markets that are rich in these valuable natural resources.

(ii) Transform the local refining and processing sector (midstream IAC-REE) into a leading hub in the region with state-of-the-art environmentally friendly technologies with the capacity to provide cost-effective services to other upstream players in the region.

(iii) Ensure that FDI incentive schemes, technological infrastructure, and talent management plans are globally competitive to intensify strong strategic partnerships and positive spill over impact between local and foreign players in both the midstream and downstream sectors at the higher end of the value chain design and development of next-generation technologies for all IAC-REE sectors, including the development of a strong recycling/repurposing market.

FIGURE 4.55

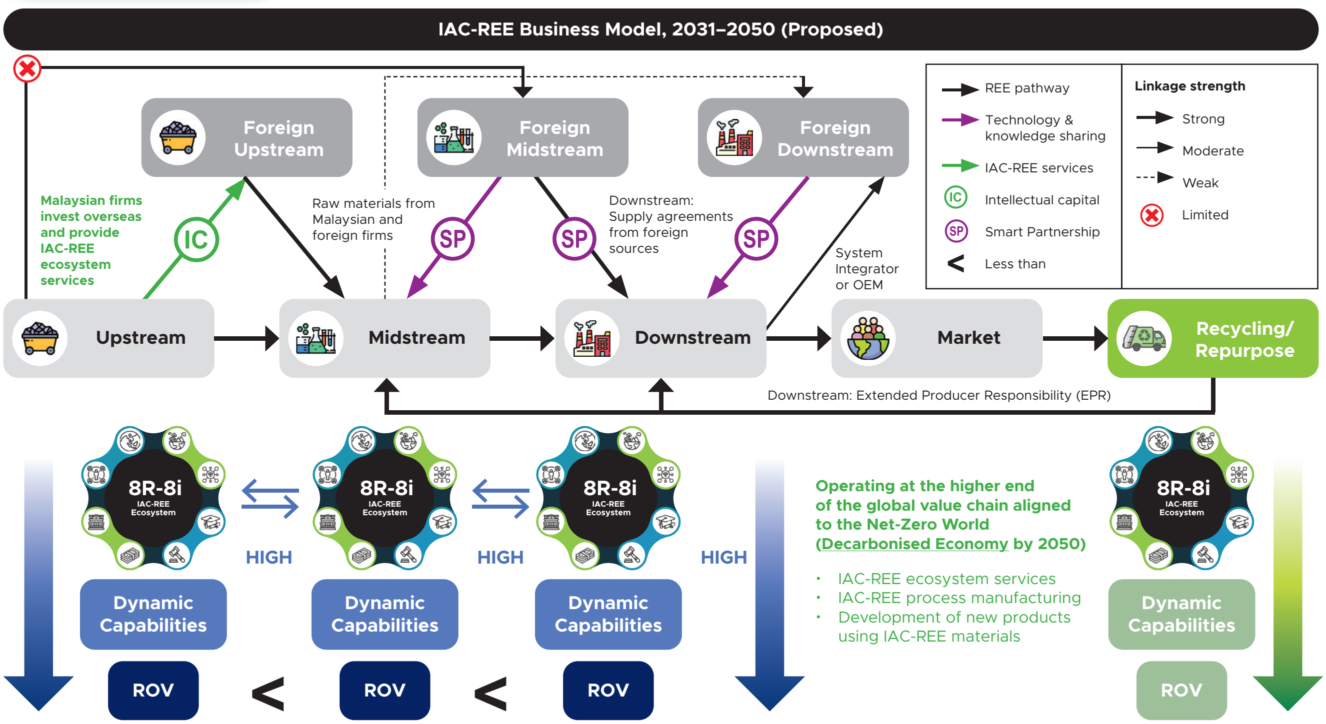


Figure 4.55: Long-term (2031–2050) development of the IAC-REE business value chain (Moving up the global value chain)

Note: Analytics by Sunway Institute for Global Strategy and Competitiveness

Firstly, the foundational conditions for a sustainable IAC-REE supply chain must be in place. The upstream and midstream sectors should establish a sustainable supply of IAC-REE to attract FDIs through smart partnerships. These partnerships would then support high-value products and services and domestic capability building within the downstream sector. However, to prevent unfettered development and severe environmental effects, as seen in other regions like China and Myanmar, strong governance and integrity systems must be in place to ensure transparency and accountability. The IAC-REE industry must meet not only strict local and global environmental standards but also foster the peoples' support and trust. A mechanism used in Canada, Australia, and several countries in the EU involves citizen participation, whereby key stakeholders are provided the opportunity to understand, deliberate, and co-design policies and initiatives.

The second crucial component involves increasing research and innovation on IAC-REE technologies and related high-value adding and sustainable applications. The study report focuses on permanent magnets and the EV segment, but the proposed business model should not be limited to this segment. Due to the wide-ranging applications of REE (e.g., medical, consumer electronics, and energy), innovations in downstream products and services can help create positive spillover effects across key economic sectors and help cement IAC-REE as a vital enabler of revenue generation for the country. Such an endeavour would require learning and research institutions to supply the IAC-REE industry with a sustainable pipeline of experts and skilled talents through programmes co-developed with industries.

The industry should be sustainable and circular while it ensures a stable supply of extract IAC-REE. For instance, IAC-REE extraction requires research and expertise in sustainable/responsible mining practices and technologies to ensure minimal impacts on the surrounding environment and local communities. As the business model covers the entire value chain, this rationale applies to post-consumer IAC-REE products and services – leveraging existing recycling programmes and facilities. However, recycling rates must be increased by improving existing facilities and programmes, increasing CEPA, strict enforcement[25], and ensure policies share recycling responsibilities with producers (e.g., extended producer responsibility). Additionally, innovations must address the efficiency and cost-effectiveness of recycling/repurposing processes and technologies; as even with environmentally sensitive consumers, the higher price points of sustainable/recycled products remain a primary barrier to adoption.

Although the business model is delineated into two horizons (short-to medium-term and long-term), it is a continuous process. The first stage is intended to address the systemic gaps within the IAC-REE ecosystem (as described in Section 4.7.8) to create the necessary foundation for sustainable growth. Only with that will the IAC-REE industry move to the next stage that generates the highest ROV and contribution to GDP. In this context, ROV includes wealth generation through high-income jobs, environmental and biodiversity protection, circular economy, and green technologies that support global decarbonisation efforts. Such a value chain can help differentiate the Malaysian IAC-REE industry from global players, as being a circular, sustainable mine to product supply chain.

[25] Household and business premise owner segregation of waste at the source is compulsory under the Solid Waste and Public Cleansing Management Act 2007 (Act 672).

4.7.9 **Economic Returns**

An integrated IAC-REE business value chain can be the catalyst to enhance the multiplier effects and positive network externalities of the IAC-REE industry, and across other economic sectors in the country. Through the adoption of a planetary health approach (aligned to the 8R-8i values-based framework) that reinforces the importance of sustainable and responsible development, the IAC-REE industry is estimated to contribute RM 8 billion to the country's GDP in 2030, with a cumulative GDP of RM 28 billion from 2025 to 2030 (Figure 4.56). With the continuation into Phase 2 of the business model, constituting the largest projected contribution, the IAC-REE industry would have contributed RM 48 billion to GDP in 2050 – an additional 1% in GDP to Malaysia's economy. The cumulative GDP from 2031 to 2050 would be RM 545 billion.

FIGURE 4.56

IAC-REE GDP Contribution Estimates (2025-2050)

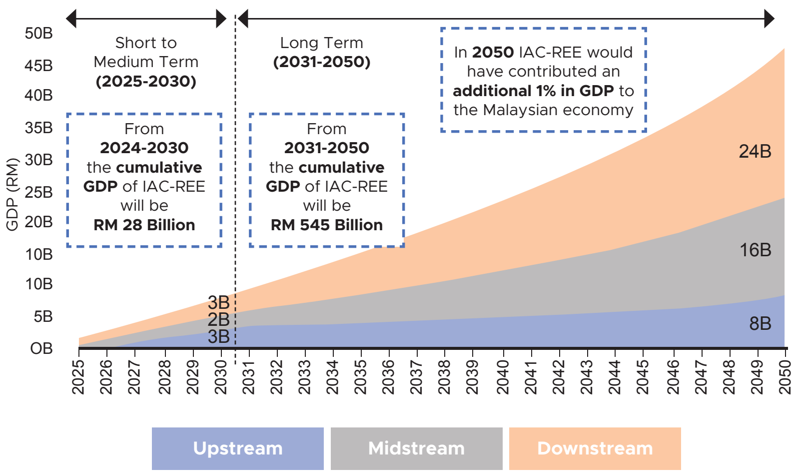


Figure 4.56: IAC-REE GDP contribution estimates (2025–2050)

Notes: IAC-REE GDP contribution was estimated using advanced econometric methods (Auto-Regressive Distributed Lag – ARDL model) and the Cobb-Douglas Production Function GDP = f(L, K, A), where L is the labour employed by the IAC-REE sector; K is the investment for the IAC-REE sector; A is the total factor productivity (TFP) or technological progress for the overall sector. Estimating the TFP for IAC-REE specifically was deemed not possible due to the lack of data. In order to overcome this limitation of the TFP for the upstream sector, the TFP for the overall mining sector was used in this study. As for the midstream and downstream sectors, the TFP for the manufacturing sector was used in the study. The figures for L and K were provided by experts in upstream, midstream, and downstream sector working groups as targets for 2025, 2030, and 2050. The data series were then interpolated using the compounded annual growth rate (CAGR) between the target figures. The full details of the target figures are available in the upstream, midstream, and downstream sector Working Group Sectoral Reports. The GDP contributions of the upstream sector were modelled using the model derived for the mining sector. On the other hand, the GDP contributions of the midstream and downstream sectors were modelled using the model derived for the manufacturing sector. This was done to ensure that nature of the IAC-REE streams are aligned to DOSM's sectoral classifications. *Analytics by: Sunway Institute for Global Strategy and Competitiveness, Sunway University based on data from mining and manufacturing sector labour, capital, and GDP, Department of Statistics Malaysia (DOSM); IAC-REE contribution, downstream working group analysis with employment and investment figures from expert panels from Upstream, Midstream, and Downstream Sector Working Groups.*

4.7.10 Fast Tracking to Achieving the National Targets

In order to ensure that the nation is not left out from the global and local rare earth markets, more so considering the fact that soon it would begin to produce heavy rare earth elements (HREE) from its own IAC-REE resources, there is an urgent need to fast track this strategic industry, beginning from 2024 (Figure 4.57). In fast-tracking the industry, the study report identified and proposed three term periods as follows:

SHORT-TERM	MID-TERM	LONG-TERM
2024 – 2025	2024 – 2030	2031 – 2050

With these proposed time frames, it is evident that, for Malaysia's IAC-REE industry to take off, the proposed recommendations (Chapter 5) must be implemented within the short-term period in order to take full advantage of the demand for REE upstream, midstream, and downstream products.

It is noted that the short and medium-terms begin simultaneously in 2024 to ensure that all objectives identified in Chapter 4 do take off concurrently. This also suggests that the Committee for the Development of the Rare Earth Industry (ComDREI), proposed to be chaired by the Chief Secretary to the Government (KSN), expected to be formed in 2024 to begin its recommended tasks by implementing the following steps and the overall 15 recommendations (as listed in Chapter 5):

(i) To monitor the progress of implementation of the strategic rare earth-based industries (covering the upstream, midstream, and downstream sectors)
(ii) To evaluate the progress of the implementation of strategies identified across three sectors and to propose measures to overcome challenges faced by the government agencies and/or the respective industries
(iii) To report to the NMC on the progress and challenges faced, as well as the ways to overcome these challenges

FIGURE 4.57

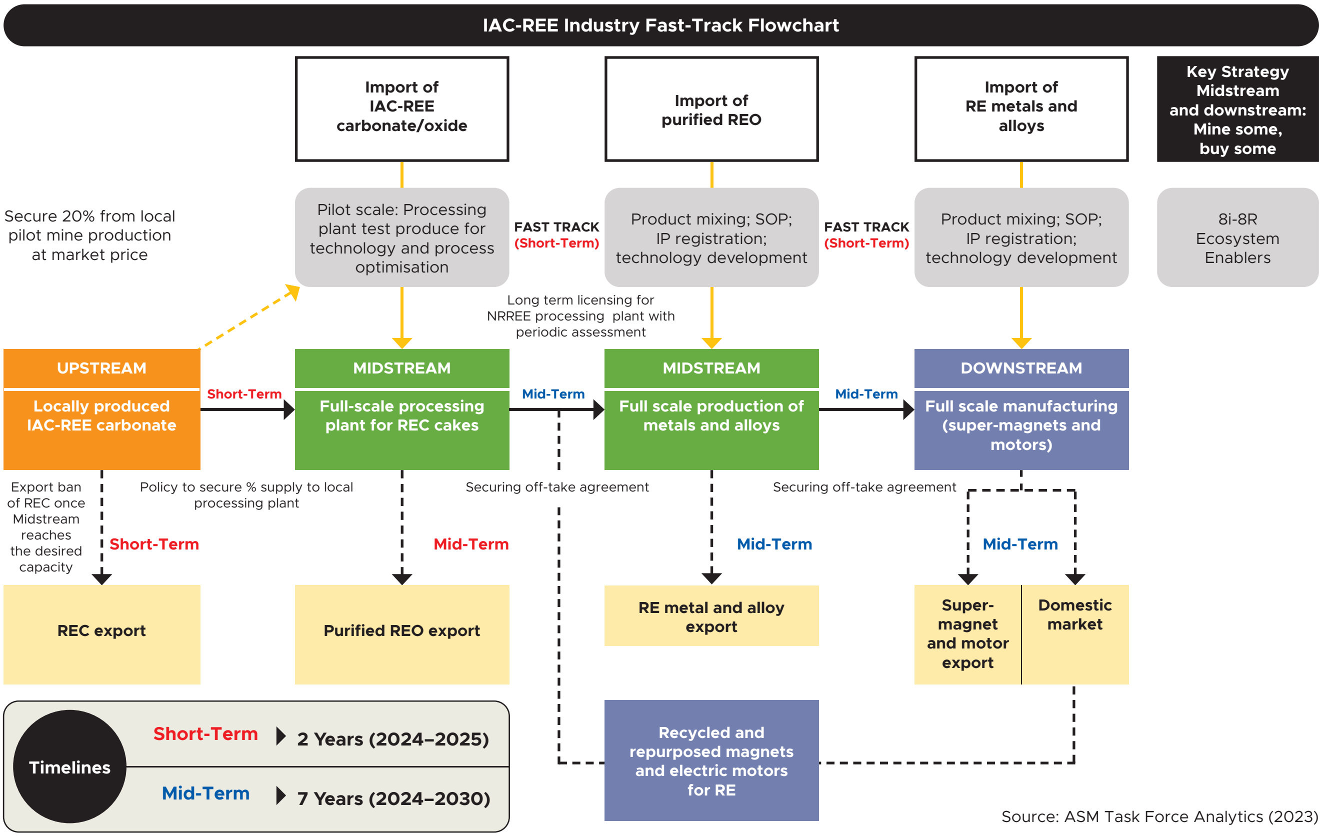


Figure 4.57: Fast-tracking the strategic REE industry

Reference: National Advanced Material Roadmap 2021-2030; TIM 2021-2030

Details of this federal-level committee and its proposed functions are presented in Chapter 5. The fast-track programme (shown in Figure 4.57) shows the sectoral roles, which are further described as follows:

(i) Upstream sector

Its main role is to produce the REC cakes from the local IAC-REE resources within the short-term period (2024–2025). REC cakes are explicitly forbidden to be exported once the local midstream sector's REPP is fully functional. The policy in place should ensure the security of supply to the local REPP. In the interim period (while awaiting the completion of the REPP), it is recommended that at least 20% of the REC be bought at the market price for use in R&D by the midstream sector. In ensuring that the REC cakes are from legal mines, they have to be tagged for tracing and tracking at the mine site by the miner and monitored by PTG/JMG.

(ii) Midstream sector

This sector plays a dual-role – it undertakes the full-scale processing of the tagged, local REC cakes for the separation and purification of rare earths as REOs (both LREEs and HREEs) within the mid-term period (2024–2030). The construction of the proposed REPP would need 36 months. The second role involves the manufacturing of rare earth metals and alloys for the downstream sector within this period. If there are insufficient local REC cakes, REPP should be allowed to source these cakes from external sources. However, it needs to ensure that the cakes are from certified sources that have been produced legally and sustainably in accordance with the local regulations.

If the local metals and alloys manufacturing plants are not ready, REOs may be exported (similar to what Lynas Corporation Ltd undertakes). Excess rare earth metals and alloys may also be sold to these foreign markets in the event that the downstream sector is not ready to purchase rare earth alloys to manufacture magnets and electric motors.

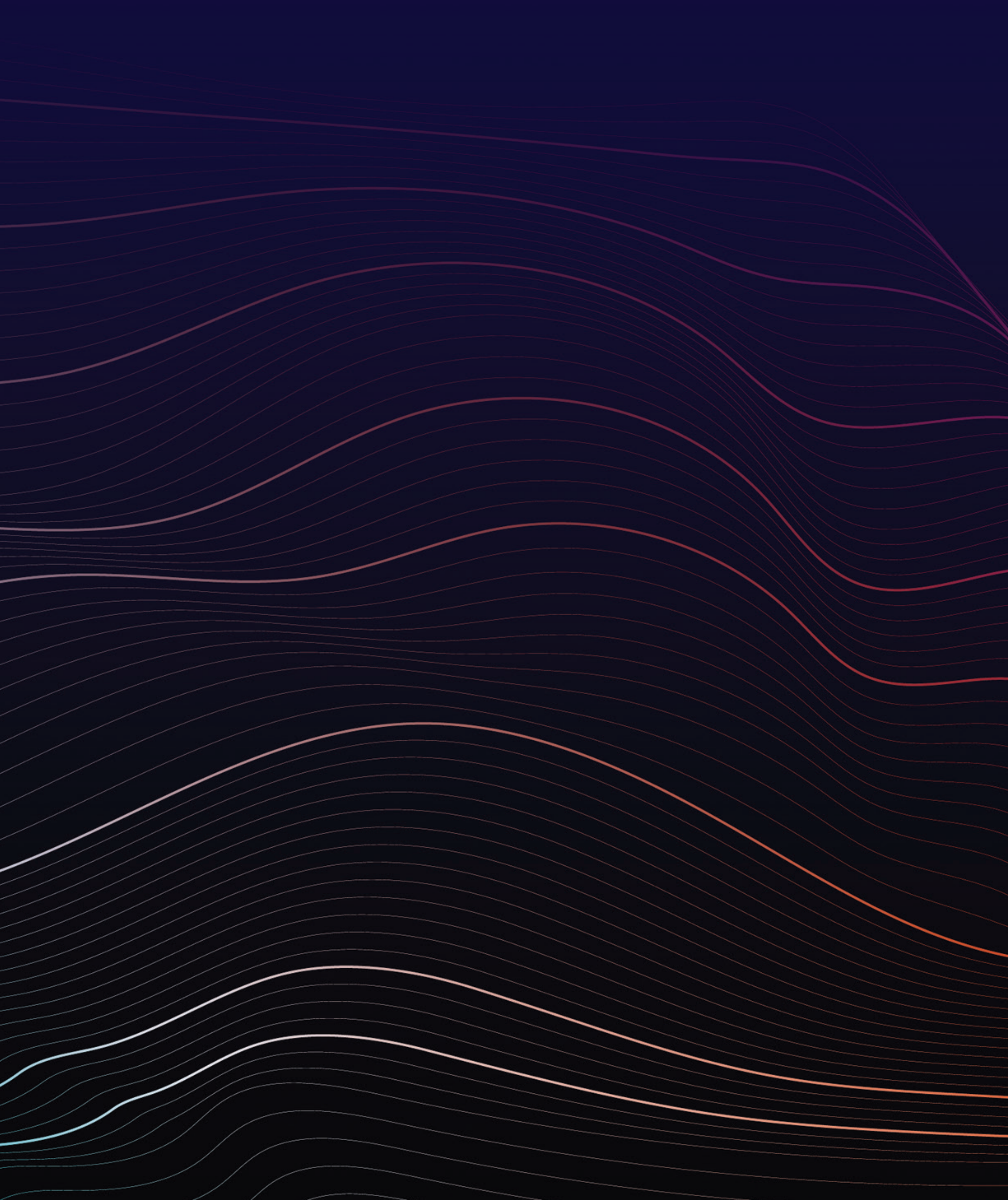
(iii) Downstream sector

This sector plays the role of manufacturing super-magnets and electric motors during the mid-term period (2024–2030), both for the domestic market and for export with priority being given to the domestic market needs.

(iv) Recycling/repurposing of used magnets and electric motors

Currently, the activities of recycling and repurposing magnets and electric motors in Malaysia are underdeveloped since these commodities are new. With the emphasis on circular economy given by the government in 12MP, it is timely for entrepreneurs and businesses to take advantage of the market to recycle and/or repurpose used rare earth products, more so with the opening up of the automobile industry to EVs.

Six industries comprising (1) the plant for the production of purified REOs, (2) the plant for the manufacturing of rare earth metals, (3) the plant for the manufacturing of alloys, (4) the plant for the manufacturing of super-magnets, (5) the plant for the manufacturing of electric motors, and (6) the plant for the recycling/repurposing of used magnets/electric motors are recommended to be sited at the MRTP to achieve, among other national objectives, the objectives of the circular economy.



5

CHAPTER

RECOMMENDATIONS AND CONCLUSION

5.1 Major Recommendations

The study proposed 14 major recommendations.

(i) Recommendation 1:

Establish a ComDREI at the federal level, with similar committees at the state level

The IAC-REE industry needs to be fast-tracked, so as not to lose out to competitors in the region and also not to be overtaken by rare earth substitutes coming into the market in the future. Therefore, a high-level committee is needed to drive this industry.

The NMC, chaired by the YAB Deputy Prime Minister, is the highest-level national entity best placed to drive this industry. However, this council, with members drawn up of ministers from related ministries and the chief ministers nationwide, is set up basically to approve policies proposed by the members. It should be noted that the country has a window of opportunity of just 10 years; therefore, it is proposed that a committee of ComDREI is established at the federal level to fast-track the industry. This committee is to report to the NMC.

The ComDREI's proposed objectives are as follows:

(i) To monitor the progress of implementation of the strategic rare earth-based industries (covering the upstream, midstream, and downstream sectors)
(ii) To evaluate the progress of the implementation of strategies identified across three sectors and to propose measures to overcome challenges faced by government agencies and/or the respective industries
(iii) To report to the NMC on the progress and challenges faced, as well as the ways to overcome these challenges

The proposed memberships are as follow:

(i) Relevant ministries
(ii) State governments
(iii) Industry consortium, consisting of foreign and local industry players, that would be formed once the industry is established

ComDREI is proposed to be chaired by the Chief Secretary to the government (KSN). The Secretariat staff should be drawn from the NRES (for the upstream sector) and MITI (for the midstream and downstream sectors) since the rare earth industry cuts across both ministries. The roles of the Secretariat are as follows:

(i) To collect and compile all the industry data
(ii) To analyse the data related to IAC-REE industry
(iii) To review the progress at the federal and state levels and table it to the committee for its review and course of action

It is further recommended that, at the state level, a similar committee be established, chaired by the state secretary, with membership drawn from the relevant state agencies. This Secretariat can be housed at the state's Economic Planning Unit. It is also proposed that the ComDREI organises the meeting at least twice a year. An advisory panel shall be established to advise the committee on technical matters related to the rare earth industry. The advisory panel should have its membership drawn from the ASM, selected private sector, the academia, Malaysian environmental NGOs, and international experts.

FIGURE 5.1

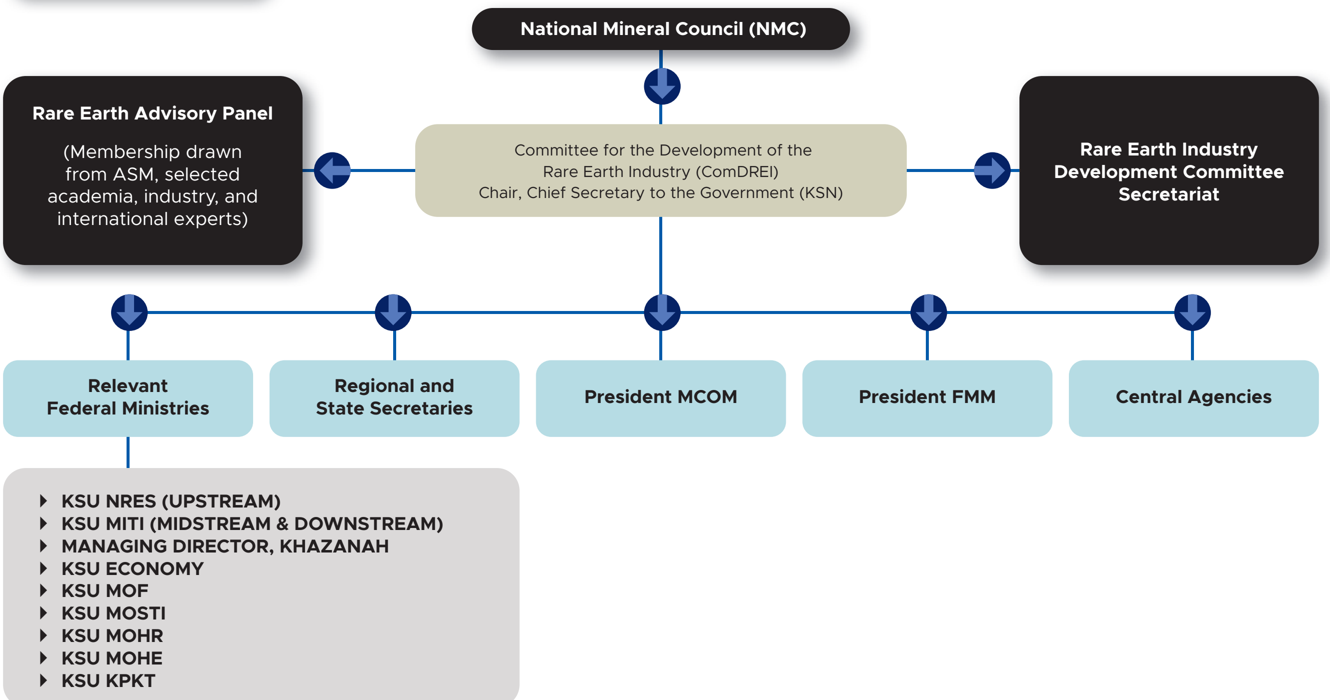


Figure 5.1: Proposed committee for the development of rare earth industry (ComDREI)

(ii) Recommendation 2:

NRES and relevant ministries at federal and state levels to jointly develop a strong communication, education, and public awareness (CEPA) programme

It is recommended that the joint ministry commissions a local industry-knowledgeable public relations firm with the necessary experience and expertise to develop a CEPA programme on a regular basis. The target audience includes parliamentarians, ADUN, local authorities, Orang Asli/ Orang Asal communities, NGOs, and CSOs. The CEPA programme communicates effectively on the extraction of rare earth resources, as well as the processing and manufacturing of the products. The ministries would also need to appear on various TV programmes to provide descriptions of the whole rare earth ecosystem. The CEPA programme should not be limited to distributing pamphlets containing FAQs only. Scripts for short videos to be shown on TV and other media should also be developed.

(iii) Recommendation 3:

Strengthen institutional governance to ensure the development of seamless integration of the IAC-REE (upstream, midstream, and downstream sectors) ecosystems.

As the IAC-REE is a strategic national resource, it is recommended that ComDREI reviews the objective of strengthening the institutional governance of various federal regulations of the ministries, covering the resources' upstream, midstream, and downstream sectors; to ensure that this industry is fully facilitated to run smoothly without administrative encumbrances.

(iv) Recommendation 4:

Provide sustainable economic and financial resources to develop an integrated IAC-REE business value chain through a comprehensive incentive system that supports a technology- and knowledge-driven IAC-REE industry, nurtures creative talents, and strengthens the domestic IAC-REE supply chain.

MOF should consider providing sustainable economic and financial resources to NRES and MITI, when necessary, to develop an integrated IAC-REE business value chain and ensure its continued development.

(v) Recommendation 5:

Set up a MRTP that is inclusive of a REPP, a metals and alloys manufacturing plant, a super-magnets and electric motors manufacturing plants, as well as a reprocessing and repurposing plant for the recycling of used super-magnets and electric motors.

A fully integrated MRTP should be established to house a REPP and a metals and alloy production plant to facilitate the development of the downstream sector. The MRTP is ideally placed in the environs of car manufacturing plants. By building from the drawing board up, the MRTP would incorporate ESG perspectives, employing state-of-the-art, environmentally friendly technologies, such as solar power, rainwater harvesting, AI communications and security systems, power grid control, water supply, water, and waste management systems.

It is anticipated that, at a steady state, the total production capacity of the Malaysian IAC-REE from all states could achieve 70,000 tonnes of REC, containing 30,000 tonnes of TREO per year. Therefore, a REPP with an annual processing capacity of 70,000 tonnes of REC would need to be set up in the MRTP, producing 30,000 tonnes of purified REO, including 10,000 tonnes of Nd/Pr oxides. MRTP should include areas for the manufacturing of super-magnet, component modules, EVs, and end-user products. The estimated capital costs for setting up a REPP with the production capacity of 70,000 tonnes per year would be RM 1.76 billion. MRTP would be promoted as a global hub that supplies rare earth-based products. FDI would be drawn in for the setup of more factories and research facilities in the MRTP. The MRTP should be a joint investment by the federal and state governments, as well as the private sector. State governments should be encouraged to invest in the REPP in order to capture some of the benefits of the midstream processing.

After the approval of MRTP by ComDREI and the government, while it is in the process of being developed at the designated site, it is recommended that MITI executes the following:

(i) Invite reputable local firms with the necessary expertise and technical knowledge to submit proposals to establish a REPP for the processing of REC bought from mining firms into purified REO (in the event that the REPP's capacity cannot be fulfilled by the local mining firms, it should be allowed to purchase RECs from legal mines overseas). The main objective of the REPP is to produce purified REO from REC bought from the local mines. The REPP would produce REO required for the manufacturing of magnets, and it should be allowed to sell the products to local or foreign firms with the priorities for the domestic market.

(ii) Invite reputable foreign firms with the necessary expertise and technical knowledge, preferably in joint venture with local firms, to establish a rare earth metals and alloys manufacturing plant using the purified REO. The objective is to manufacture specific rare earth metals and alloys for sale to the super-magnet manufacturing plants established at the MRTP.

(iii) Invite reputable foreign firms with the necessary expertise and technical knowledge, preferably in joint venture with local firms, to submit proposals for the establishment of a rare earth super-magnets manufacturing plant using the rare earth alloys manufactured in the MRTP (or purchased from overseas if the local production capacity is insufficient);

(iv) Invite reputable local firms in joint venture with foreign firms, equipped with the necessary expertise and technical knowledge to submit proposals for the establishment of a rare earth-based electric motors manufacturing plant using the rare earth alloys/magnets manufactured in the MRTP (or purchased from overseas if the local production capacity is insufficient).

In line with the 12MP's emphasis on circular economy, the establishment of a reprocessing and repurposing plant at the MRTP is recommended, with the objective of collecting and reprocessing/repurposing used super-magnets and electric motors. In order to fulfil this objective, MITI can begin to invite reputable local firms in joint venture with foreign firms, equipped with the necessary expertise and technical knowledge to submit proposals for the establishment of the plant.

(vi) Recommendation 6:

Set up a REC central buying house.

Apart from the high HREE content, REC from IAC mines are critical sources of Tb and Dy, which currently fetch high prices. With the demand growth of high-temperature magnets, Tb and Dy would become a critical high-tech commodity in near future. It is proposed that a central buying house is set up as a GLC to purchase all REC produced from Malaysian upstream mines, as well as to procure legal and sustainable REC from other countries that are developing IAC mines (Myanmar, Laos, Vietnam, Thailand, Uganda, DRC, Brazil, and Chile). The central buying house would then sell the REC to the local midstream sector plants for refining (into metals) and later the manufacturing of alloys, with the set up in MRTP. Building up a stock of critical high-tech commodity would put Malaysia in a strong position in the rare earth magnets supply chain.

(vii) Recommendation 7:

Conduct government-to-government (G2G) negotiations to obtain necessary technology and knowledge transfers (e.g., China, Japan, South Korea, Australia, and the USA).

It is recommended that MITI and KLN jointly engage on a G2G basis with China, Japan, South Korea, Australia, USA, and other countries to obtain the necessary rare earth-related technology and knowledge, as well as human resource development.

(viii) Recommendation 8:

Ensure that the federal ministries and agencies as well as state governments, in any collaboration/agreement made with foreign investors, insert a condition for local talent development and technology transfer.

It is recommended that the relevant federal ministries and state governments insert a condition in any collaboration/agreement made with foreign investors regarding the local talent development in the IAC-REE industry. This would ensure that the villagers and communities living in the vicinity of the industrial area are given preference for employment. At the same time, TVET graduates are given the opportunities for employment and continuous upskilling.

(viiii) Recommendation 9:

Ensure the appointment of NRES as the lead agency that formulates and manages the incentives for the exploration and mining of strategic critical technology minerals.

It is recommended that NRES is appointed as the lead agency that formulates and manages the incentives for the exploration and mining of strategic critical technology minerals. This recommendation is further strengthened when it is considered that JMG, the department that is responsible for mineral exploration and mining (although minerals are under the state's purview), is assigned under NRES.

(x) Recommendation 10:

Ensure the setup of a cross-ministerial one-stop centre by NRES that contains the latest REE information.

It is recommended that NRES sets up a cross-ministerial one-stop centre that contains the latest REE information, which are to be updated on a regular basis.

(xi) Recommendation 11:

Introduce science, technology, innovation, and economy (STIE)-driven solutions to foster strong collaborative partnerships among all stakeholders in the IAC-REE ecosystem, putting in place a robust chain of custody anchored on the 10-10MySTIE, as outlined in the 12MP.

It is recommended that ComDREI initiates discussions with the relevant ministries to introduce STIE-driven solutions using 10-10 MySTIE technologies to ensure a strong chain of custody that can foster strong collaborative partnerships among all stakeholders within the IAC-REE ecosystem. Establishing a strong chain of custody is necessary to trace and track the resources easily from the point of extraction to the production of super-magnets and electric motors. Simple but cost-effective RFID and QR codes can be implemented during the interim period.

(xii) Recommendation 12:

NRES to designate Mineral Research Centre (PPM), under JMG, as the Rare Earths R&D national focal point to coordinate Rare Earths R&D with universities and research institutes under sustainable regular research grants and necessary funding.

It is recommended that NRES designates PPM JMG, as the country's rare earth focal point and provides sustainable research grants and funding to purchase the needed assets and facilities for R&D. PPM would serve as the focal point and coordinate the R&D activities of all universities and research firms/institutes on REE. PPM's added objectives involve undertaking R&D on REE extraction (with the emphasis on environmentally-friendly green methodologies) and REE separation technologies, as well as innovative and cost-effective technologies for the production of HRE metals and alloys.

(xiii) Recommendation 13:

Collaborations of TVET, universities, and industries to provide upskilling courses through micro-credential or stackable modular units

It is recommended that MOHE, MOHR, and MITI initiate joint discussions to facilitate collaborations involving TVET, universities, and the rare earth industry in providing upskilling courses through micro-credential or stackable modular units.

(xiv) Recommendation 14:

Ministry of Higher Education (MOHE) to initiate cooperation between faculties in universities to offer rare earth-related courses in geology, mining, metallurgy, mineral processing, and chemical engineering in order to produce talents knowledgeable about REE resources.

It is recommended that MOHE initiates or facilitates cooperation involving geology, mining engineering, metallurgy, mineral processing, and chemical engineering faculties in universities to produce geologists, mining engineers/mineral processing engineers, and chemical engineers who are knowledgeable about REE for the IAC-REE industry.

5.2 Sector-Specific Recommendations

Five sectors have put forward 85 recommendations, which are presented in the following subsections.

5.2.1 Upstream Sector

The upstream sector employed the 8i's ecosystem approach to develop 28 recommendations as follows:

i. Infrastructure

(i) JMG to step up both follow-up and reconnaissance investigations on the anomalies identified during the JMG-ASM (2014) survey and the 11MP reconnaissance survey
(ii) Government to provide sufficient funding for these investigations
(iii) Government to provide incentives for the private sector to invest in detailed investigations and feasibility studies in order to upgrade resources to the reserves status and subsequently, mine the resources
(iv) Prioritise other areas, apart from PFR and ESA, for IAC-REE exploration and mining activities through the issuance of more EL and ML
(v) Government to facilitate the opening up of more REE analytical facilities
(vi) Undertake a pilot ISL project in a controlled environment within the PFR area supervised by JMG for a feasibility study

ii. Infostructure

(i) Allocate sufficient funding for JMG to continue and complete digitalisation process
(ii) JMG, as custodian of mineral resource data, to liaise with other agencies and organisations possessing IAC-REE resource data and form and lead a committee to manage the digitalisation of national IAC-REE resource data and integrate all available data into MyGEMS available for sharing

iii. Intellectual capital

(i) Universities to include IAC-REE-related subjects into the curriculum
(ii) Universities and JMG to send relevant staff for training on IAC-REE; so that upon their return, they can impart their knowledge and, in the case of universities, to teach IAC-REE-related subjects
(iii) Issue more EL and ML for IAC-REE exploration and mining to more firms; so that more geologists, mining engineers, and workers can be employed and have on-the-job training opportunities in IAC-REE exploration and mining
(iv) Local government to establish G2G arrangement with the foreign government and include training and technology transfer as a component

iv. Integrity

(i) Improve the legal and administrative framework with the setup of a committee to specifically look at the applicability of the present legislations in governing IAC-REE resource development
(ii) Promote good governance in the public and private sectors, especially to wipe out bribery, corruption, and malpractices
(iii) Optimise the NMC or set up strategic partnerships to resolve issues pertaining to the development of IAC-REE resources at federal and state levels
(iv) Compulsory ESG reporting to be extended to all mining firms
(v) Ensure fair and transparent tenement application and approval system

v. Incentives

(i) Appoint a government agency to be responsible for establishing and managing incentives, particularly for the development of IAC-REE resources and for the mining sector in general (similar to what MIDA and MITI do for the manufacturing sector)
(ii) NRES to formulate and manage the incentives for exploration and mining of strategic critical technology minerals
(iii) State government to craft and offer a fiscal regime that allows investors to attain return on investment

vi. Institutions

(i) Establish a formal institutional framework for the development of IAC-REE resources
(ii) Identify the roles and responsibilities of each entity to reduce overlapping and duplication of work and ensure that efforts of the individual entities are co-ordinated and complementary

vii. Interactions

(i) Rationalise the formal establishment of various aforementioned strategic partnerships in an organised manner for improved effectiveness
(ii) Step up engagements/CEPA programmes to educate the public and NGOs
(iii) Organising conferences, seminars, forums, and workshops for intellectual discourse on IAC-REE and its development
(iv) Greater interaction between the public and private sectors

viii. Internationalisation

(i) Fast-track the development of IAC-REE resources nationwide to keep up with the rest of the world
(ii) Government and industry players to establish collaborations with other countries and firms undertaking IAC-REE resource development in order to build up and strengthen knowledge and information sharing.

5.2.2 Midstream Sector

Three recommendations for the midstream sector are as follows:

i. Set up a REPP of large capacity

The demand growth for rare earth magnets indicates the long-term market for purified rare earth magnet metal oxides; correspondingly, there would be growth in rare earth mining projects in countries with IAC deposits. By setting up an efficient REPP of large capacity in Malaysia, an alternative market for the REC products from the IAC mines can be provided, which, in turn, would boost Malaysia's Tb and Dy outputs. Therefore, it is proposed that the Malaysian REPP should have excess capacities over and above the local upstream mines production in order to become a regional processing hub for the REC produced from legal mines within the region.

ii. Develop own rare earth mining and separation chemicals

In preparation of the possible future disruption of extractants and lixiviant chemicals for IAC-REE mines, Malaysia must focus on the development of own efficient lixiviant and extractant chemicals using as much locally available chemicals as possible.

iii. Set up a REC central buying house

As discussed in Section 5.1.1 (Recommendation 6)

5.2.3 **Downstream Sector**

The downstream sector employed the 8i's ecosystem approach to develop 42 recommendations as follows:

i. Institutions

(a) Develop a national strategic policy to promote the downstream sector of the IAC-REE industry and drive the ecosystem growth

(b) Strengthen institutional support by establishing a one-stop centre (OSC) and empowering the government agency or National Advanced Material Consortium (NAMC) to facilitate the development of the downstream sector of the IAC-REE industry and to avoid the overlapping of roles and responsibilities. NAMC can be leveraged:
- (i) To identify a champion across the industry value chain and to be positioned in the consortium
- (ii) To optimise the national resources, market instruments, and fiscal incentives to drive the downstream sector
- (iii) To assess the risks associated with the IAC-REE downstream
- (iv) To identify the needs for R&D to develop collaboration models for product development and improvement
- (v) To provide grants based on thematic development involving key partners
- (vi) To develop the industry ecosystem for the IAC-REE downstream
- (vii) To perform industry insights in the monitoring of the performance of the downstream sector

(c) Create a dedicated GLC or empower the existing GLC as an industry champion for the IAC-REE downstream to spearhead the industry; business collaborations involving the GLC and potential end-users to penetrate and stimulate the local market and global business opportunities

(d) Establish the Critical Material Institute as a Centre of Excellence for R&D, focusing on IAC-REE-based products

ii. Internationalisation

(a) Commit to long-term G2G collaboration for the localisation of high-tech manufacturing technology for REE-based products via any government scheme, such as Industrial Collaboration Programme (ICP)

(b) Promote the involvement of local Malaysian experts in IAC-REE international associations

(c) Implement a strategic approach at the World Economic Forum or global platform to demonstrate the IAC-REE country's ecosystem in order to attract FDIs

(d) Revise and review the export quota of rare earth carbonate from upstream and rare earth metal products from midstream to ensure adequate supply for the local downstream from time to time—for example, 30% for export and 70% for the domestic manufacturing market
(e) Create spillover effect for trade commodities between countries

iii. Intellectual capacity

(a) Forge the collaboration between industry and academia by strategizing the research activities driven by industrial problems, focusing on process improvement and new product innovation
(b) The role of the government in coordinating the partnerships involving private sectors (foreign or local firms) and universities to form a collaboration model in the forms of licensing, royalty basis, co-innovation and co-sharing, and multilateral patent pool
(c) National upskilling programme for the manufacturing of IAC-REE-based products by leveraging on the existing talent pool for the manufacturing activities – to formulate the mechanism to retain the talent chain and incorporate the knowledge for the undergraduate students; to enhance and introduce the knowledge of IAC-REE industry via TVET
(d) Exchange programme for human resource development and transfer of knowledge among universities and industry players – to uplift the visibility of local rare earth experts for knowledge sharing
(e) Review talent policy to balance between building talents or to attracting talents (especially foreign talents) considering that the transfer of technology and knowledge from international experts at this stage is critical
(f) Review talent policy to balance between building talents or to attracting talents considering that the transfer of technology and knowledge from international experts at this stage is critical
(g) Encourage policy for work permits to hire foreign talents and build local talents – need a balanced approach for local and international talents
(h) Promote a talent-friendly policy to ensure foreign experts' contributions towards human capital development programmes for short- and long-term measures

iv. Incentives

- (a) Introduce special fiscal incentives to promote investments for the IAC-REE downstream sector and accelerate the take up from local end-users
  - (i) Optimise the existing incentives offered by the government on GITA and GITE (green technology), industrial automation, and etc.
  - (ii) Introduce performance-based incentive mechanisms and time-based incentives
  - (iii) Introduce soft loan with a specified grace period for the IAC-REE industry
  - (iv) Incentives for patent applicants in protecting the ideas for new product invention and manufacturing process for the super-magnets and electric motors as home-grown product and technology
  - (v) Encourage the adoption of local content
  - (vi) Encourage the application of locally produced rare earth metals
- (b) Develop equity conditions between local and joint venture partners
- (c) Import and export activities: Impose export duties for rare earth materials to ensure adequate supply for local downstream sectors
- (d) Incentives to intensify circular economy, such as urban mining or utilising the by-products as value-added products (currently by-products are considered as waste materials)
- (e) Allocate and strategize the targeted funding and grant for R&D&C&I downstream activities based on the TRL
- (f) Adopt industrial collaboration programme (ICP) as an offset programme or any government scheme for the technology transfer and procurement for the manufacturing machinery and equipment.

v. Integrity

- (a) Introduce a business-friendly environment for midstream operating license based on at least 10 years, instead of the annual/periodical renewal application, in order to exert positive impact on businesses in the downstream sector
- (b) Reclassification of chemicals used in the manufacturing activities for scheduled waste management
- (c) Develop industrial standards and guidelines for the manufacturing of IAC-REE-based products.
- (d) Protective clause on the percentage of rare earth resources specified for domestic use (safeguarding resources) as part of the policy and enforcement during the first five years of the national downstream industry rollout
- (e) Establish national testing and certification to uphold the quality and reliability of the Malaysian IAC-REE-based products
- (f) Establish regulatory framework and governance on the ESG reporting for IAC-REE downstream ecosystem to comply with the sustainability agenda
- (g) Uplift the IAC-REE downstream sector for the reporting under 12MP mid-term review (Chapter 3: Propelling Growth of Strategic and High Impact Industries as well as Micro, Small, and Medium Enterprises)

vi. Interaction

(a) Quantify the potential contributions of the IAC-REE industry on sustainability and ESG towards achieving Malaysia's decarbonisation trajectory by 2050

(b) Empower the industries' association network or consortium for the development of the industry ecosystem and facilitate the demand and supply of IAC-REE downstream

(c) Adopt the quadruple helix model for the society involvement in every decision-making stage through targeted public engagements for full support, especially from local communities

(d) Establish a strategic partnership with ASEAN and neighbouring countries to promote technology transfer and knowledge exchange for IAC-REE-based products – for examples, Malaysia and Thailand establish technology transfer partnership for the battery manufacturing industry; Malaysia and Vietnam establish a partnership for the magnet production industry.

(e) Collaboration with the state government and regional economic corridor authority to drive the IAC-REE downstream activities, such as super-magnet production at the targeted industrial park zone based on the cluster model

vii. Infrastructure

(a) Access the industry needs and gaps to optimise the existing infrastructure and encourage shared facility services

(b) Establish local testing and services for downstream manufacturing activities and uplift the existing capability of related institutions, such as SIRIM and UMPSA

(c) Establish linkage to the centre of interest (COI) (i.e., InvestPerak)

(d) Align with the state government to develop a specific high tech eco industrial park for the downstream manufacturing activities with integrated infrastructures in order to showcase the advanced industry cluster zone

viii. Infostructure

(a) Establish CEPA under UKK for each related ministry

(b) Digital database of local and global industry supply chains and ecosystems on IAC-REE for the targeted users from the government, industry, academia, and public

(c) Platform for virtual industrial networks to access information on the policies and best practices, availability of infrastructures, regulations, skills, and technology applications

5.2.4 Environmental, Social, and Governance Sectors

The ESG Sector developed the following four strategies and 10 recommendations:

i. **Strategy 1** – To prescribe minimum ESG topics to be covered in disclosures, including the integration of these topics into the EIA and SIA requirements through sector-specific guidelines by the Department of Environment (DoE) and PLANMalaysia, respectively.

(a) Increase credibility, validity, verifiability, and traceability of ESG materiality analysis for firms within the IAC-REE ecosystem through an integrated dashboard and repository

(b) Develop specific EIA and SIA guidelines related to the rare earth industry with the incorporation of specific requirements for predicting and monitoring specific impacts on related ESG topics

(c) Ensure the conduct of sustainability assessment at both corporate and site-specific (national) levels for improved transparency and accountability (proposed to provide incentives to encourage such initiatives in the earlier stage)

(d) Set up a dashboard (under JMG) that would integrate data from all agencies that can be accessed for the sustainability assessment preparation

ii. **Strategy 2** – To increase the level of stakeholder engagement within the IAC-REE ecosystem, establishing an inclusive long-term engagement among all stakeholders at local, national, and global levels

(a) Establish an integrated ESG repository and research centre as the country's reference point for global data sharing, fostering the collaborations of the industry (ESG reporting), the government (raw data), universities (research/reference centre)

(b) NRES, with the cooperation with the state governments, to undertake regular communications, education, and public awareness (CEPA) programmes through briefing sessions and effective information dissemination

iii. **Strategy 3** – To extend the ESG disclosure requirements beyond the public-listed firms

(a) Incentivise firms (beyond public-listed firms) within the IAC-REE ecosystem for having ESG disclosures

iv. **Strategy 4** – To expand the talent pool for ESG practitioners experienced in disclosures related to firms within the IAC-REE ecosystem by increasing the levels of structured and on-the-job training programmes

(a) Formulate guidelines to provide guidance and training in ESG practices (and the understanding) in regards to the IAC-REE ecosystem

(b) Promote the collaborations of TVET, universities, and industries to provide upskilling courses through micro-credentials or stackable modular units

(c) Federal and state governments (especially MITI/MIDA) to ensure the inclusion of a condition for local talent development in any collaboration made with foreign investors

5.2.5 Integrated Business Model Sector

The integrated business model sector proposed three recommendations as the key way-forward to develop an integrated IAC-REE business value chain as follows:

(i) Strengthening institutional governance to ensure the development of seamless integration of the IAC-REE ecosystems

Institutional governance of the entire value chain can be strengthened by incorporating the “Whole-of-Government” and “Whole-of-Society” approach to ensure the buy-in of all stakeholders in the development of the entire IAC-REE ecosystem. There is a need for a dedicated agency[26] with “clout” to provide oversight on the development of the IAC-REE industry. The agency needs to foster strong cooperation and collaboration between the federal government, state governments, industry players (upstream, midstream, and downstream sectors), learning institutions, and community groups to create a conducive environment for the local IAC-REE industry to build strong dynamic capabilities and become globally competitive. This includes ensuring that policies and incentive systems at the state and federal levels are streamlined, harmonised, forward looking, and business- and investor-friendly. Additionally, the agency needs to facilitate high-level coordination between institutional firms to ensure proper implementation of policies and initiatives. A formal citizen participation platform should be established to allow stakeholders the opportunity to understand, deliberate, and co-design policies to improve public trust and support. This should also come in tandem with the strengthening of environmental and social performance of government and industry projects through strict enforcement of environmental regulations and ESG performance metrics.

(ii) STIE-driven solutions to foster strong collaborative partnerships among all stakeholders in the IAC-REE ecosystem (chain of custody)

Putting in place a sound STIE strategy, particularly the adoption of the 10-10MySTIE framework, is recommended to develop a chain of custody that can seamlessly integrate, monitor, implement, and refine policies and strategies with respect to the 8R-8i values-based framework and ESG requirements. The previous sections introduced several approaches to chain of custody for the upstream, midstream, and downstream sectors. Moving forward, the 10-10 MySTIE framework was considered due to its holistic approach that can cover several key technologies, in addition to blockchain technology, to support the use of traceability and accountability systems. Furthermore, MOSTI has already invested resources into implementing initiatives that incorporate the 10-10 MySTIE framework, which include fundings like MOHE grants and MOSTI’s Malaysia Grand Challenges. It remains crucial that

26 Refer to the proposed Board of Minerals Development Malaysia (LPMM) in the Blueprint for the Establishment of Rare Earth-Based Industries in Malaysia (2014)

investment be made to all relevant 10-10 technologies, as blockchain technology requires these necessary auxiliary technologies to perform optimally. An example of a chain of custody framework leveraging the 10-10 MySTIE is shown in Figure 4.53. The chain of custody plays a key role in fostering a strong collaborative platform for all stakeholders across various sectors of the IAC-REE industry and ensuring their adherence to the 8R-8i values-based framework and ESG standards.

The proposed integrated IAC-REE business value chain can be the key catalyst for the country's aspiration of developing a vibrant IAC-REE "circular economy" industry. In this context, the STIE framework contributes the following:

(i) Durable design of technologies derived from rare earth-based products, which can be reused safely and recycled in a way that allows easy removal/treatment of harmful substances.
(ii) Reintegration of end-of-life rare earth-based products and their reintroduction into new components within the value chain.
(iii) Repair and refurbishment of rare earth-based products to provide them multiple lifecycles and for the creation of second-hand markets.
(iv) Introduction of incentives and policies to encourage consumers to recycle end-of-life rare earth-based products, instead of disposing them at waste dumpsites.
(v) Invest in advanced recycling technologies and increase incentives for the integration of recycled rare earth-based products into new products.
(vi) Invest in advanced recycling technologies that extract high-value minerals from end-of-life rare earth-based products and maintains them at high quality.
(vii) Improve existing recycling programmes and facilities (e.g., BuyBack centres and e-waste collection centres).
(viii) Introduce and incentivise extended producer responsibility (EPR) and design for recycling to include producers in recycling efforts.
(ix) Strengthen the enforcement of Act 672 that mandates every household and business to segregate waste at source.

(iii) Economic and financial resources to develop an integrated IAC-REE business value chain

Adequate resources are critical as support for the firms and other stakeholders to enhance the enablers of the ecosystem in building strong dynamic capabilities and improving their ROVs. In this context, comprehensive economic and financial resources should be introduced for the sectors within the IAC-REE industry, which include the following:

(i) *Infrastructure and logistics support:* More investments are allocated to develop seamlessly integrated transportation infrastructure and logistics support system for efficient transportation of IAC-REE materials from mining sites and processing facilities to manufacturing centres, including their integration with advanced technologies, such as Industry 4.0 technology.

(ii) *Investment in talents, capability development, and CEPA programmes:* The creative workforce across all sectors of the IAC-REE ecosystem is critical for the successful development of an integrated IAC-REE business value chain. There is a need to increase investment in technical expertise (TVET and STEM areas) for all three sectors, as well as to nurture talents with multidisciplinary skill sets that can operate across different sectors. These skill sets are critical to ensure seamless integration of the operations across the three sectors. Additionally, these investments should be channelled into non-STEM areas, particularly in business development, entrepreneurial skillsets, community development, and cross-cultural competence. Talents in these areas are critical to ensure firms operating in the local ecosystem have the cultural savviness to engage with local communities in the design and development of local projects, such as developing CEPA programmes to minimise conflicts with the indigenous population and address concerns from NGOs and civil society.

(iii) *Investment risk management systems:* Financial institutions should ensure mandatory and voluntary risk management meet ESG requirements when assessing investments related to the IAC-REE industry. This will play a key role in firms incorporating environmentally friendly technologies, practices, and business models for the mining, processing, and production of IAC-REE products and services. The government can play a key role by mandating financial institutions to put ESG compliance requirements in place for major IAC-REE investment plans.

(iv) *Biodiversity and environmental offsets:* These schemes should be introduced to compensate unavoidable IAC-REE development projects that contribute to the degradation of the environment. These offsets can be a key instrument for raising financing in rehabilitating mining sites that have had adverse effects on the biodiversity of the ecosystem. The offsets should be incorporated in all IAC-REE development projects; so that adequate funding is available for revitalising the environment long after the IAC-REE development project is completed.

(v) *Strategic R&D funding:* Given how critical the IAC-REE industry for the development of major technologies and other economic sectors, the government should prioritise this industry receipt of national R&D funding. These investments should be directed to, the development of innovative mining and processing of IAC-REE materials that are environmentally friendly and meet ESG standards, such as advanced recycling technologies that can create a vibrant "circular economy" within the IAC-REE industry.

(vi) *ESG compliance support for SMEs:* Financial support (e.g., tech financing, R&D grants, and tax incentives) is allocated to firms, especially SMEs in the industry, that comply with the ESG requirements.

(vii) *Attract high-end FDIs:* The government and industry should work closely to develop strategies to attract high-end FDIs into the IAC-REE industry, especially foreign technology-intensive players, to use Malaysia as a "test-bed" for the development of advanced technologies in the mining of IAC-REEs, recycling, processing plants, and development of products like magnets, batteries, and other applications derived from IAC-REE. In this context, government agencies, such as MIDA, should intensify and focus on the incentives for the IAC-REE industry, incorporating the strong elements of knowledge and technology transfer to local players in the ecosystem.

(viii) *Sustainable supply chain support:* The sustainability of the IAC-REE industry is dependent on the incorporation of ESG standards across the entire value chain (chain of custody). This involves major financial investments in technology, regulatory architecture, development of standards and certifications, innovative financial support systems and architecture, and capability development programmes. Investments should be channelled not only into technologies but also a wide range of expertise within the sectors of the IAC-REE industry, involving inter-operability skillsets that can seamlessly integrate the operations across the entire value chain.

5.3 Conclusion

The nation's IAC-REE resources have the potential to be a new source of economic growth, providing vast employment opportunities for skilled and semi-skilled Malaysians, in a wide array of technological industries as well as in the R&D sector, both in the industries and universities.

Through the quadruple helix model with regard to the stakeholder consultations with government authorities, academia, industry, NGOs, and CSOs, an integrated IAC-REE business model is established, covering the value chain from REE mining, processing, and manufacturing to magnet recycling/repurposing. It also covers the importance of rare earth-related R&D.

The integrated designed business model is intended to capture a holistic ROV from the fast-tracking of this strategic industry, resulting the following effects:

(i) Creative talent: Nurture creative and high-skilled next-generation talents for all sectors of the IAC-REE industry
(ii) New knowledge: Generate responsible next-generation mining technologies, processing systems, downstream sectors, and recycling markets
(iii) Knowledge networks and value chains: Integration of horizontal and vertical supply chains (chain of custody) locally and globally, as well as the strengthening of technology and knowledge transfer
(iv) Societal and environmental impact: Contribute technologies for the EV industry and renewable energy, empower the local community, and improve their quality of life through job creation
(v) Branding and positioning: Position Malaysia as an essential player in the global value chain to attract domestic and foreign direct investments
(vi) Wealth creation: Contribute to the industry's competitiveness, create high-income job opportunities, and increase the GDP contribution

By 2030, the industry has the potential to create 24,800 jobs and is estimated to contribute RM 8 billion to the country's GDP in 2030, with a cumulative GDP value of RM 28 billion from 2025 to 2030.

Malaysia
has all the necessary ingredients to become
the region's vertically integrated rare earth-based products supplier

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Appendix 1
STUDY TERMS OF REFERENCE AND METHODOLOGY

1.0 Objective of the Study

The objective of the study was to propose the formulation of a business model to develop the IAC-REE industry in Malaysia. In order to achieve this, the proposal for the upstream sector of the IAC-REE industry was based on data from the state of Perak as a case study. Overall, the process of developing the IAC-REE business model proposal focused on the matters as set out in the scope of service given in the Study Terms of Reference.

2.0 Methodology

Site Visits and Focus Group Discussions

The task force conducted a series of site visits and FGDs to collect data, information, and views for the draft final report and final report. Five site visits were made, in the order of dates visited, as follows:

(i) Proposed Rare Earths Elements Purification Plant, Bukit Beruntung, Selangor (11 October 2022)
(ii) Lynas Advanced Material Plant (LAMP), Gebeng, Pahang (3 November 2022)
(iii) Centre for Sustainability of Ecosystem and Earth Resources (Pusat Alam), Universiti Malaysia Pahang, Gambang, Pahang (4 November 2022)
(iv) Pengarah Tanah dan Galian, Perak, Ipoh (10 November 2022)
(v) IAC-REE In-Situ Leaching Pilot Plant Site, Kenering, Gerik, Perak (13 December 2022)

Eight focus group discussions (FGDs) were held, in the order of dates, as follows:

(i) Upstream the sector’s FGD with DOE, JPS, and PLANMalaysia (29 September 2022)
(ii) Environmental, social, and governance (ESG) sector’s FGD with Suruhanjaya Syarikat Malaysia (morning of 20 October 2022)
(iii) Midstream sector’s FGD with Ranhill Utilities Berhad (afternoon of 20 October 2022)
(iv) Downstream sector’s FGD with MIDA (28 October 2022)
(v) Upstream sector’s FGD with *Jabatan Tenaga Atom, Agensi Nuklear* Malaysia and MIDA (22 November 2022)
(vi) Downstream sector’s FGD with the industry, government, and academia (29 November 2022)
(vii) Upstream sector’s FGD with KeTSA/JMG/MCOM (5 December 2022)
(viii) Environmental, social, and governance (ESG) sector’s FGD with NGOs (8 December 2022)

With the inputs gathered during the site visits and from the FGDs, each working group prepared its standalone report containing information relevant to its sectoral area, as well as recommended strategies and recommendations.

3.0 Sectoral Approach

3.1 Upstream Working Group

The upstream working group's report on the business model covered information on field exploration, in-situ leaching, and on-site processing of IAC-REE. In comparison to the midstream and downstream sectors, tangible potential returns from the development of the upstream are relatively small. However, the upstream sector plays a highly important role; without it, the development of the rare earth industry in Malaysia would become meaningless, as one of the main purposes of establishing the rare earth industry in Malaysia is to capitalise on its fortuitous endowment of IAC-REE. Furthermore, foreign and local investors would not invest in the midstream and downstream sectors unless an established long-term sustainable source of supply of REE is guaranteed.

The working group focused on the following aspects:

(i) Establishment of the existence of REE resources within the ion adsorption clay deposits
(ii) On-site extraction of IAC-REE resources
(iii) Review of methodologies for exploration, mining, and on-site processing of ion adsorption clay resources
(iv) Chain of custody over resources
(v) Review of the current governance ecosystem, policies, and regulations
(vi) Discussion on the loss on value (LOV), return on value (ROV), and net positive impact (NPI) from extraction of IAC-REE
(vii) Fiscal regime
(viii) Business model for the upstream sector
(ix) Challenges facing exploration, mining, and on-site processing of IAC-REE deposits
(x) Aligning and harmonising the understanding of mineral resource development, particularly IAC-REE deposits, among various government agencies and the private sector for investing in ISL
(xi) Deliverable

The deliverable of this working group involved a standalone report with the proposed business model for the upstream sector, covering exploration, the in-situ leaching, and on-site processing of IAC-REE resources based on the outcomes of the aforementioned studies. In addition, all information on the stocktaking of commercial and institutional analytical facilities available for the upstream sector of the IAC-REE industry are presented in Table 1.

TABLE 1

Organisation	Laboratory Location	Facilities and Equipment	Type/s of Analyses	Accept Commercial Samples? Yes/No	Price Indication	Normal Turnaround Time
JMG	BPT, Ipoh, Perak	LA-ICP-MS	Full range of REE; U and Th	Yes	1,800/sample	14 working days
		XRF	Major elements	Yes	700/sample	14 working days
		XRD	Mineral identification	Yes	120/sample	14 working days
UMPSA UMK	Gambang, Pahang	ICP-MS	Full range of REE	Yes	NA	14 working days
	Batu Melintang, Kelantan	ICP-OES	Multi-element analysis	Yes	225/sample	14 working days
		ICP-OES	Single element analysis	Yes	90/sample	14 working days
		ICP-MS	REE analysis (17 elements)	Yes	235/sample	14 working days
		ICP-OES	Elemental analysis	Yes	30/sample	14 working days
			Environmental analysis 1 (pH, DO, TDS, temperature, and turbidity)	Yes	30/sample	14 working days
			Environmental analysis 2 (BOD_5, COD, ammoniacal nitrogen, oil and grease, TSS, chloride, fluoride, iron, and hardness)	Yes	200/sample	14 working days
		XRD	Minerals analysis	Yes	135/sample	14 working days
		XRF	Major oxide/elements	Yes	50/sample	14 working days
Nuclear Malaysia	Bangi, Selangor	Gamma spectrometer, XRF, XRD, FESEM	Radioactivity measurement (in Bg/g unit) using nuclear techniques, such as gamma spectrometer and neutron activation analysis. These techniques complement the usual techniques for elemental analysis using ICPMS and XRF	Yes	NA	14 working days
		Has facilities that can separate rare earth carbonate/rare earth chloride	Currently working on REE from minerals; this process can be applied to pregnant leach solution or rare earth carbonate obtained from in-situ leaching of ion adsorption clay REE. Any kind of collaboration in midstream activities (especially REE separations are open to all).	NA	NA	

Organisation	Laboratory Location	Facilities and Equipment	Type/s of Analyses	Accept Commercial Samples? Yes/No	Price Indication	Normal Turnaround Time
Greenchem Nanotech Solution Sdn Bhd	Bukit Beruntung, Selangor	‣ ICP-MS ‣ REE leaching test apparatus ‣ Separation test apparatus ‣ Process equipment to separate and analyse LREE and HREE, and to purify PrNd, TbDy, and SEG	‣ Element analysis of full range of REE ‣ Column leaching test ‣ Bulk leaching optimisation test ‣ Soil composition testing ‣ REE carbonate/oxalic recovery test ‣ REE separation test ‣ Contamination test of Al, Fe, Mg, Ca, Zn, and etc. ‣ Moisture test	Yes	NA	‣ ICP-MS analysis test: ‣ Liquid: Four working days ‣ Solid: Seven working days Leching test: Seven working days Process optimisation and separation test: 7–14 days

Table 1: Stocktaking of commercial and institutional analytical facilities available for the upstream sector of the IAC-REE industry

The business model for the upstream sector includes proposed strategies and costs, including the use of technologies, for the preparation of sustainability, conservation, and rehabilitation plans in both IAC-REE mining and post-mining stages. The objective is to make this a living document, easily accessible, readable, and implementable by the relevant ministries, agencies, and the industry. Infographics of facts, figures, data, and statistics are presented, and narratives are kept to the minimum.

3.2 **Midstream Working Group**

The midstream working group's report on the business model covered the following:

(i) Potential technologies for the separation and purification of REO from the upstream in-situ leach mine site products
(ii) Suitable technologies to be implemented to produce purified REO suitable for the local downstream sector, especially for the manufacturing of rare earth super-magnets and electric motors
(iii) Feasibility of producing metals and alloys locally
(iv) Characterisation of the Malaysian IAC-REE mine products
(v) Identification of the relative percentage concentrations of rare earth magnet metals (Pr, Nd, Sm, Tb, and Dy) in the IAC-REE mine products (Figure 1)

FIGURE 1

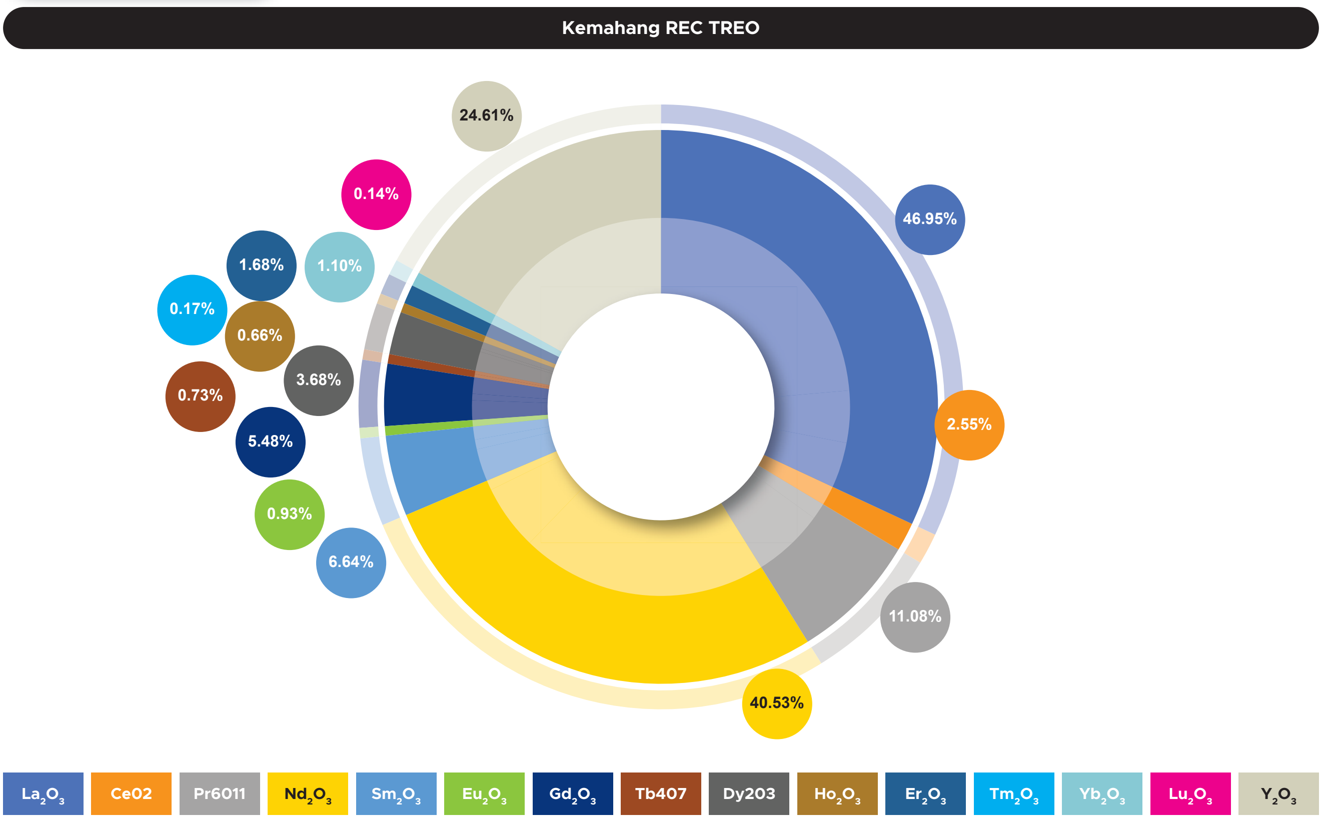

Figure 1: Example of REO fractional distribution chart

(vi) Chain of custody over mined resources
(vii) Focus on the separation and purification of rare earth super-magnets
(viii) Rare earth magnets constituted 92% of the IAC-REE industry value, with the increasing demand due to the global new energy initiative. Therefore, this working group is prudent for the Malaysian IAC-REE industry to focus on the production of rare earth super-magnets from local IAC-REE deposits.
(ix) Review the technologies for separation and purification of REE and other potential technologies available in the market, including a review of various rare earth separation technologies, including solvent extraction (SX), ion exchange (IX), membrane separation, liquid emulsion membrane separation, and chromatographic separation. [References were made to cross-discipline (such as biotechnology, petroleum, and pharmaceutical) studies to evaluate the applicability of their chemical separation technologies for REE separation.]
(x) Identify suitable technologies to be implemented in Malaysia
(xi) Fiscal regime
(xii) Business model proposal—to develop a business model for the setup of a local REE separation and purification plant with merits given to either a centralised separation jointly with a purification plant or to have satellite separation plant with its semi-finished products sent to a centralised purification plant
(xiii) In order to expedite the business model and allow the separation plant to start operating once the supplies of REC from the local mines will be provided, IAC-REE-type REC/REOs will be imported. It is to optimise separation technology to ensure it is prepared for when the upstream mining production is ready.
(xiv) Deliverable

The deliverable of this working group involved a proposed business model for the midstream separation and purification of IAC-REE products for the manufacturing of rare earth super-magnets and electric motors in Malaysia. The business model for the midstream sector includes proposed strategies and costs, including the use of technologies. It also aims to establish an ESG-compliant REE separation and purification industry, as well as in regards of the production of metals and alloys. This serves as a bridge in the vertical integration of the IAC-REE industry in Malaysia.

3.3 Downstream Working Group

Rare earths are essential inputs to high-technology and high-growth industries. Manufacturing primarily involves the downstream sector within the overall ecosystem of the IAC-REE value chain. Currently, China remains as the world's main producer of REE and rare earth products. However, Malaysia has the world's largest single rare earth processing plant, outside China, located in Gebeng, Pahang. REE are considered as one of the game changers, as reported in the MOSTI's recently launched National Advanced Materials Technology Roadmap 2021–2030. The demands for REE have become increasingly significant in different industrial sectors, namely consumer electronics, mobility, energy, medical, aerospace, and defence. Products and applications, ranging from catalytic converters, magnetics in motors, satellite communications, and energy storage, makes these resources valuable and highly sought for by many countries and industries. Therefore, it is imperative for Malaysia to leverage on its available resources and capabilities and participate in establishing and fortifying the current available ecosystem to establish a winning situation for the environment, society, and governance.

i. Objectives

(i) To develop a potential manufacturing business model for the IAC-REE downstream-related products
(ii) To propose suitable products for the downstream sector of the IAC-REE industry in Malaysia, especially of high value and of high market demand
(iii) To recommend and provide inputs to the government for ease of business and enhanced competitiveness

ii. Scope of work

As per the study's Terms of Reference (TOR), there are different scopes related to the development of the downstream manufacturing business model, which are listed as follows:

(i) Identify high-value-added products based on the ISL mining of the IAC-REE resources, which are viable to be manufactured in Malaysia
(ii) Examine the ecosystem for the local development of the IAC-REE industry at the downstream level, including ensuring the "chain of custody" aspects over the purified resources received from both upstream and midstream sectors
(iii) Provide strategies to enhance the development of the downstream sector of the IAC-REE industry in attracting potential investors for technology transfers and high-value-added activities
(iv) Outline the value chain of the downstream sector of the IAC-REE industry
(v) Evaluate and propose the IAC-REE downstream manufacturing business model

This scope of work would guide the relevant working group and stakeholders in producing the appropriate business model for downstream manufacturing as the main outcome. The development of the business model for downstream manufacturing can be classified as a business approach, a national approach, and a hybrid approach. Figure 2 shows three distinct aspects of consideration for the downstream manufacturing business model.

FIGURE 2

BUSINESS APPROACH	NATIONAL APPROACH	HYBRID APPROACH
Product / Services	Malaysia's Competitiveness	Leveraging Both
Market	New Sector / Contributor Towards Economy	
Business Strategy	Self Reliance	
Cost and Profitability	Beyond Profitability i.e. ESG & SDG	
Technical / Gaps	Politics (where would it go) *KETSA	
Commercial – Business Model	Economic Council	
Legal – IP etc		

Figure 2: Downstream manufacturing business model

iii. Hybrid approach

With the consideration of these three suggested approaches, after studying their strengths and limitations, the study opted for the hybrid approach. Details of the study are included in the downstream sector's standalone report. Under the aspect of methodology, the working group also explored numerous other factors, which covered the following:

(i) Supply and demand perspectives
(ii) Case study on the applications of REE
(iii) Economic modelling and business canvas
(iv) Strategic recommendations
(v) Deliverable

The deliverable of this working group involved a viable IAC-REE manufacturing downstream sector business model with targeted products or services suitable for Malaysia.

3.4 **Environment, Social, and Governance Working Group**

The mining industry contributes both positive and negative effects across 17 Sustainable Development Goals (SDGs) and 169 targets identified by the United Nations General Assembly (UNGA) for 2015–2030. Almost all SDG targets have bearing on the mining industry, as shown in Figure 3.

FIGURE 3

Figure 3: Mining and 17 SDGs (Columbia Center on Sustainable Investment, UNDP, UN Sustainable Development Solutions Network & World Economic Forum, 2016)

The most commonly associated UN SDGs for the mining industry include SDGs 6, 7, 12, 14, and 15 (for environmental sustainability), SDGs 1, 3, 5, 10, and 16 (for social inclusion), and SDGs 8 and 9 (for economic development).

There is growing demand among the quadruple helix partners, which include the government, consumers and investors, the community, and society, on the role of businesses to move beyond the pursuit of profits alone and to be aligned with the sustainability agenda. Responsible and ethical businesses need to fulfil its adoption of sustainability goals through their adherence to the regulatory requirements and to be seen to act accordingly through other non-regulatory initiatives, including CSR efforts. The increasing demand for transparency and accountability on the firms' social and environmental impacts drives the need for ESG disclosures. ESG disclosures also address the effectiveness of CSR efforts in achieving SDGs, as shown by the linkages in Figure 4. The common global consensus on ESG disclosures is based on the global reporting initiative (GRI). These disclosures should follow internationally recognised ESG standards that consider all materiality topics for both internal and external stakeholders.

FIGURE 4

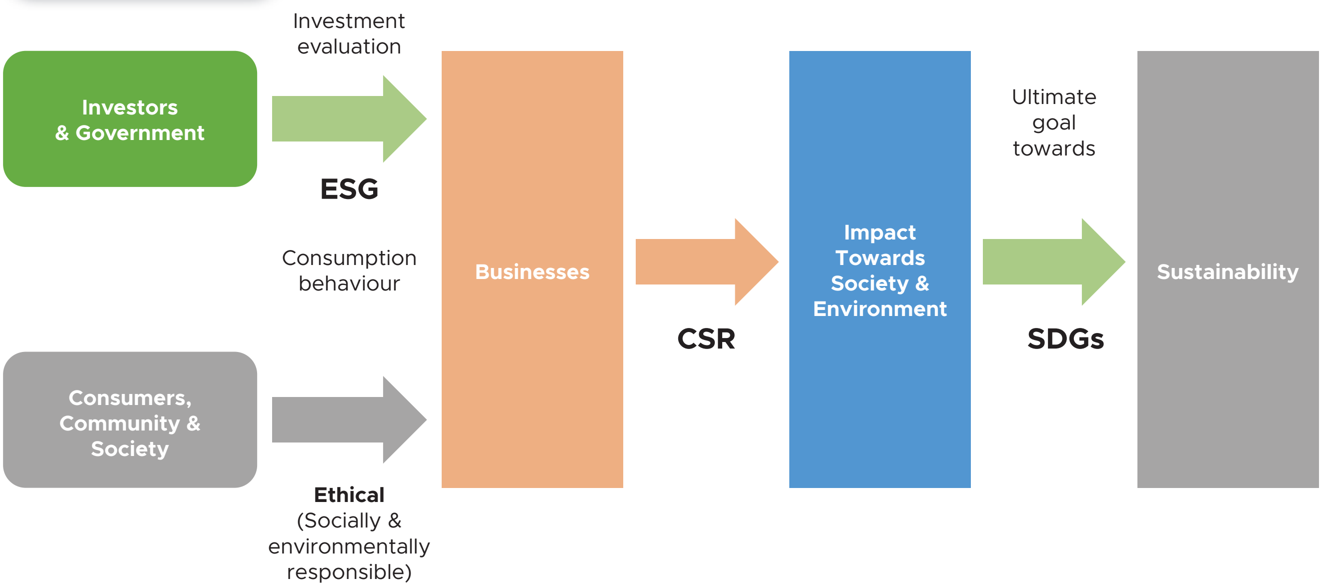

Figure 4: Relationships of SDGs, CSR, and ESG (Raja Ehsan Shah, 2022)

The mining industry can foster economic development by providing opportunities for decent employment, business development, increased fiscal revenues, and infrastructure linkages. Many of the minerals produced by mining, including ion adsorption clay rare earth elements (IAC-REE) are also essential building blocks to technologies, infrastructures, energy, and agriculture. When it comes to the upstream sector, extracted physical ore goes through a beneficiation process. Subsequently, in the midstream sector, IAC-REE are extracted and purified before these metals can be produced. As for the downstream sector, IAC-REE are critical components across a wide range of applications, especially rare earth magnets, high-tech consumer products (e.g., cellular telephones and computer hard drives), EVs, and hybrid vehicles. The demand for REE has increased to cater to the technological shift towards decarbonisation, which is driven by the shifts towards the electrification of industrial processes. In recent decades, the mining industry has made significant advances in mitigating and managing such impacts and risks by improving how firms manage their environmental and social impacts, protect the health of their workforce, achieve energy efficiency, report on financial flows, and respect and support human rights. Further consideration of impacts and risks is required to address the inevitable increase in the overall IAC-REE industry in order to meet the growing demands for REE.

ESG provides a comprehensive framework that enables the IAC-REE industry to make the right choices for the balance of benefits to the environment, economy, and the people. New standards and frameworks against which mineral-related investments should be measured are required, even at the global level. This can address the challenges faced by the IAC-REE industry in determining the appropriate priorities and how reporting should be done. The entire IAC-REE industry (upstream, midstream, and downstream sectors) must deliberate the risks associated with ESGs, such that their needs to attract investments, obtain licensing rights, and good working relationships with the civil society can be successfully achieved.

i. Approach: Scene setting

12MP (2021–2025) sets out strategies in various game changers, chapters, and priority areas to boost the minerals and mining industries towards growth and sustainability. The relevant chapters in 12MP are as follows:

(i) Chapter 2: Restoring Growth Momentum of 12MP, particularly Strategy A2 that sets out the direction of repositioning the mining industry to be more agile, sustainable, and competitive
(ii) Chapter 7: Enhancing Socioeconomic Development in Sabah and Sarawak, particularly Strategy B6 that sets out to encourage mining operators to subscribe to the sustainability rating in order to ensure the adoption of sustainable mining practices
(iii) Chapter 8: Advancing Green Growth for Sustainability and Resilience, particularly Strategy B3 that encourages mining operators to subscribe to the sustainability rating

ESG features are prominently as a driver in two key game changers of the 12MP. In the case of the Game Changer II of Theme 1 on Resetting the Economy in the 12MP, focus is given to the investments of the private sector in encouraging ESG elements to support the green economy agenda. As for the Game Changer VIII on Embracing the Circular Economy, both public and private sectors are encouraged to adopt and integrate the SDGs and ESG principles in their decision-making process.

The second edition of the Sustainability Reporting Guide (2nd Edition), which was published in 2018 (2018 SR Guide), provided guidance on how to incorporate sustainability and evaluate material EES risks, with the intention to generate long-term benefits in terms of business continuity and value creation (Bursa Malaysia, 2018).

The Securities Commission, through the Corporate Governance Strategic Priorities 2021–2023, outlined 11 targeted initiatives on ESG fitness and leadership of the boards. At present, there are no specific ESG guidelines for the IAC-REE industry, with the Securities Commission and Bursa Malaysia focusing on the general adoption of ESG. Based on these gaps in the current ESG ecosystem in Malaysia, the following approaches have been adopted by the ESG Working Group:

(i) Requirements from *Bursa Malaysia* on ESG
(ii) IAC-REE industry clustering by *Bursa Malaysia*
(iii) Existing ESG reporting system for the IAC-REE industry in Malaysia
(iv) Availability of talents to expand ESG agenda (particularly for the IAC-REE industry)

Therefore, the proposed work plan is based on the application of ESG principles to incorporate essential ESG elements for the IAC-REE industry with specific reference to IAC-REE.

ii. Work plan

(i) Conduct ESG materiality analysis to address the sustainability, conservation, and rehabilitation of the environment, society, and stakeholders throughout the IAC-REE value chain
(ii) Assess the current status of the governance ecosystem, regulatory framework, and other relevant governance framework for its readiness to integrate ESG requirements for the IAC-REE industry in Malaysia
(iii) Identify and describe the opportunities of integrating ESG elements into the IAC-REE business value chain in Malaysia (ESG materiality[27] analysis serves as the basis to map out the IAC-REE business value chain in Malaysia concerning the associated risks and opportunities in each component of the value chain)

iii. Deliverables

(i) ESG materiality model for the IAC-REE industry in Malaysia that specifically addresses the material components within the upstream, midstream and downstream sectors
(ii) Overview of risks and opportunities associated with the ESG materiality for stakeholders within the IAC-REE business value chain in Malaysia.

3.5 Integrated Business Model

Details are provided in Chapter 2 (Section 2.1.2).

[27] Materiality, in the context of environmental, social, and corporate governance (ESG), refers to the effectiveness and financial significance of a specific measure as part of a firm's overall ESG analysis; material factors are fundamental financial elements for the long-term success of a firm's ESG strategy.

Appendix 2
HORIZON SCANNING: RARE EARTH INDUSTRY

1.0 Global Landscape

The demand for REE, especially for high-performance super-magnets and energy-efficient electric motors (the 2 functional products identified in the Downstream Sector of this Study), had witnessed a sharp increase as both RE-based products, among others, are needed to reduce CO_2 emissions globally. The Energy Efficient Motors Market respectively grew 16% in 2021 and 20% in 2022. It is expected to reach a 10% annual growth in the coming years. The expected trend shows the massive supply chain for rare earths as critical components in electric motor making (Figure 1) (Lynas Corporation/Lynas (M) Sdn Bhd., 2022).

FIGURE 1

Rare Earth Demand for Magnet

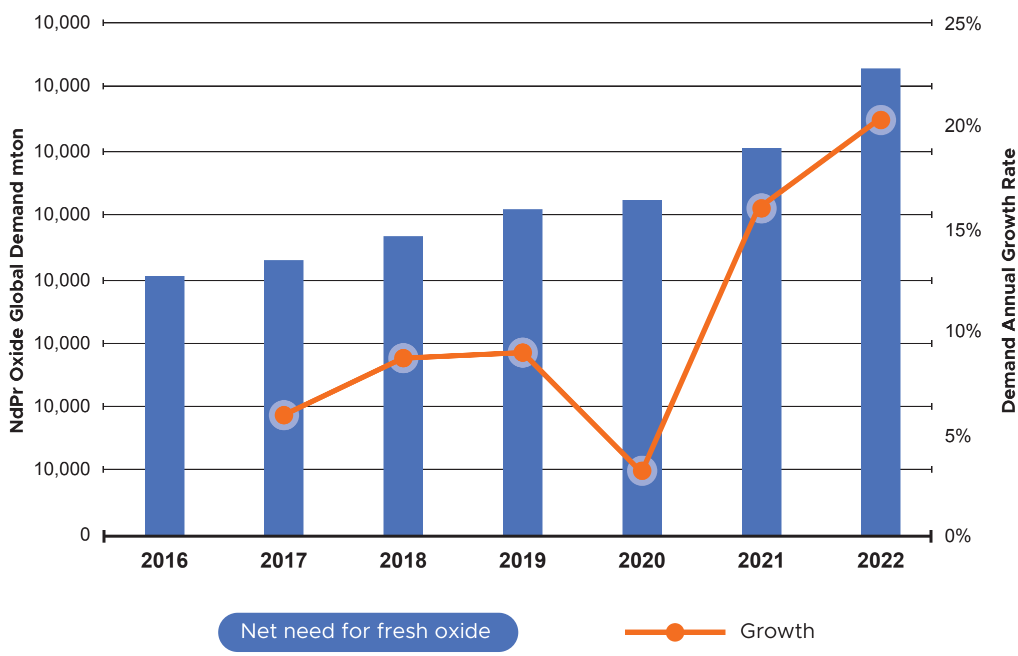

Figure 1: Rare Earth Demand for Magnets (Lynas Corporation/Lynas Malaysia Sdn Bhd, 2022)

As for super-magnets, the required REE are generally neodymium (Nd) and praseodymium (Pr), along with dysprosium (Dy) and terbium (Tb), which are used to improve temperature resistance. These four REE are also used for energy-efficient electric motors.

It is estimated that, in the next 10 years to 2030, some 1,000 ktonnes of high-performance magnets would be produced from the current production of 35 ktonnes per year in China and 15 ktonnes per year in Japan. Therefore, the annual production capacity in both countries would need to be doubled. In terms of energy-efficient electric motors, the current annual production globally is 25 million motors per year and, by 2030, the production of over 500 million motors is expected by 2030. This rate of production would require the existing annual production capacity to be doubled. In order to produce these functional products by 2030, the current production capacity of 63 ktonnes per year in China needs to be doubled by 2030 to some 126 ktonnes per year, whereas, at Mount Weld, Australia, Lynas (current production capacity of 7 ktonnes per year), its production capacity is expected to double to 14 ktonnes by 2030 (Figure 2).

FIGURE 2

What does it take from Resource to Motors to deliver on e-mobility

	Additional requirement in next 10 years	Current Production Capacity	Additional production capacity needed
Resource	Double Rare Earth Production by 2030	**China:** 63 ktons/year **Lynas:** 7 ktons/year	China and Lynas to double their existing production capacity over next 10 years
High Performance Magnets	+1000 ktons HP Magnets over 10 years (+100 ktoins/year)	**China:** 35 ktons/year **Japan:** 15 ktons/year	Double the existing annual production capacity
Energy Efficient Electric Motors	+500 million motors over 10 years (+50 million/year)	25 million motors/year globally	Double the existing annual production capacity

Figure 1: Rare Earth Demand for Magnets (Lynas Corporation/Lynas Malaysia Sdn Bhd, 2022)

2.0 Global Benchmarking: Country Profiles

A total of six countries were identified for the benchmarking exercise, namely China, Russia, Australia, Vietnam, Japan, and the USA. The country profiles are presented in Table 1.

TABLE 1

Profile	China	Vietnam	Australia	Japan	USA	Russia	South Africa
Industry Value Chain	1. Upstream 2. Midstream 3. Downstream	1. Upstream 2. Midstream (separation and recycling of rare earth magnets) 3. Downstream	1. Upstream 2. Midstream	1. Downstream 2. Rare earth metal recycling (testing phase) 3. Upstream (deep sea and exploration phase)	1. Upstream 2. Downstream	1. Upstream	1. Upstream
Status	1. By 2021, 60% of rare earth production relied on China. 2. Consumed 80% of all rare earth produced worldwide 3. “Strategic emerging industries” were developed, including aerospace, high-speed rail, high-end manufacturing equipment, and etc., which all rely on rare earth.	1. Approximately 18% of global rare earth reserves 2. Largest rare earth supplier to Japan by 2017 3. Collaborates with Japan’s Shin-Etsu Chemical Co Ltd for magnet production 4. Establish rare earth magnet recycling plant from appliances like air conditioners and compressor motors 5. The second-largest reserves of rare earths (22 million metric tonnes) (2022)	1. The country is ranked sixth in the world for rare earth resources and ranked world’s second for production, but many of these deposits remain untapped. 2. Australia has the world’s third-largest reserves of lithium, is the world’s largest producer of lithium, and has large resources of cobalt, manganese, tantalum, tungsten, and zirconium. 3. In January 2020, Geoscience Australia and United States Geological Survey signed agreement to develop rare earth. 4. Secured agreements with Japan and other non-Chinese countries on the take-off of projects (e.g., Lynas financed by JOGMEC from Japan)	1. In regards to the overseas rare earth development projects, Japan initiated or entered partnerships with a host country, including the Mount Weld project in Australia, the Don Pao project in Vietnam, and the Indian Rare Earth project in India, as well as the partnership with Lynas of Australia on a separation and purification plant in Malaysia.	1. China’s rare earth exports to the USA accounted for 78% of USA’s rare earth imports, while rare earths from Estonia, France, and Japan only accounted for 14% in total. 2. Collaborated with Australia-based Lynas Corp to secure non-Chinese rare earth sources	1. The world’s third-largest reserves of the group of 17 metals, as of 2022 2. Imports 90% of processed rare earths from China 3. Major projects like Tomtorskoye (joint venture between state-owned Russian entity Rostec and ICT Group), Zashikhinskoye deposit and etc. 4. Exports 95% of rare earth concentrates it produces due to the lack of separation plants	1. Steenkampskraal mine (SMM) received its water license in 2019; the last permit to start construction and production activities. It is expected to produce 30,000 tonnes of ore per year and 2,700 tonnes of REO per year, with Proven and Probable Reserve of 799,799 tonnes of ore graded at 8.68% (high grade) 2. In 2017, Rainbow Rare Earth started its production, sold 475 tonnes of concentrates within the first six months of operation. 3. TechMet funded a separation plant at Rainbow Rare Earth’s Gakara project in Western Burundi 4. Songwe Hill mine has REE grades of up to 2.2% over 6.7 m in drilling studies completed in 2018 (cost covered by a subsidiary of Singapore-based Noble Group)

Profile	China	Vietnam	Australia	Japan	USA	Russia	South Africa
Strength	1. Low land cost 2. Low labour cost 3. Matured technology and knowledge in in-situ leaching mining and rare earth processing 4. Strong governance and national direction	1. Low labour cost 2. Strong collaboration with international players (e.g., China and Japan) to set up mines, processing plants, and magnet manufacturing plants	1. Strong technology and knowledge in rare earth mining and LRE processing 2. Possess at least half a dozen rare earth projects ready for development	1. Strong manufacturing industry (e.g., super-magnets, batteries, and motors) 2. Developed end-user industries (e.g., automotive and renewable energy)	1. Used to be the largest rare earth producer in 1960–1980s	1. Fast-moving nuclear energy and technology development that can use thorium as by-product of the rare earth industry 2. High number of reserves	1. Most REE from South Africa are LREE. 2. Steenkampskraal mine possesses high-grade REE, of 2.58% neodymium grade. 3. The Gakara project is one of the highest grade rare earth element mining projects globally, with an estimated in-situ grade of 47–67% total rare earth oxide (“TREO”), and the company targets the production rate of 5,000 tpa by the end of 2018.
Key Policies	1. Shifting low-wage manufacturing towards high value-added industry 2. Rare Earth Industry development plan 2016-2020 3. Made in China 2025 Blueprint		1. Critical Mineral Strategy 2019 2. Launched Critical Mineral Facilitation Office in 2020	1. Established Strategies to Secure Rare Metals in 2009, with the focus on four key pillars (securing resources overseas, recycling, substitute development, and stockpiling) 2. Measures to Secure the Stable Supply of Rare Metals Going Forward (2007) 3. Japan’s rare metal stockpiling policy—what goes into the strategic reserve (seven minerals) at what reserve level (60-day domestic consumption equivalent) had remained the same since the stockpile system was established in the mid-1980s.	1. Advanced Transformational Research, Development, and Deployment across Critical Mineral Supply Chains (recycling & reprocessing technology) 2. Strengthening America’s Critical Mineral Supply Chains and Defence Industrial Base (The Department of Energy and Department of Defence provided funding for rare earth value chain processing and technologies development in 2019)		
(China Ministry of Industry and Information Technology; Sprecher et al., 2017; Mancheri et al., 2018; John Seaman, 2019; Lei et al., 2017; S&P Global Market Intelligence & USGS, 2022; S&P Market Intelligence, 2020; Vietnam’s reference: Vo, 2022; USGS, 2022; Australia Critical Mineral Strategy, 2019; Kyodo News, 2021; Nikkei Aisa, 2021; Lee, 2018; ASM Analytics, 2023)							

Table 1: Global benchmarking—Country profiles

3.0 Countries' Strategies in Building Their Rare Earth Industry: An ASM 8i's Ecosystem Framework Assessment

This section utilises the 8i-Ecosystem Framework to assess the strategies each country has identified as the key enablers in their respective IAC-REE industry (Table 2).

FIGURE 3

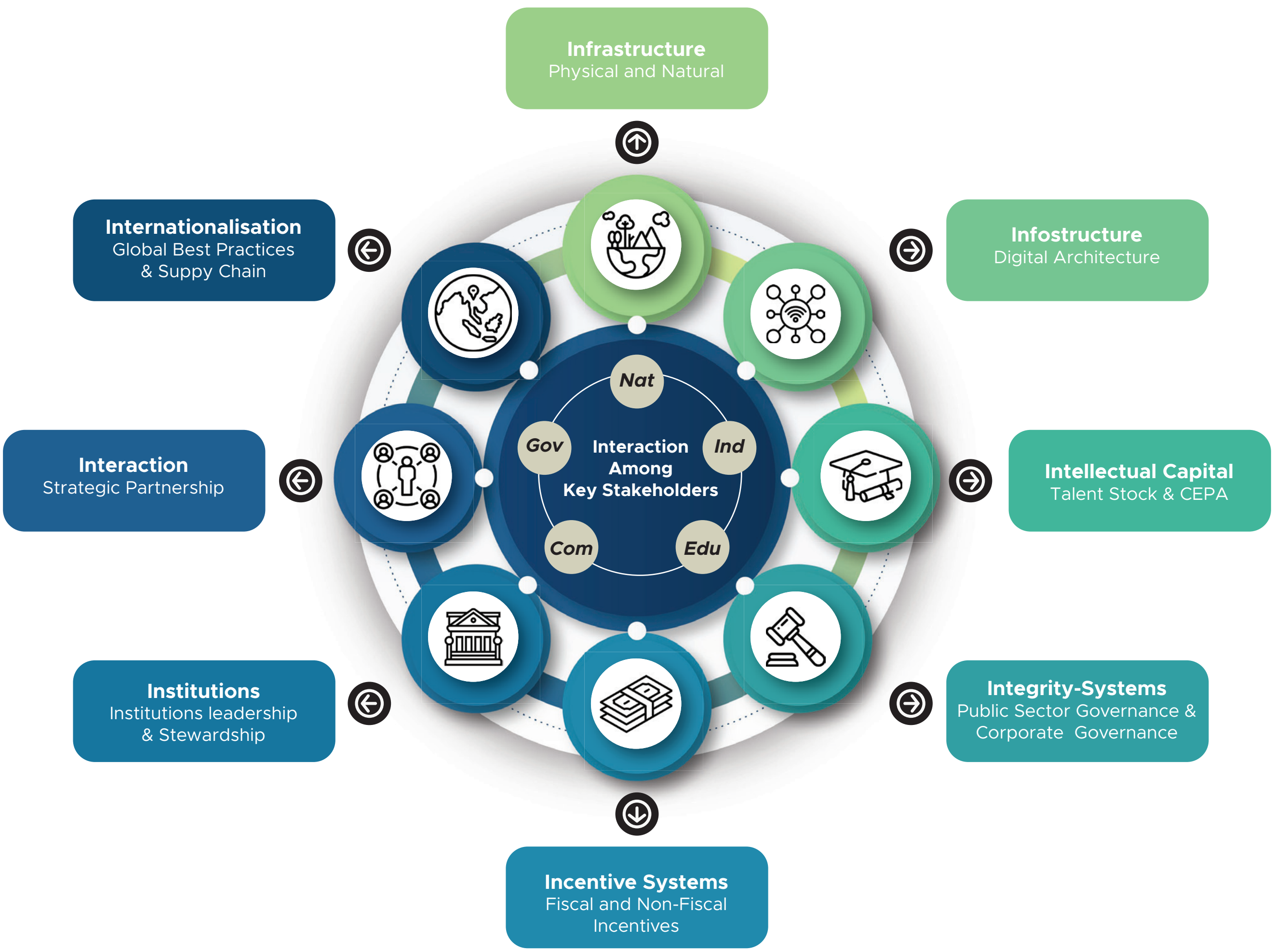

Figure 3: 8i Ecosystem Framework to characterise the IAC-REE ecosystem (Nair, 2011; Nair et al., 2022)

TABLE 2

8i's	Strategies
Institution	1. Established high-tech industry that require rare earth (e.g., information technology, environmental protection technology, and circular economy) (CN) 2. Close small-scale rare earth operation and consolidate larger ones, phasing out unlicensed mines, encourage company merging, and reduced mining enterprise for easier management (CN) 3. State funded programmes to support the development of rare earth mining industry (RU)
Interaction	1. Pursue circular economy through the use of the by-product of rare earth processing in other industry (e.g., the use of thorium in the nuclear energy sector) (RU) 2. Identify potential investors and offtake opportunities through roadshows and maintain the relationship with targeted investors (AUS) 3. The collaboration between the industry and university to seek for solutions for rare earth metal recycling and smelting (JP)
Integrity	1. The incorporation of expert quota allocation for strict environmental verification system (firms that do not pass the environmental audit would not receive the quota until they pass the audit) (CN) 2. Increase R&D on processing for improved product quality and implementation of clean production (CN) 3. Establish Major Projects Facilitation Agency (AUS) 4. Following the establishment of the supply chain, restriction to foreign investment for the industry is important for national security to prevent unwanted takeover by foreign firms. (JP)
Infrastructure	1. Establishment of national strategic base for rare earth concentrate stockpiling to guarantee future supply (CN) 2. Upgrade of the road for road safety and accessibility for freight vehicles (AUS) 3. Improve connectivity to the ports, agriculture, mining regions, airport, and other transport hubs (AUS) 4. Reduced flooding impact (AUS) 5. Increased freight capacity (AUS)

8i's	Strategies
Infostructure	1. Improved data and knowledge base of Australia's resource potential by Geoscience Australia, firms, and state governments (AUS)
Intellectual capacity	1. Export credit agency to provide specialist finance solutions to businesses (AUS)
Incentive	1. The Act provides tax incentive for purchase or acquisition of critical minerals and metals extracted from deposits in USA 2. Stable rare earth supply at lower cost to local firms through export quota, taxes, and price-distorting measure; export rebate policy decreased gradually and eliminated by 2005 (CN) 3. Lowered tax rate on rare earth extraction from 8.0% to 4.9% in 2019 for more investments in rare earth mining (RU) 4. Australia's Cooperative Research Centre to provide grant funding to support industry-led research (AUS) 5. Government's investment in exploration activities and research in technology to de-risk exploration and attract investors (AUS)
Internationalisation	1. Higher investment overseas and collaboration with international partners to secure supply (e.g., Madagascar, Greenland, California, and Australia) (CN) 2. Set up of the Foreign Policy White Paper that favours foreign investment in critical mineral industry (AUS)

* (CN: China; RU: Russia; AUS: Australia; JP: Japan)
(China Ministry of Industry and Information Technology; Sprecher et al., 2017; Mancheri et al., 2018; John Seaman, 2019; Lei et al., 2017; S&P Global Market Intelligence, 2020; business.gov.au, 2023; Nikkei Asia, 2021; Nissan Motor Corporation, 2021)

Table 2: Country-based strategies for their REE industry using the 8i's Ecosystem Approach

4.0 National Policy Instruments as Guides to the Development of the IAC-REE Business Model

In assessing Malaysia's readiness to fully enter the full rare earth market ecosystem, the study undertook an assessment of the available policy and regulatory instruments, as well as relevant blueprints towards underpinning the development of a IAC-REE business model. Malaysia possesses a list of competitive advantages as follows:

(i) In the publication entitled "Blueprint for the Establishment of Rare Earths-Based Industries in Malaysia", ASM identified the rare earth business as a strategic industry for Malaysia. The Australian Lynas Corporation's establishment of the rare earth processing plant in Gebeng, Pahang prompted ASM to undertake a more detailed evaluation of the rare earth business opportunities. The blueprint discussed fairly comprehensively the rationale for venturing into the industry, including the risks and opportunities involved, and presented a pathway for the country to effectively tap this new potential growth area. The following information were included (ASM, 2014):

- Upstream sector covering the aspects of exploration, mining, and related R&D
- Midstream sector covering mineral processing, management of waste residues, and related R&D
- Downstream sector covering areas of value-added green industries using rare earth metals, recycling of rare earth-containing electrical and electronic consumer and industrial appliances, and the management of waste residues, as well as related R&D
- The necessary human resources at all levels of expertise
- The social and environmental impacts of rare earth-based industries
- Governance aspects covering laws and regulations
- Economic impacts of the rare earth industry
- Opportunities for Malaysia
- The rare earth industry roadmap for Malaysia

(ii) Although the 12MP (2021–2025) did not specifically highlight rare earth, REE, or the industry, it did identify two out of three themes: Resetting the Economy (Theme 1) and Advancing Sustainability (Theme 3). Theme 1 focuses on restoring the growth momentum of key economic sectors, and propelling strategic and high-impact industries, as well as micro, small, and medium enterprises to realign growth in a sustainable trajectory, as well as strengthening Malaysia's position in the global supply chain. Malaysia would move towards high-value-added and high-skilled economic activities and set its sight on becoming a high-income nation driven by advanced technology. Over the next five years, concerted efforts would be undertaken to rejuvenate all the economic sectors, namely services, manufacturing, agriculture, mining and quarrying, as well as construction. Theme 3 focuses on advancing green growth and enhancing energy sustainability. One of the two game changers in Theme 3 for implementation involves "embracing the circular economy". In acknowledging the need to address the challenge of balancing the socioeconomic development and environmental sustainability, the circular economy model would be embraced. The public and private sectors would be encouraged to adopt and integrate the SDGs and ESG principles in their decision-making process. Apart from creating green job opportunities and ensuring resource security, the circular economy would reduce waste generation, pollution, GHG emissions, and dependency on natural resources. In order to expedite the transition, an enabling ecosystem would be put in place, while more sharing economy models would be promoted. The use of recycled materials and recycling of production waste would be increased, while the responsibility of producers in managing their end-of-life products would be extended. All these initiatives would expand the green economy and facilitate the attainment of a low-carbon future (Source: EPU: 12th Malaysia Plan).

(iii) KeTSA's TIM (2021–2030) reported the country's possession of RM 747.2 billion worth of IAC-REE in its ion adsorption clay deposits nationwide (Source: TIM 2021–2025).

(iv) MIDA's Chemical and Advanced Materials Division recognised the potential of REE downstream sector, as well as the advantages of having REO production as raw materials in the country. The government, through the MIDA, has been promoting the production of advanced materials, including rare earth magnets under the Promotion of Investment Act (PIA) 1986. In order to continuously support this, MIDA would continue its collaborations with the relevant stakeholders to attract potential investors to develop the industry. The support would focus on the downstream manufacturing activities, as well as integrated projects, including the manufacturing of rare earth metals that can convert oxides into metals. Therefore, MIDA encourages potential investors to explore the business prospects of the REE ecosystem (Figure 4) (Source: Gearing Malaysia as a Rare Earth Elements (REEs) Powerhouse (February 2022)).

(v) Standard Operating Procedure (SOP) for Non-Radioactive Rare Earths Mining in the State of Perak provides the framework for the mining of REE occurring within ion adsorption clays overlying granitic bodies in that state. A pilot project at the site in Kenering, Gerik was approved by the state government for a local mining firm to implement the SOP. The SOP was audited by JMG on 16 December 2022, and the report was submitted to the state government.

(vi) The publication entitled "Low Carbon Mobility Blueprint (2021–2030): Decarbonising Land Transport" described its vision of driving the sustainability principles to assess the best options in energy and GHG mitigation planning in transportation, particularly land transportation, using the scenario analysis for a business-as-usual case. The vision is to be realised through three objectives covering energy, economy, and environment over four focus areas. In terms of rare earth-based super-magnets and electric motors, the most relevant focus area to these products is the Focus Area 2 on GHG and energy reduction via electric vehicle adoption, which covers electric cars, electric buses, and electric motorcycles (Source: Low Carbon Mobility Blueprint (2021–2030): Decarbonising Land Transport, KASA, 2021).

FIGURE 4

The REEs Ecosystem

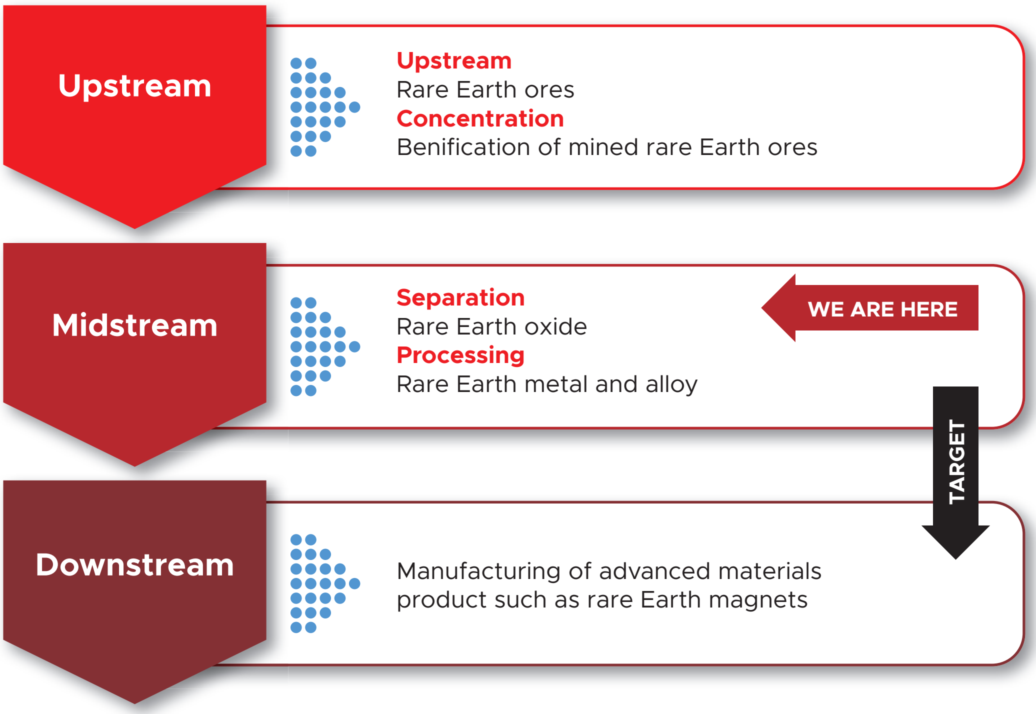

Figure 4: The REE Ecosystem (MIDA's Chemical and Advanced Materials Division e-Newsletter, 2022)

(vii) MOSTI's publication entitled "National Advanced Materials Technology Roadmap (2021–2030)" described advanced materials as novel or improved materials engineered for targeted and improved properties that provide distinct advantages in (physical or functional) performance and application when compared to conventional materials, which enable and provide technological innovation solutions and are sustainable to the economy, environment, and society. The publication outlined the performance of various materials, technological innovations, market's economic status, process technologies, key initiatives, and strategic partnerships to drive industrial transformation. Rare earth was identified as an advanced material in the publication (Source: National Advanced Materials Technology Roadmap (2021–2030), MOSTI, 2022).