

Blueprint for

# The Establishment of Rare Earth-Based Industries in Malaysia



## Summary for Policy Makers



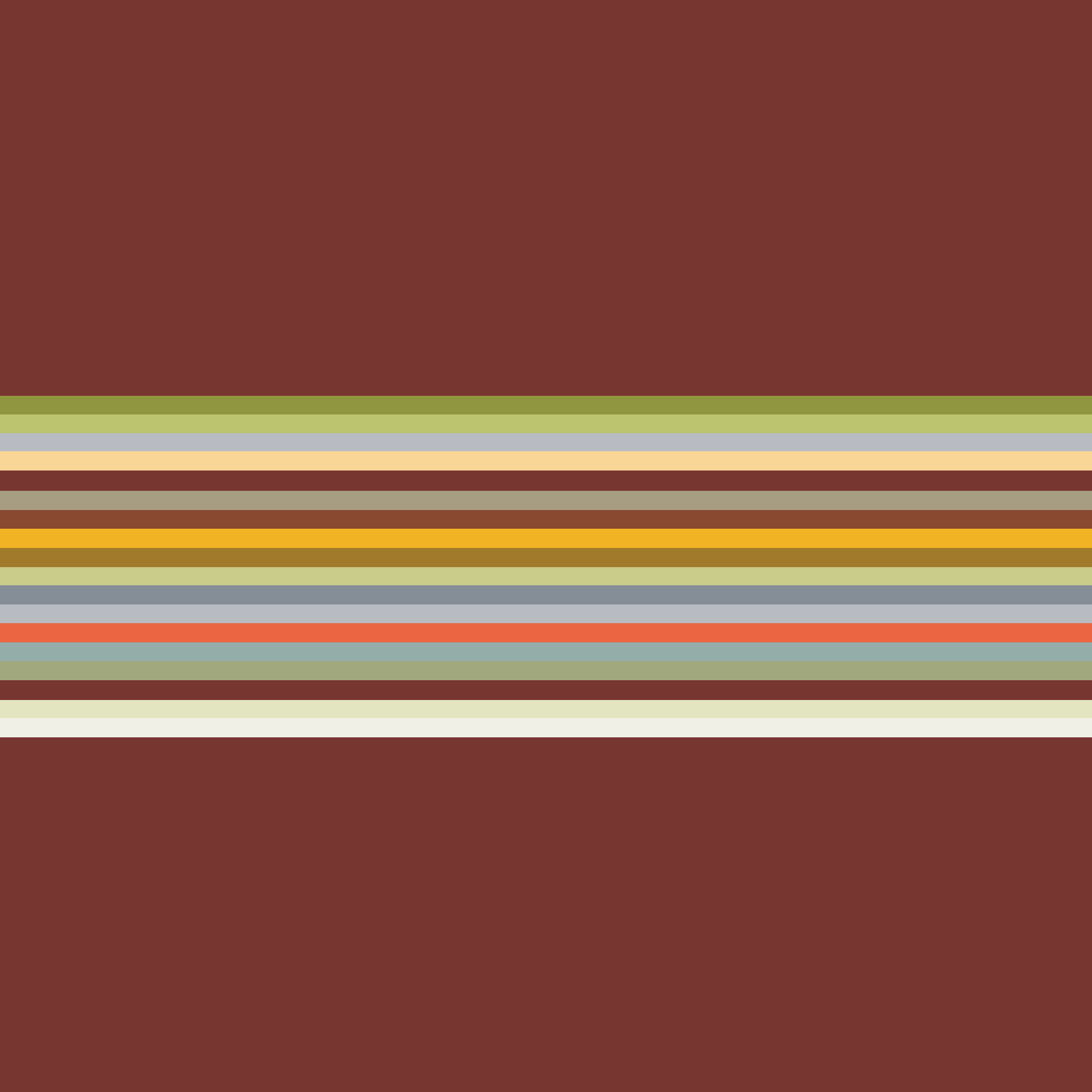


Blueprint For  
**The Establishment Of Rare Earth-Based  
Industries In Malaysia**

“A Strategic New Source For Economic Growth”

**Summary for Policy Makers**





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# FOREWORD

I would like to take this opportunity to extend my sincere gratitude to the Academy of Sciences Malaysia for the publication on the “Blueprint For The Establishment of Rare Earth-Based Industries in Malaysia – A Strategic New Source for Economic Growth”. The publication of this Blueprint is one more step towards achieving MOSTI’s vision to utilise, deploy and diffuse science, technology and innovation for knowledge generation, wealth creation and societal well-being. The Blueprint contains much information covering the upstream-to-midstream-to-downstream activities covering the full rare earths ecosystem for establishing rare earths-based industries in the nation. This publication will help to provide insights into the dynamics and trends in rare earths research areas, their results and outcomes as well as to chart future STI strategies that will support the government’s economic transformation agenda.

I believe this publication will be instrumental in promoting and disseminating Malaysia’s own potential wealth in rare earth resources as well as the separation and extraction of rare earths metals for the production locally of the many high-value green technology products for either local use or export overseas. The Blueprint will certainly be a source of reference that could be readily and easily accessed by policy makers, researchers and practitioners.

I offer my congratulations to the Academy of Sciences Malaysia (ASM) for its timely effort in publishing this “Blueprint For The Establishment of Rare Earth-Based Industries in Malaysia – A Strategic New Source for Economic Growth”. MOSTI will continue to support the Academy of Sciences Malaysia in its efforts to identify new sources of economic growth through Science, Technology and Innovation.



**The Honourable Datuk Dr. Ewon Ebin**

*Minister of Science, Technology and Innovation (MOSTI)*

# FOREWORD

I would like to convey my congratulations to the ASM Task Force on Rare Earths for the “*Blueprint For The Establishment of Rare Earth-based Industries in Malaysia — A Strategic New Source for Economic Growth*”. This effort would not have been possible without the strong support and co-operation from the Government, through the Ministry of Science, Technology and Innovation, in providing the necessary allocation to undertake this effort.

The Academy believes that this Blueprint can help various industries, from miners to mineral processors to metallurgists and other industrialists, both Malaysians and foreigners, to put Malaysia on the global map as a centre for rare earths mineral production, processing, and the establishment of related rare earth-bearing industries producing magnets, catalysts, phosphors and so on. This would definitely enhance our chance of achieving the high income target by 2020.

The Blueprint includes information on:

- Upstream Sector covering 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, management of waste residues as well as related R&D;
- The necessary human resources at all levels of expertise;
- The social and environmental impact of rare earth-based industries;
- Governance aspects covering laws and regulations;
- Economic Impacts of rare earth industries;
- Opportunities for Malaysia; and
- The rare earth industries roadmap for Malaysia.

The production of this document is in fulfilment of the Academy’s many functions, among which are to provide independent advice to the Government through dissemination of ideas and suggestions amongst decision- and policy-makers, scientists, engineers and technologists through identifying where the innovative use of science, engineering and technology can provide solutions to particular national problems towards sustained national development. This Blueprint will be disseminated and made available to the various relevant Ministries, universities, research institutes, venture capitalists, industrialists, NGO’s and others for wider public consumption.

**Tan Sri Dr Ahmad Tajuddin Ali, FASc**  
*President,*  
*Academy of Sciences Malaysia*



# PREFACE

The Academy of Sciences Malaysia undertook the development of a *Blueprint for the Establishment of Rare Earth-based Industries in Malaysia — A Strategic New Source for Economic Growth*. This aspiration is in line with its view that rare earth (RE) elements can form the basis of many value-added downstream industries in the country, and especially of those industries which can contribute to the green economy of the nation. However, it is not only the downstream industries that can benefit from this use of RE but also the upstream (mining and primary processing) and mid-stream (secondary processing and related activities) industries.

With the re-emergence of RE minerals processing in the country through the investment of an Australian company, the ASM Task Force on Rare Earth had identified the potential of developing the mineral industry as a strategic industry focusing on RE, in effect, establishing a domestic total RE supply chain.

With the new global interest in, and demand for, RE minerals and, especially the metals, it also now presents Malaysia with the opportunity to be among the global players in developing the RE and at the same time revitalize its RE mining and processing activities. RE are now of strategic importance for high-tech and green-tech industries. A number of other countries such as USA, Canada, Vietnam and India are also thinking along similar lines. In the process, it is hoped that the development of RE mineral industry can provide the impetus for the development of downstream RE-based industries which ultimately can function with or without the availability of local RE minerals resources. The establishment of a RE industry will help in moving Malaysia's green economy forward.

The main objective of this Blueprint is to prepare a document which can outline the benefits of establishing and developing a RE industry in Malaysia in the upstream, mid-stream and downstream sectors (including identifying the necessary capacity building needs).

This effort was basically a desktop exercise focusing on the following aspects:

- 1 Malaysia should strategize its mineral industry development by focusing on RE minerals as a strategic mineral commodity;
- 2 Using technology transfer and international experience as the platform for a strategic government / private collaboration;
- 3 The availability of local sources of RE minerals would greatly facilitate the establishment of downstream RE-based processing and manufacturing activities. Such activities would bring wide ranging benefits including export earnings, import substitution, human resource development, R&D and creating a knowledge-based economy. It will also give a boost to Malaysia's Green Economy; and
- 4 RE-based industries will benefit other sectors in the nation's economy from the many possible spin-off industries that can take off.

I would like to take this opportunity to thank all chapter contributors, all well known experts and specialists in their own subject matter including MIDA, comprised mainly national experts but also including an expert each from the USA and Australia. I also would like to thank the members of the Task Force who were enthusiastic in providing relevant support and useful feedback in our deliberations.

I would also like to thank the Ministry of Science, Technology and Innovation in providing the necessary allocation and providing strong support in our effort.

Finally, I hope that this Blueprint will spur various industrialists to take a look (and in other cases, a "re-look") at the many opportunities now at hand in Malaysia and take advantage of the available incentives provided by the Government.

**Tan Sri Dato' Academician Ir. Ahmad Zaidee Laidin, FASc**  
*Chairman,*  
*ASM Task Force on Rare Earth*

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# Acknowledgements

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4. Ministry of Science Technology and Innovation, Malaysia
5. Mr Jack Lifton, Founding Principal, Technology Metals Research LLC, USA (Chapters 1 and 9)
6. Mr Teoh Lay Hock, Geological and Mineral Business Consultant, Kuala Lumpur (Chapters 2 and 10)
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17. Prof Amran Abd. Majid, Universiti Kebangsaan Malaysia, Bangi, Selangor (Chapter 8)
18. Malaysian Investment Development Authority, Kuala Lumpur (Appendix).

We would also like to take this opportunity to thank various international organizations and their personnel for providing us with much technical and non-technical input on rare earths. The organizations are:

- (i) Chinese Society of Rare Earths, Beijing, China
- (ii) Peking University, Beijing, China
- (iii) General Research Institute for Non-Ferrous Metals, Beijing, China
- (iv) Rhodia Rare Earths Processing Plant, La Rochelle, France
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- (vi) Centre for Social Responsibility in Mining, University of Queensland, Brisbane, Australia
- (vii) JKTech Pty Ltd, Sustainable Minerals Institute, University of Queensland, Brisbane, Australia
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- (xii) National Institute For Material Science (NIMS), Tsukuba, Japan
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- (xv) Curtin University, Perth, Australia
- (xvi) University of Western Australia, Perth, Australia
- (xvii) Central Institute of Technology, Perth, Australia
- (xviii) Commonwealth Scientific and Industrial Research Organisation, Perth, Australia
- (xix) Department of Mines and Petroleum, Perth, Australia
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# SUMMARY

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MAKERS

# SUMMARY FOR POLICY MAKERS



## 1.0 BACKGROUND

In an ongoing effort to sustain the nation's economy, Malaysia is always on the lookout for new business opportunities and economic growth areas. The Academy of Sciences Malaysia has been actively involved in studies to seek such opportunities through its Mega-Science Framework studies. In an earlier report by the Academy, the rare earths business was identified as a strategic sector for Malaysia. As the world struggles to embrace green technology, the role of rare earths has become increasingly significant in the global economy. The rare earths elements find wide use in a range of products and gadgets which demonstrate the efficient use of energy as well as more effective deployment of renewable energy including wind power and solar photo-voltaic. The establishment of the rare earths processing plant by Lynas Corporation's has also prompted a more detailed evaluation of the rare earths business opportunities, especially on how best can Malaysia as a country participate. This blueprint aims to discuss the rationale for venturing into the industry, including the risks and opportunities involved, and provide a pathway for the nation to effectively enter this new potential growth area.

## 2.0 THE RATIONALE

Recent years have witnessed a growing world interest in rare earths elements (REEs). As a result of many years of R&D, rare earths have emerged as critical elements in the manufacture of a range of products which support the global push for green technology. Rare earths are used in the manufacture of permanent magnets, metal alloys, catalysts (used in oil refining), polishing powders, phosphors, glass additives and ceramics. In 2012, the demand for rare earths oxides for use in the manufacturing of permanent magnets and metal alloys accounted for some 20percent of global demand or 21,000 tonnes of rare earths oxides. Catalysts accounted for 19 percent, or 20,000 tonnes, followed by polishing powders accounting for 13 percent, or 14,000 tonnes. These are some of the high value, high demand rare earths-based products. It is expected that this demand will increase over time with applications in green technology (next-generation wind turbines, electric vehicles etc), medical technology (MRIs etc), in defense technologies and for energy efficient appliances and devices. More specifically, the demand for heavy rare earths elements (HREEs), used in magnets for various uses and other high-value products, is expected to increase as China keeps its HREEs for its own uses and has reduced its export quotas.

As the world struggles to avert the negative consequences of climate change and global warming, the demand for rare earths is predicted to rise in the coming years. The global demand for rare earths oxides (REOs) is projected to reach around 162,500 tonnes in 2016. Current world demand now stands at 133,650 tonnes. Most of the demand comes from the developed economies of the world especially the EU, USA, Japan and South Korea. The downstream manufacture of rare earths based products are now mainly centered in such countries. For many years, China has been the leading producer and supplier of rare earths to the world. They are still very much in control of world supply since they account for more than 90 percent of global production. A few years back, China took a decision to rationalize the country's rare earths production. The pressure to change was driven by a number of factors. The uncontrolled proliferation of illegal rare earths miners created a lot of environmental problems for communities living close to the mining sites. More regulations were then put in place to crack down on such practices. Many of the mines which could not meet the new standards of operation had to be closed down. This affected world supply driving up the global prices of rare earths.

At the same time, as a result of robust economic growth, China's demand for the downstream products grew. Consequently, China introduced a policy to expand investment in downstream manufacturing. The policy included a restriction on the export of rare earths. This again rattled their traditional buyers especially Japan and South Korea. Both countries were desperately looking for alternative suppliers. The sudden change in China's rare earths policy prompted new investment interests around the world. In the USA, the Molycorp Group took steps to revive their dysfunctional rare earths plant in California. Here in Malaysia, Lynas, an Australian group, obtained the green light to set up one of the largest rare earths processing plant outside China, under strong protest by some environmental groups. The plant which experts claim is the most modern in terms of the technology is now fully operational. The supply of REOs is expected to amount to 169,600 tonnes in 2016 if China maintains its production of rare earths oxides and both Lynas Corporation's and Molycorp (currently, the only two existing global operations outside China) meet their target productions.

Though supply is expected to meet demand in the coming years, the supply outside China is expected to face limitations. Downstream manufacturers outside China, such as in countries including Japan, South Korea and the EU will be badly affected because of uncertainties in supply. The supply of heavy rare earths oxides is especially vulnerable with the clamp-down in China's production on environmental and security grounds. Experts predict the global availability of heavy rare earths is expected to decrease substantially. There is therefore going to be a growing demand for rare earths, both light rare earths and heavy rare earths, from non-Chinese sources.

### 3.0 HARNESSING MALAYSIA'S POTENTIAL

It has always been known that, in Peninsular Malaysia, there are occurrences of rare earths-bearing minerals which have been mined as by-products of tin mining. Various sources, such as the United States Geological Survey reports for 2012 and 2013, have estimated that Malaysia had some 30,000 tonnes to 43,000 tonnes respectively of rare earths mineral reserves. The 2013 study by the Academy of Sciences Malaysia (“Revitalising the Rare Earths Mineral Programme in Peninsular Malaysia as a Strategic Industry”) showed that, apart from alluvial xenotime and monazite (these are rare earths-containing minerals that are being recovered as by-products of tin mining) and there are other potential sources of REs which are worthwhile investigating, especially those associated with ion adsorption clays.

In Peninsular Malaysia, there are areas in Perak and Selangor where similar deposits of ion adsorption clays are also found. In fact, in 2013, in a presentation by a Japanese Geological Survey expert to the Academy of Sciences Malaysia, he had reported that the samples he had collected from an area east of Kuala Lumpur contained encouraging amounts of heavy rare earths elements (HREEs). The advantage of exploring for such ionic clay deposits is that the rare earths in these deposits are not associated with radioactive thorium or uranium. There is therefore an increased interest in identifying ion adsorption clays in similar geological environments in the Southeast Asian region and elsewhere.

HREEs are the strategic metals for producing green-tech and high-tech products from wind turbines to smart-phones to military applications. These are critical metals for the production of high-end products by many high-tech companies in the world, such as Apple, GE, Boeing in USA, Toyota and Samsung in the East and including the global military-industrial complexes. Having indigenous HREEs will give Malaysia a competitive advantage for attracting FDI in high-tech industries. Mining, processing and separation of HREEs can be a new source of economic growth for Malaysia.

For Malaysia to develop a high-tech centered, domestically self-sufficient, rare earths-based consumer product manufacturing economy, it will be necessary for it to secure first, for its own use. Sources of the rare earth elements within Malaysia should be developed for competitive advantage. Technologies would be necessary to develop a domestic total rare earth supply chain, so that the rare earths-containing minerals mined within or imported to Malaysia can eventually be converted into components of consumer goods.

Such a rare earth total supply chain could be profitable immediately as it feeds the rare earth enabled technologies, such as computer storage (hard disk drives) and the manufacturing of the many rare earth permanent magnets for motors, generators, and sensors used on an automobile. Further uses included in alternative energy production and in domestic motor driven appliances, just to name a few, all of which are already being assembled in Malaysia with imported rare earth enabled components.

With the existing automotive and electronic manufacturing industries, Malaysia has sufficient existing domestic demand for rare earth permanent magnets to support a total rare earth industry supply chain, and the south Asian regional demand coupled with the rapidly rising Chinese cost structure gives Malaysia a unique opportunity to become a competitive regional supplier of rare earth enabled finished goods.

As a Malaysian domestic total supply chain develops, it will be able to supply the critical core technology rare earth metals required to make rare earth permanent magnets, displays, lasers, and batteries to support not only the existing but also a larger domestic high-tech industry that can manufacture consumer high-tech items. Such items can be immediately exported, as they are now, and more importantly domestic production can be utilized to decrease outbound cash flows now required to support, by purchasing, finished retail goods, to feed the growing Malaysian domestic consumer demand for high-tech personal electronics.

The main aim of the Blueprint is therefore to outline the necessary development approach and the roles to be undertaken by the various stakeholders for achieving the desired outcome of the proposed rare earths-based industry.



The Blueprint’s objective is to provide the necessary information for the policy makers or investors to make informed decisions on establishing industries, whether in mining, in processing or in the many downstream industries using rare earths metals.

The principal goal is to initially use the local available resources containing heavy rare earths elements (HREEs) towards establishing a full rare earths supply chain, leading to the sustainable development of the high-tech industry in Malaysia. At this point in time, this will make Malaysia the first and only country outside of China to establish the full rare earths supply chain.

If, on investment and investigation by the Government, the ion adsorption clays are found to occur in encouraging quantities, the state government should invite investors, whether as wholly local ventures or in joint-partnership with foreign expert mining companies to determine the economic viability of the resource. If the company finds that the deposit can be mined economically, the state government should award a mining lease to the company to mine the ore and process the ore to produce concentrates.

In the event that the concentrate throughput is large, the company should preferably also have processing facilities on-site to process the concentrates to produce high-purity rare earths oxides (REOs) as the production of REOs will be a value-added initiative. Depending on the final use of the REOs, the relevant RE-based manufacturing companies can be invited to set up their plants in Malaysia.

If it is found that Malaysia does have “economical and minable reserves of HREEs,” the expected desired outcomes are:

- a) to become a regional manufacturing center for RE-based and RE-enabled industries ;
- b) to become a regional center for the R&D on RE-based technology and products;
- c) to become a strategic location in the region for FDI to relocate their high-tech R&D and manufacturing activities; and
- d) to contribute to achieving the status of high-income nation through the strong economic multiplying effects created by the RE-related industries.

In this context, the establishment of a heavy rare earths processing plant (Lynas’s plant in Gebeng produces mainly light rare earths) is advocated, initially using local rare earths resources. It is also proposed that the rare earths metals manufacturing plant that can convert the oxides to metals (which are then used as feedstock in downstream green tech manufacturing plants) be established in the country. The light rare earths oxides could also be utilised in the manufacture of catalysts for use in oil refineries. The nation should therefore capitalize on the presence of the plant being in Malaysia to establish value-added downstream industries in the country.

The Blueprint provides details of Road-Maps in each sector of the full rare earths supply chain, that is, in the upstream, midstream and downstream sectors for implementation from the start of the 11<sup>th</sup> Malaysia Plan period, that is, 2016. The Government has a major role to play in the upstream sector of exploration, R&D and capacity building. The relevant Ministries have been identified. For the detailed investigations in upstream, midstream and downstream sectors, the role of Government is to facilitate the entry of investors, whether local, foreign or as joint ventures of the two parties, into these sectors.

The total rare earths supply chain, in the short- (2016 – 2020), medium (2021 – 2025) and long-terms (2026 – 2030 and beyond), consists of the following industries:

1. Rare earth minerals (ores) mining (including the recovery of rare earth minerals, such as monazite and xenotime, as by-products of cassiterite (tin) mining or from locally occurring ion adsorption clays;
2. The extraction of the desired (in this case, the mixed rare earth) values from the ore concentrates produced in step one;
3. The safe removal of nuisance elements (mostly iron but also radioactive elements such as thorium and uranium found in monazite and xenotime) from the material produced in step 2;
4. The separation and purification of the rare earths in commercial quantities from each other by solvent extraction, ion exchange, and possibly by newer cheaper and more efficient technologies such as solid phase extraction;
5. The preparation of high-purity rare earth metals, alloys, and forms from the products produced in step 4 above;
6. The production of rare earth permanent magnets, batteries, lasers, and engineered chemicals leading to:
7. The production of consumer products requiring rare earth permanent magnets, batteries, lasers, and commercial catalysts for automotive exhaust control and petroleum reforming.

Most of Steps 1 and 7 and Steps 2, 3, 4 already exist or have been done commercially in Malaysia. Steps 5 and 6 can be achieved with domestic resources alone (preferable approach) or by importing technology from politically reliable sources.

As a start therefore, the Government would need to invest some **RM10 million to explore for rare earths in ion adsorption clays in Perak** (Fig. 1). The allocation, to be given to NRE/JMG, will be used for undertaking reconnaissance field investigations. Once Perak is completed and the report submitted to the Government, the Government could provide additional allocation, amounting to **RM30 million, for JMG to undertake similar studies elsewhere in the country.**

Cross-cutting all these steps and at every step is the need for enhancing capacity building to ensure that there are sufficient and fully-trained Malaysians from the vocational/technical levels to graduates in various science, engineering and technological fields to fulfill the expected demand.

As in any industry, there are always issues and risks to be managed. In this industry, the issues and risks cover the following areas:

- Impact on society and environment
- Global supply and demand
- Technology
- Forecasted reserves
- Available Expertise
- Research and Development

The full rare earths supply chain is a multi-billion ringgit industry when all three sectors are taken into consideration. Therefore, for the private sector to invest in Malaysia in this industry, various incentives and safeguards would need to be offered to attract them. Malaysia has the necessary institutions to ensure that these safeguards are vouched for. At the same time, the local universities and vocational institutes would have to produce the capable work-force needed to work in these high-tech industries.

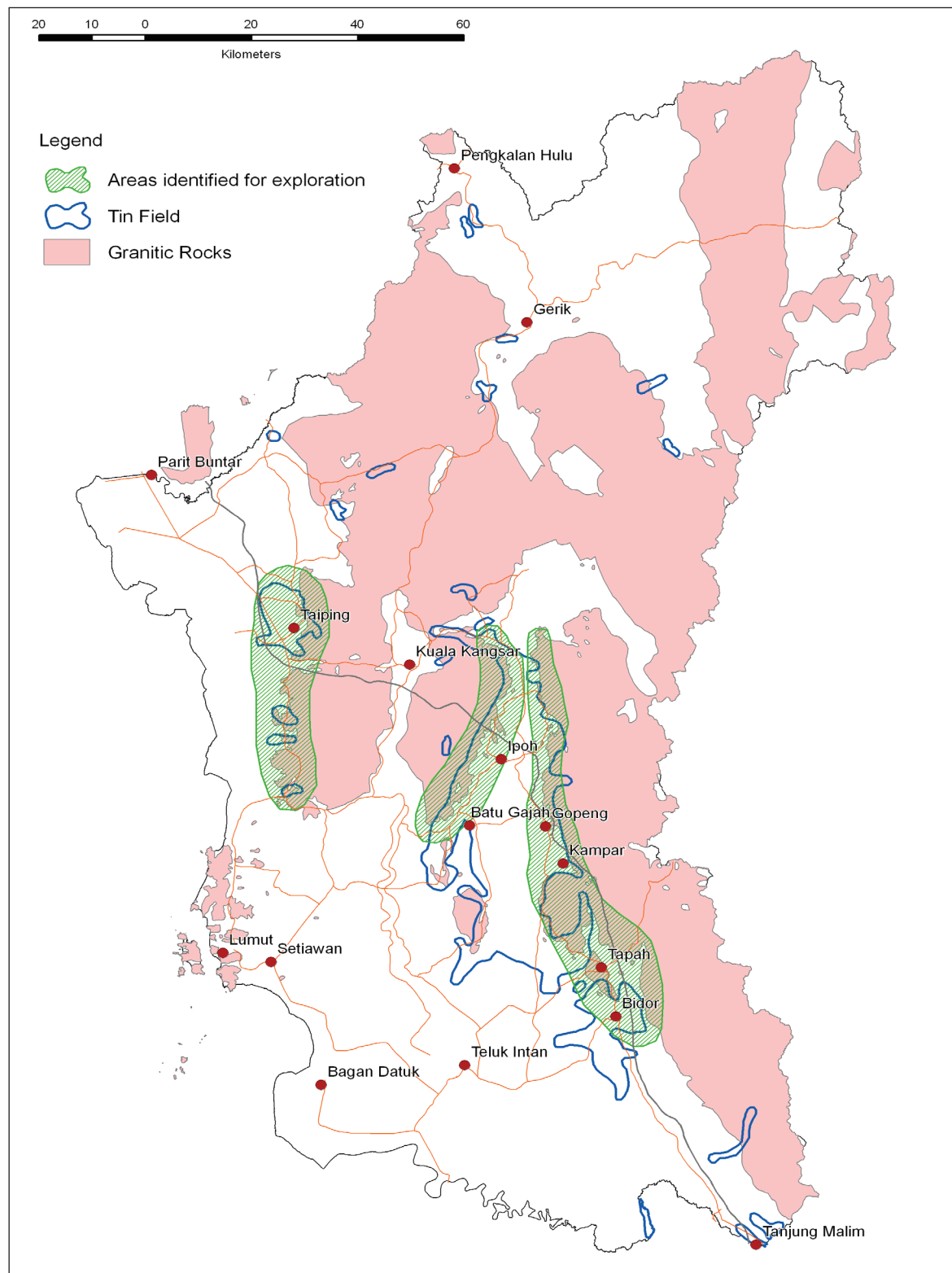


Figure 1: Areas Identified for Exploration of Ree-Hosting Ion Adsorption Clay Deposits in Perak

In an initial economic assessment by the Academy of Sciences Malaysia, the expected minimal contributions of the rare earths (REs) industry to the national economy in terms of FDI, GDP and estimated employment are 2.4percent (RM1.5 billion), 1percent (RM 10.137 billion) and 0.04percent (5000 jobs per annum) respectively by year 2020.

These figures do not take into consideration the potential multiplier effect from establishing downstream industries that use the rare earths metals or oxides as catalysts in the oil refineries, thus saving the nation much in terms of foreign exchange savings.

To drive the full rare earths supply chain, there would need to be a driver of the national rare earths agenda. It is proposed that a Board of Minerals Development Malaysia be established by an Act of Parliament to drive the initiative. Under this Board, an Institute of Critical Materials Technology Malaysia (ICMTM) should be established to play the roles pertaining to advanced and critical materials and the relevant industry sectors. ICMTM should be structured and organized such that it is industry-driven. Initially, ICMTM should consider having international technological partners with proven capabilities in rare earths research and development, such as with those in Australia, China, Japan, South Korea and the USA.

As a start, it is proposed that the Government invite investors, both local and foreign, to participate in the rare earths industry in the country. There is however one area where the Government would need to invest initially and that is in the area of rare earths exploration nation-wide.

## 4.0 UPSTREAM, MIDSTREAM AND DOWNSTREAM SECTORS

### 1.1 Upstream Sector

It is suggested that the Government invest some RM10 million to undertake exploration for rare earths in ion adsorption clays in Perak. The allocation, to be given to NRE/JMG, will be used for undertaking reconnaissance field investigation, involving soil profile sampling and determination of pattern of REE distribution along the profile. Comparisons could be made with REE distribution patterns obtained from studies already done elsewhere in the region.

JMG would be the most appropriate agency to undertake this type of investigation as they have the necessary manpower with the basic geological and scientific foundation. The allocation would cover the costs for such investigations including the purchase of appropriate equipment for analyzing the REEs. From the reconnaissance field investigation, areas with potential could be identified for follow-up investigation. The follow-up investigation would involve closer sampling and delineation of anomalous areas and horizons with high concentrations of REEs. The anomalous areas delineated could be investigated in more detail, including conducting excavation for test leaching and evaluation of extractability of the REEs. An assessment of the possible reserves could then be undertaken.

Once Perak is completed and the report submitted to the Government, the Government could provide additional allocation, amounting to RM30 million, for JMG to undertake similar studies elsewhere in the country.

The involvement of JMG could be up to the stage of obtaining enough information to attract investors. The follow-up and detailed investigations could then be taken up by the private sector should the initial results prove attractive.

As mining is a state matter, the private sector, whether local or foreign, would only consider investing large sums in undertaking detailed investigations leading to mining only if they are given first refusal rights to mining as well as a fairly long mining lease of around 20 – 25 years. This is because investments by these companies, including mine closure and land rehabilitation after mining, could run into tens of millions in one lease. The investment would cover operational costs (such as mining, processing, labour, administration, energy, maintenance, shipping costs, among others, such as royalties), capital costs (such as site development, pre-production, labour, equipment, tailings dam, and others).

**As an example, the Bear Lodge open pit mine in Wyoming, USA, had a start-up cost of RM251 million (US\$87 million) and Operating Costs amounting to RM25,000/tonne REO (US\$8,480/tonne REO).** A local company, or a consortium, will probably be able to mount similar start-up operations here in Malaysia for a fraction of the cost, thereby reducing the Operating Costs immensely.

## 1.2 Midstream Sector

Using Lynas Corporation's investments in Malaysia as an example, it was reported that, in Phase 1, the capital cost for the processing plant amounted to RM1.6 billion (AUS\$539.33 million) in 2011. Phase 2's capital cost is estimated RM790 million (AUS\$263.4 million). Phase 1 will result in 11,000 tonnes of REO being produced; Phase 2 will ramp up the production to 22,000 tonnes REO. With such high costs and the expertise needed, foreign companies can be invited to invest here either as partners with local companies or on their own.

The processing here by Lynas Corporation's is only to produce high-purity rare earths oxides (REOs) for sale to buyers overseas. A further step that would need to be taken is to establish plants to manufacture RE metals from the REOs. It is these metals; which fetch a very high price when compared to the REOs, and they are used in many high-tech and green-tech industries. Some of the well known companies are Apple, Samsung, GE, Boeing, Air Bus and Toyota to name a few. There is currently no information available on the capital and operational costs of establishing such a plant here. However, this is where G-to-G consultations with China may help as the Baotou Rare Earths Research Institute has established such facilities in Baotou.

## 1.3 Downstream Sector

The required financial/human capital and technology investment for downstream industries would depend very much on the types of manufacturing industries to be established. The market is vast for the major end uses for rare earth elements, such as for automotive catalytic converters, fluid cracking catalysts in petroleum refining, phosphors in lighting, color television and flat panel displays (cell phones, portable DVDs, and laptops), permanent magnets and rechargeable batteries for hybrid and electric vehicles, generators for wind turbines, as well as for medical devices. There are in addition defense applications, such as jet fighter engines, missile guidance systems, anti-missile defense, space-based satellites and communication systems. For each of the industries, investments can run into hundreds of million ringgit. Malaysia would need to identify its niche areas to invite the relevant investors.

## 5.0 THE ACTION PLANS-IMMEDIATE, SHORT AND LONG TERM PLANS

The Blueprint provides detailed Road Maps for each of the three Sectors for implementation as follows:

### 1.4 Upstream Sector

In the Upstream Sector, 5 Road- Maps have been developed, focusing on four types of resources and the R & D work to complement the development of the identified potential resources. The five road maps are:

Road Map No. 1 – On-shore alluvial xenotime and monazite

Road Map No. 2 – REE-hosted ion adsorption clays

Road Map No. 3 – RE potential in off-shore marine sediments

Road Map No. 4 – RE minerals in primary (hard rock) deposits

Road Map No. 5 – R & D in the upstream RE sector

In the immediate term (within 2014 - 2015), priority should be given to implementing Road Map No. 2 (REE-hosted ion adsorption clays in the Perak state) whereas in the short-term (1 – 5 years, from 2016 - 2025), the focus on ion adsorption clays can extend to other states where the geology is favorable.

In the short-term too, the implementation of Road-Map 1 (on-shore alluvial xenotime and monazite), could be implemented by the relevant states, specifically Perak, Pahang and Kelantan, inviting local companies to undertake detailed exploration for tin and other associated minerals, such as, zircon, ilmenite and struverite, including xenotime and monazite, in the alluvial tracts in these states. If these companies find economically minable quantities of these minerals, the states could issue long-term mining leases to these companies.

In the short- to long-terms (6 – 15 years, up to 2030), the Government would need to implement Road-Map No. 4 (RE minerals in primary (hard rock) deposits) and Road-Map No. 5 (R & D in the upstream RE sector). Road-Map 4 is essentially focused on evaluating the possibility of extracting xenotime and monazite from tin mineralized granitic rocks and its viability to do so commercially. The most appropriate starting point is to study the quarry dust in the quarries working on the tin mineralized granites. For Road-Map No. 5, the Government would need to initiate investigations RE-related R&D activities (the proposed list is given in the Blueprint).

Finally, in the long-term, for Road-Map No. 3 (RE Potential in Off-Shore Marine Sediments), the Government (both Federal and State) could offer near off-shore marine areas to the private sector for exploration of RE-bearing minerals. It is important that strict environmental regulations be imposed and enforced on these companies when they undertake the prospecting (and, later, mining).

All of the above Road-Maps would need to be coordinated and implemented by the Ministry of Natural Resources and Environment. Where mining is concerned, the Ministry would need to work with the relevant state governments. As allocations are needed to implement the activities, the Ministry of Finance is an important player.

### 1.5 Midstream Sector

As mentioned earlier, the midstream sector in the rare earths industry consists of activities ranging from the cracking of rare earths minerals into rare earths oxides down to the production of metals and alloys.

Although the processing technologies for the midstream sector are fairly well known, gaps do still occur in “cracking” and processing technologies, especially in ensuring that:

- (i) newer technologies are more environment-friendly and resource-efficient, and
- (ii) the necessary human capital to support this sector of the industry is available.

In this respect therefore, the Road Maps for the midstream sector should focus on research and education (both in the vocational/technical and tertiary levels) in the immediate- to long-terms (up to 2030).

The areas of research which can be explored include:

- Process improvement in refining RE
- New Solid – Liquid Extraction methods
- Thorium and Uranium Extraction for Fuel
- Scale up and process design study
- Bioprocessing as an alternative to the current chemical processing
- Sustainability

As for education, important areas to be included in the curriculum and syllabus of the tertiary education are

- Solid chemistry/ Properties
- Combination of different ore materials
- Urban Mining (Recycling )
- RE chemistry
- Advancement in process technology
- Unit Operations
- Separation technology

In addition, the study of chemistry of rare earths should be included to strengthen the fundamentals. These include fundamental chemistry, molecular chemistry and engineering chemistry.

To strengthen research and education in rare earths, and make it relevant to industry, supporting infrastructure is needed. This includes establishment of instrumentation relevant to RE midstream applications, pilot plant sized separation equipments and analytical instruments.

All of the above Road-Maps would need to be coordinated and implemented by the Ministries of Education (for Secondary and Tertiary levels) and Ministry of Human Resource (for vocational/technical level). As allocations are needed to implement the activities, the Ministry of Finance should also be involved in decision-making.



### 1.6 Downstream Sector

Based on the overview and analyses of the downstream sector of the RE industry, it was concluded that Malaysia has certain advantages in some areas of rare earths applications, such as the manufacture of RE magnets, batteries, lightings, catalysts, glass, lenses and polishing powder.

In order to set up these industries, the following issues need to be addressed in the immediate- to long-terms:

- (i) Technology – the know-how to manufacture the products;
- (ii) Funding – the financial resources to establish the facilities and operations; and
- (iii) Human capital - the manpower with the necessary knowledge to support the operations.

There are other factors such as raw materials, infrastructure, environment, etc. that need to be considered as well. Of all these, the technology and know-how factor appears to be the weakest aspect of Malaysia for venturing into rare earths-related downstream industry.

To address the problem, Malaysia should adopt the following strategic approaches.

- (i) Attract more foreign direct investment (FDI) to address financial resource needs and more importantly, the need for technology and know-how in high-tech industry;
- (ii) Build up the human capital (skilled workforce) relevant to the industry; and
- (iii) Encourage and support more research and development (R&D) activities to develop new technology and develop research capabilities (including manpower) for the industry especially moving up the value chain.

All of the above Road-Maps would need to be coordinated and implemented by the Ministries of International Trade and Industry, Education (for Secondary and Tertiary levels), Human Resource (for vocational/technical level). As allocations are needed to implement the activities, the Ministry of Finance should also be involved in decision-making.

## 6.0 BOARD OF MINERALS DEVELOPMENT MALAYSIA – THE RARE EARTHS INDUSTRIES DRIVER

To drive the rare earths (and other critical materials) agenda of the nation, it is proposed that the Government establish, by an Act of Parliament, the **Board of Minerals Development Malaysia** in 2016. For the acquisition of technology and funding, the recommendation is for the Board to promote foreign direct investment (FDI) and also to promote outward investment with the intention of acquiring the technology through technology transfer. The Board needs to be structured such that there are both public sector and private sector representatives to drive the Board and its agenda.

To develop human capital and to undertake research and development, the recommendation is for the Board to set up a national level **Institute of Critical Materials Technology Malaysia (ICMTM)** in undertaking the implementation of all the above Road-Maps. **The Institute of Critical Materials Technology Malaysia (ICMTM)** will play the roles pertaining to research in advanced and critical materials and their use in the relevant industry sectors. Considering the relevance of ICMTM to the development of advanced and critical materials-based industries, it is important that the institute be structured and organized such that it is industry-driven.



Among the roles that ICMTM could play are:

- (i) Design of direction, strategy and national master plan for the relevant industry sectors especially in technology, manpower, infrastructure development;
- (ii) Sourcing and management of funding and other resources and infrastructure for R&D in areas related to the industry sectors;
- (iii) Bridging and coordination between industry and universities in R&D and human resource development relevant to the industry sectors;
- (iv) Spearheading major R&D research programmes related to the industry sectors in collaboration with various industry players and universities, and
- (v) Setting up and managing major research facilities and equipment which are open for access by industry and universities.

There should be Government research funding allocated for R&D in advanced and critical materials and such funding should be made available and managed through ICMTM. Besides that, ICMTM should also work with the industry on funding from industry in some key research areas which are of interest to specific industry players.

ICMTM should also play the role as the bridge between industry and universities in human resource development for the industry by ensuring universities and polytechnics are well aware of and take necessary actions on the human power needs of industry.

A master plan on human development for the industry (from upstream to downstream) which includes projection of future needs should be formulated and reviewed by the Board continuously.

## 7.0 CONCLUSION

Before concluding, it is relevant to discuss rare earths pricing. Today's Chinese prices are irrelevant to the future and irrelevant to non-Chinese rare earth producers unless those producers wish to sell into China in competition with domestic Chinese producers.

China gain has a conundrum with respect to rare earth pricing. Costs of operation are skyrocketing in China. China has opposed the importing of domestically available raw materials such as the rare earths for the social reason of maintaining high employment. This driver has kept rare earth prices inside China below what is needed by the Chinese domestic mining and refining industry. The strain is showing in the heavy rare earth sector as excess refining capacity due to shortages of feed stocks. But at the same time that the Chinese government makes importing heavy rare earth concentrates difficult, it also makes developing heavy rare earth resources difficult due to concentrate prices that are too low for non-Chinese developers. Therefore it is felt that a rare earth total supply chain built outside of China, say, in Malaysia will draw end-use device manufacturers, including both Japanese and Chinese to Malaysia. It is also suggested that such an undertaking will shift the locus of the global rare earth industry away from China and that such a shift would add tens of billions of ringgit to the Malaysian economy.

Malaysia is uniquely situated to take advantage of this dilemma. It has been a rare earth producer and exporter for a long time; it now has the largest single light rare earth separation facility in the world and that facility can be supplied indefinitely from Australian resources. Malaysia has good sources of heavy rare earths and the ability to attract specialized refining and fabricating vendors to cover the entire spectrum of rare earth enabled products.

A pilot program must be initiated and funded immediately and the Rare Earths Blueprint details how that can be achieved.

Is there enough future global and/or regional demand for the rare earths to justify an investment by Malaysians, privately with public support, to create a total domestic rare earth supply chain within the country? The Blueprint in fact gives a definitive answer to the question “Can Malaysia build a domestic total rare earth supply chain?” The answer is yes. As for the larger question “Is it the right thing for Malaysia to do right now,” again the answer is emphatically yes.

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