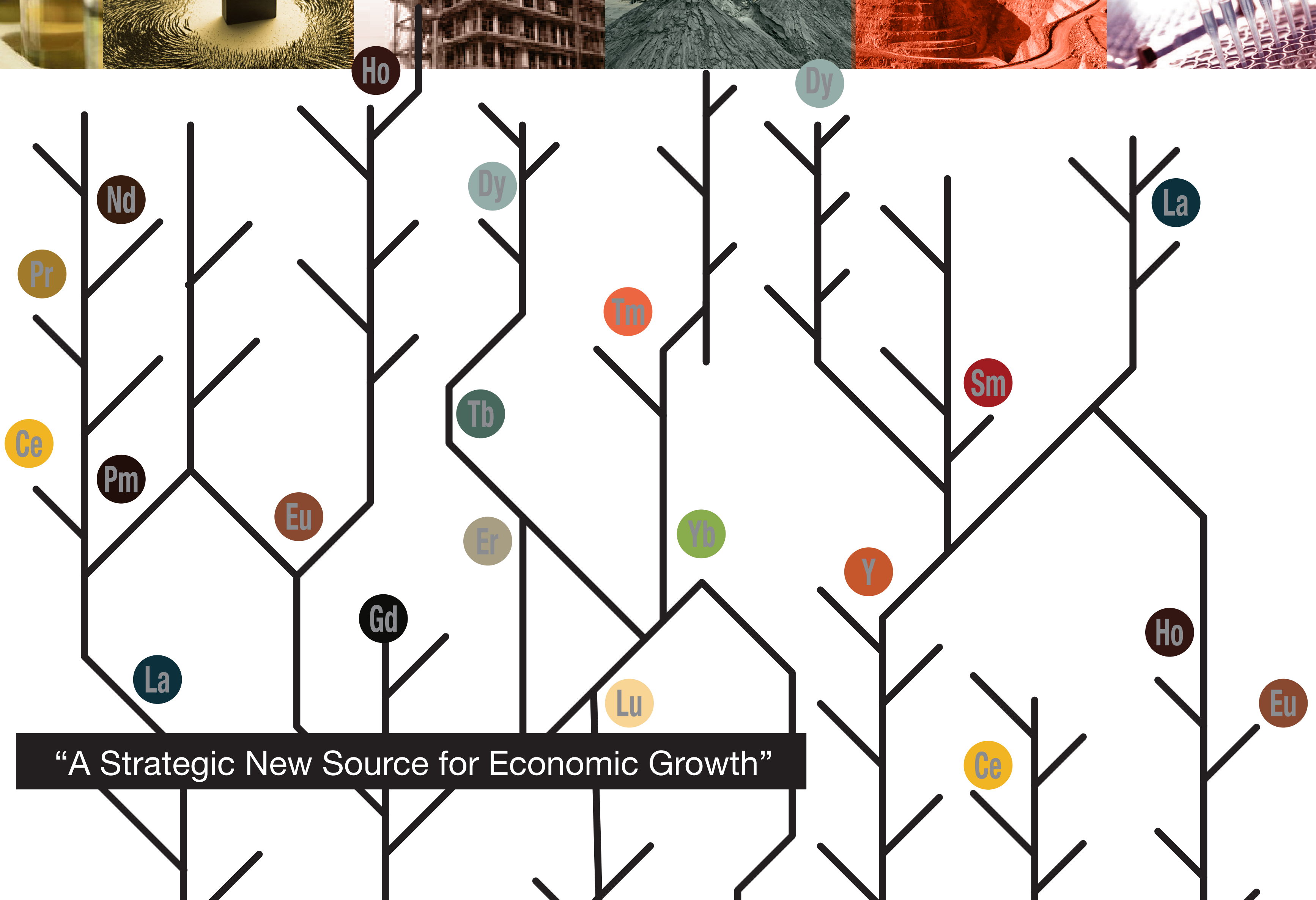
Blueprint for

The Establishment of Rare Earth-Based Industries in Malaysia



"A Strategic New Source for Economic Growth"

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Blueprint For

The Establishment Of Rare Earth-Based Industries In Malaysia

"A Strategic New Source For Economic Growth"

Summary for Policy Makers

MOSTI

AKADEMI SAINS MALAYSIA

2014

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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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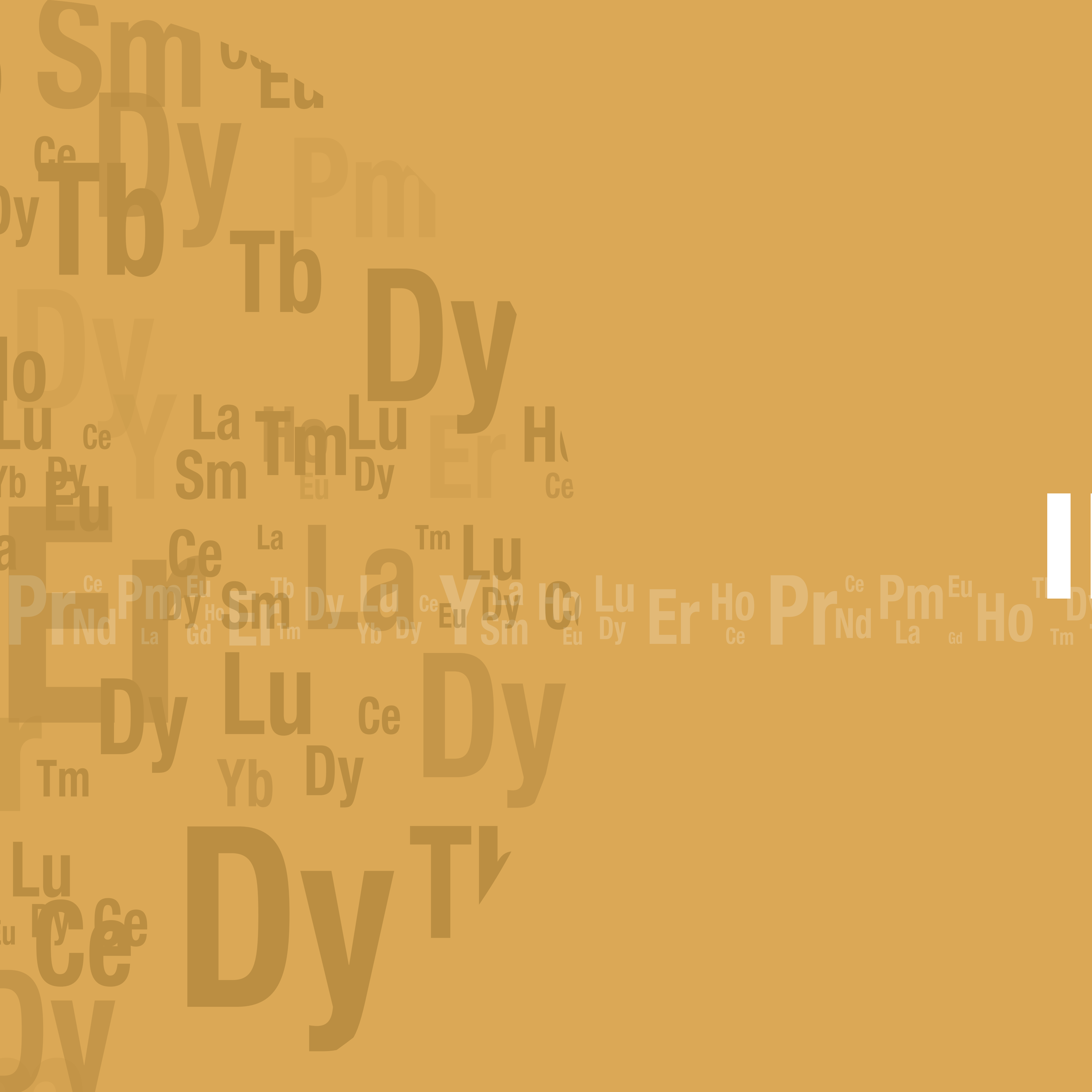
The ASM Task Force on Rare Earth would like to put on record its heartfelt appreciation to the following organizations and personalities for their support and contribution to the successful development of this Blueprint:

1. Economic Council, Malaysia
2. Ministry of Finance, Malaysia
3. Ministry of International Trade and Industry, Malaysia
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)
7. Prof Dato' Badhrulhisham Abdul Aziz, Universiti Malaysia Pahang, Gambang, Pahang (Chapters 3 and 10)
8. Dr Meor Yusoff Meor Sulaiman, Senior Research Officer, Malaysian Nuclear Agency, Bangi, Selangor (Chapter 3)
9. Prof Lee Sze Wei, Universiti Tengku Abdul Rahman, Petaling Jaya, Selangor (Chapters 4 and 10)
10. Prof Muhammad Ghazie Ismail Universiti Teknologi Melaka, Melaka (Chapter 5)
11. Ir. Hazzairi Ishak, Tenaga Nasional Berhad Integrated Learning Solution Sdn Bhd, Bangi, Selangor (Chapter 5)
12. Prof Saleem H. Ali, Centre for Social Responsibility in Mining, Sustainable Minerals Institute, University of Queensland, Australia (Chapter 6)
13. Prof Ramli Bahroom, Open University Malaysia (Chapter 7)
14. Dr Zorah Abu Kassim, Open University Malaysia (Chapter 7)
15. Dr Wardah Mohamad, Open University Malaysia (Chapter 7)
16. Prof Dato' Sukiman Sarmani, FASc, Universiti Kebangsaan Malaysia, Bangi, Selangor (Chapter 8)
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
(v) Karlsruhe Institute of Technology, Karlsruhe, Germany
(vi) Centre for Social Responsibility in Mining, University of Queensland, Brisbane, Australia
(vii) JKTech Pty Ltd, Sustainable Minerals Institute, University of Queensland, Brisbane, Australia
(viii) Korea Institute for Rare Metals, Seoul, S. Korea
(ix) Samsung SDI Co. Ltd. Cheonan Plant, Seoul, S. Korea
(x) Institute of Geoscience and Mineral Resources, Seoul, S. Korea
(xi) Geological Survey of Japan, Advanced Industrial Science and Technology, Tsukuba, Japan
(xii) National Institute For Material Science (NIMS), Tsukuba, Japan
(xiii) MIDA offices in Seoul and Tokyo
(xiv) Department of State Development, Government of Western Australia, Perth
(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
(xx) Polytechnic West, Carlisle Campus, Perth, Australia.



NTRODUCTION

Jack Lifton

INTRODUCTION

Jack Lifton
Founding Principal, Technology Metals Research LLC, USA

1.0 SUMMARY

A “Blueprint” is a numerically and graphically detailed set of directions created by engineers to enable other engineers to build or reproduce something. It is intended as a specific guide to be used by anyone. The Blueprint being presented here has a wider scope. It is intended to give all of the information necessary to the readers, be they policy makers or investors, who want to make an informed decision about implementing, or investing, in the creation of a total domestic rare earth supply chain in Malaysia. Such a supply chain would make Malaysia a competitive participant in the large and growing global market for mass produced consumer products based upon rare earth enabled technologies.

No technological impediment is foreseen to implementing the Blueprint, but, as with all large undertakings, there will be financial risks. Quantifying those risks is itself a principal function of this Blueprint.

The opportunity being discussed here is for Malaysia to become a center for the manufacturing of rare earth permanent magnets, phosphors, lasers, and oil-refining catalysts. In order for that to come about Malaysia must first produce domestically or acquire control over the minerals from which critical rare earths can be extracted. It will then be necessary for Malaysian industry to learn how to extract the desired rare earth elements from these minerals, separate the individual rare earths from each other and purify them to a level for industrial use. At this point, the separated and purified rare earths, a valuable group of commodities with a global market will be in production and be able to be sold globally “as is.”

The next step in the creation of a domestic Malaysian rare earth supply chain will be the creation of a domestic industry that produces, from the separated and purified individual rare earth elements, the individual high purity rare earth metals, alloys (for magnets and steel making), phosphors, and fine chemicals for the production of lasers, medical equipment, industrial equipment, and fluid cracking catalysts (for the oil refining industry). These “raw materials” produced at this stage will be also be saleable into the global high tech market “as is.”

Finally, a domestic Malaysian high-tech consumer and industrial end-use product industry will be created to manufacture and supply rare earth permanent magnets to the OEM automotive industry, the aerospace industry, the power generation industry, and the consumer portable electronic industries. Many of these industries already exist in Malaysia, such as OEM automotive and computer hard-disk drive manufacturing. These industries would be large-end users of rare earths permanent magnet-based components, such as electric motors and generators. The existing domestic Malaysian end-users of rare earths-enabled products will give the domestic rare earths component manufacturers a solid market anchor.

The following chapters in this Blueprint detail the necessary steps to achieve the above goals. The result will be a dynamic domestic manufacturing industry anchored upon a domestic total rare earth supply chain.

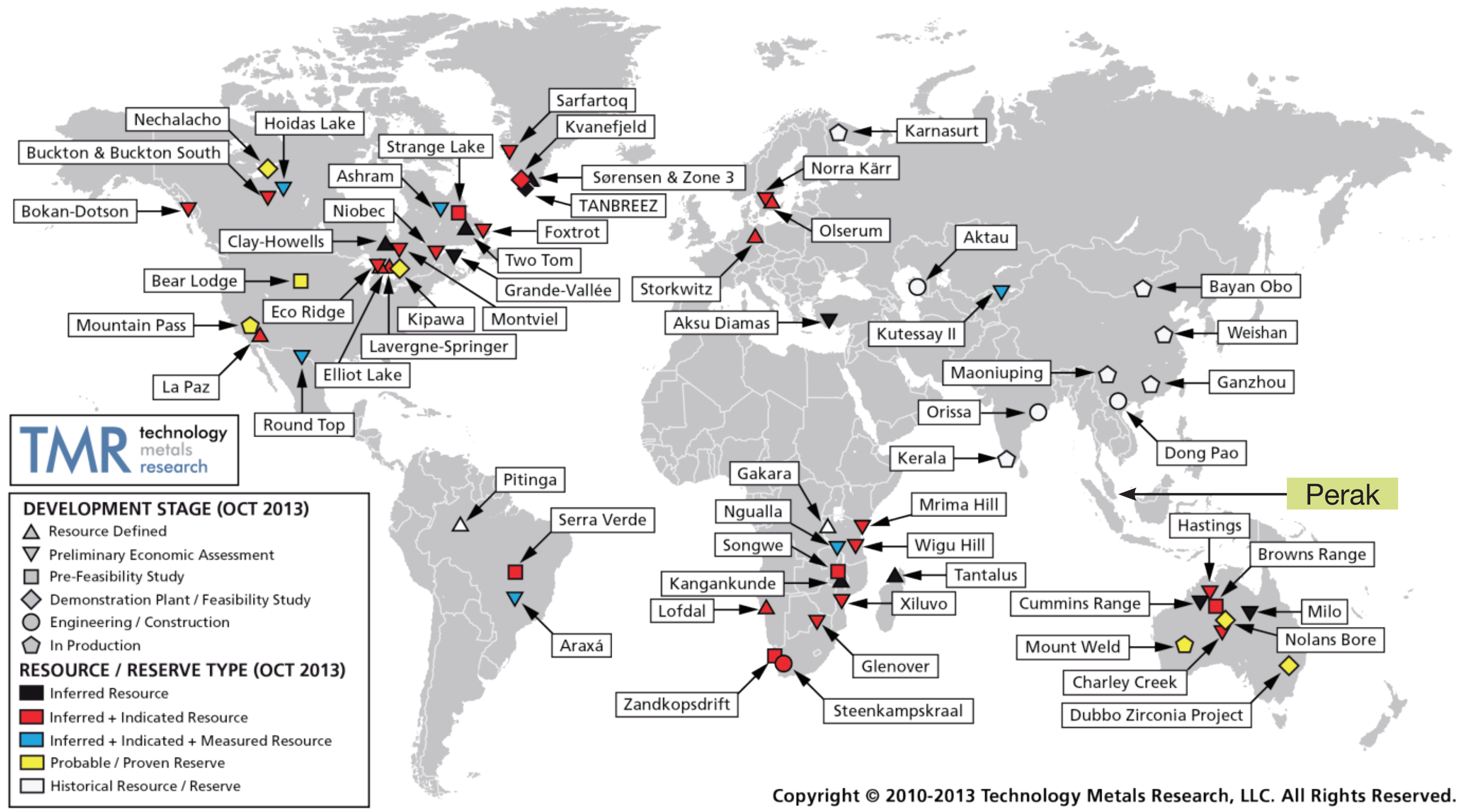
Today, only China, has achieved this status, but China's rare earth total supply chain was created haphazardly and it is now suffering from excess capacity and an inability to increase its production of the key "heavy rare earths" that are critical for manufacturing rare earth permanent magnets and phosphors, the two highest revenue-producing sectors. This is primarily due to a massive environmental problem caused by unplanned and unethical leaching, which has been now abruptly made subject to strict national government control. This has reduced Chinese domestic production of heavy rare earths after being idle indefinitely as the Chinese government tries to work out a safe way to continue production while remediating the damage already done.

The Chinese rare earths industry has now focused on a large-scale recycling program to try to sustain its supplies of heavy rare earths.

Chinese domestic rare earth prices are being impacted by the costs of this remediation and of recycling. There is, due to this problem, an ideal opening for competitors to step in and avoid the Chinese mistakes and create a clean total rare earths supply chain unburdened by overcapacity, supply problems in key ingredients, and a generally low quality of product.

As such, the focus here will be on where the rare earths and their markets are right now, and then project where they are going and what role Malaysia could play in the global growth of that market.

1.1 The Geographic Distribution of Rare Earth Resources in the past and from Recent Exploration



(Source: Technology Metals Research LLC)

Figure 1. Geographic Distribution of Rare Earths Resources/Reserves and those in Development Stage

It is to be noted that in Figure 1, the global graphic, there are just two producing mines outside of China; Molycorp's Mountain Pass, California operation, which has just been restarted after being idle for more than a decade, and Lynas Corp.'s Mt Weld in Australia. Both are very large deposits of relatively high-grade light rare earths-bearing minerals. The overwhelming majority of the deposits in this global graphic are primarily of light rare earths.

The global problem is that there are no deposits, which have been developed outside of China to produce the heavy rare earths which are the key rare earths needed to mass produce miniaturized consumer and military electronic devices.

The best bet for sourcing the key heavy rare earths for magnets and phosphors are either as by-products of tin (cassiterite) processing or from ion adsorption clays in Viet Nam, Thailand, Malaysia, or the Indonesian Archipelago. In places where tin has been mined and/or refined for a long time, such as Malaysia/Indonesia and Brazil, it is believed that enormous quantities of the yttrium/dysprosium mineral, xenotime have been accumulated in residues.

Chapter 2 details a plan for locating and developing domestic Malaysian resources of rare earths-bearing minerals. Two minerals, monazite and xenotime, containing rare earths elements in their crystal structures, have been produced in Malaysia and exported for many years as by-products of tin mining. It is certain that many more deposits of such minerals are located in Malaysia.

1.2 The Geography of Actual Global Rare Earth Supply

The details of actual existing and operating global rare earth supply must be looked at from the perspective of the geography of the global rare earth supply. The overall actual detail (as best as can be known, because the data is from Chinese sources) for the most recent audited years appears in Table 1. As this is being written in late 2013, it means that any data in the Table below for 2014 and beyond is speculative. But it is very important for the reader to know that the most speculative of the data is that for the ROW's, the Rest-Of-the-World's, i.e. not China's, future production. Note that almost all of the supply of all of the rare earths and also of yttrium comes now from the People's Republic of China. In China, the light rare earths are mostly produced as by-products of iron mining in Inner Mongolia. Thus the global supply of light rare earths is underwritten and virtually subsidized by the massive Chinese iron ore mining industry. It is critically important to note that this type of "virtual" subsidy is neither official (dictated by the Chinese central government) or unusual in the global mining business.

The writer was recently in China as an invited guest of the Chinese Society of Rare Earths to speak at the 7th Annual Conference on Rare Earths Applications and Developments. A speaker from Inner Mongolia discussed light rare earths' production there and concluded that the region could supply the entire world's demand for light rare earths indefinitely. This was a statement of fact. The only reason therefore to produce light rare earths outside of China is to insure security of supply, and the writer thinks it is very important to understand that any producer of light rare earths outside of China must have a plan to utilize that production, or face a perilous competition from what must certainly be the world's lowest cost producer of light rare earths.

The issue in the global rare earths' markets is the security of supply of the heavy rare earths. This cannot be achieved unless the ROW produces and processes heavy rare earths! This is again where even China has a problem. Limited resources and environmental remediation are challenges right now to continued export from China of the heavy rare earths. It is foolish to bet that the Chinese would continue to export a resource that even now is running short in China.

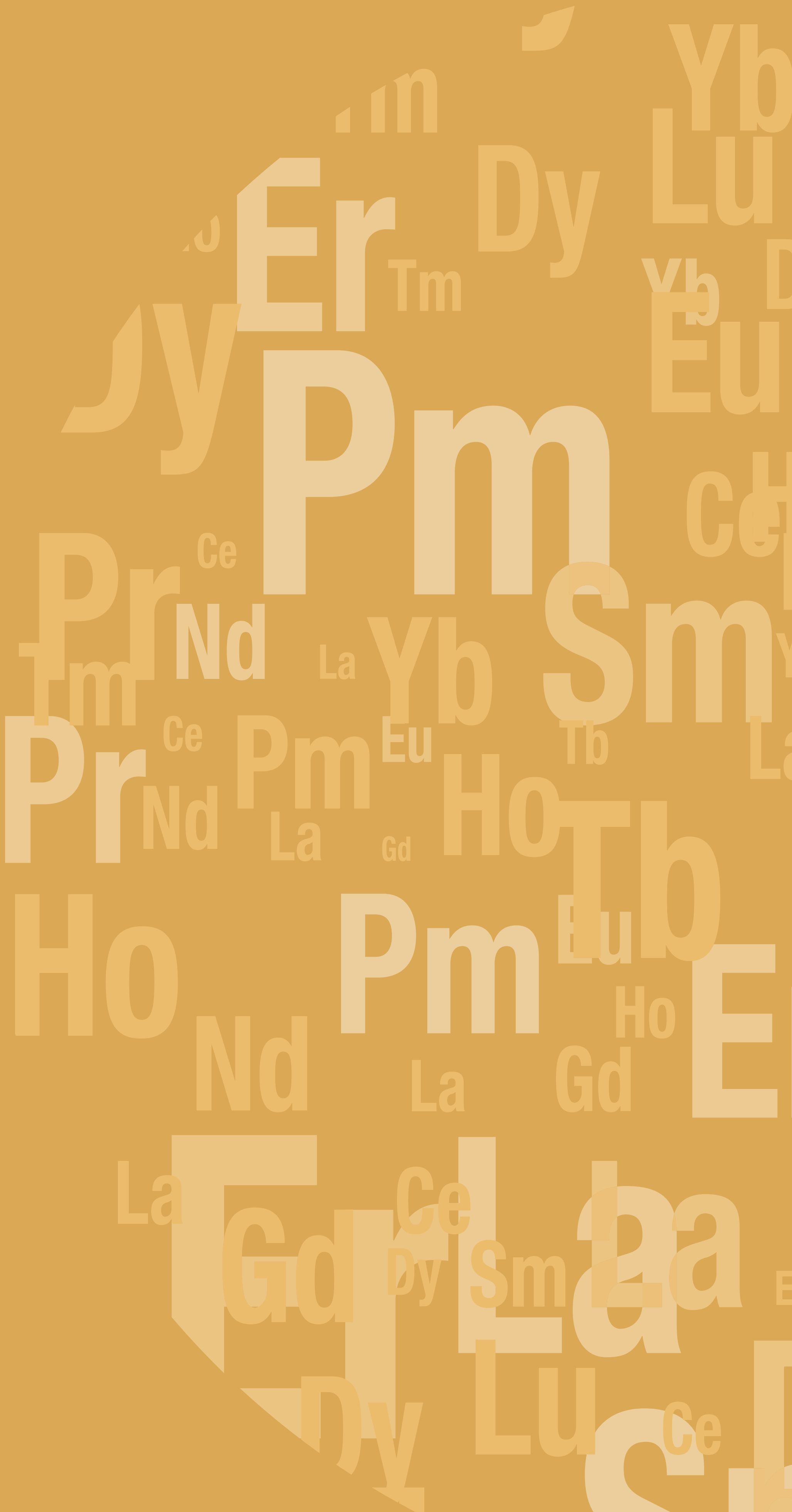


TABLE 1. – RARE EARTH OXIDES SUPPLY (2005 – 2035)

Global TREO	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
China	110,000	120,000	120,800	124,500	129,400	118,900	96,900	82,000	90,000	95,000	100,000	105,000	110,000	115,000	120,000
ROW	5,900	5,690	4,550	4,400	3,650	3,150	4,850	3,911	14,700	38,650	48,400	64,600	112,300	128,900	134,300
Total TREO	**115,900**	**125,690**	**125,350**	**128,900**	**133,050**	**122,050**	**101,750**	**85,911**	**104,700**	**133,650**	**148,400**	**169,600**	**222,300**	**243,900**	**254,300**
La_2O_3	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
China	27,812	30,565	30,179	31,222	32,540	30,141	25,534	21,754	23,876	25,203	26,529	27,856	29,182	30,509	31,835
ROW	2,237	2,225	1,758	1,669	1,458	1,330	2,207	1,723	3,928	10,988	13,111	16,566	27,713	31,260	32,145
Total La_2O_3	30,049	32,790	31,937	32,891	33,998	31,471	27,741	23,477	27,804	36,190	39,640	44,422	56,895	61,769	63,980
CeO_2	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
China	44,198	48,614	47,335	48,398	50,745	46,710	40,192	34,454	37,816	37,916	42,017	44,118	46,219	48,320	50,421
ROW	2,502	2,488	2,011	1,975	1,587	1,330	1,879	1,576	7,120	18,714	23,037	29,795	50,076	56,095	57,785
Total CeO_2	46,700	51,102	49,346	50,374	52,332	48,040	42,072	36,030	44,396	58,630	65,055	73,914	96,295	104,415	108,205
Pr_6O_{11}	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
China	4,617	5,070	5,043	5,263	5,523	5,124	4,264	3,637	3,992	4,214	4,436	4,657	4,879	5,101	5,323
ROW	253	230	183	177	146	125	193	156	702	1,817	2,297	3,059	5,215	5,866	6,052
Total Pr_6O_{11}	4,870	5,299	5,226	5,440	5,669	5,249	4,458	3,793	4,694	6,031	6,733	7,716	10,094	10,967	11,374
Nd_2O_3	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
China	13,911	15,320	15,337	16,133	16,972	15,782	13,093	11,130	12,216	12,895	13,574	14,252	14,931	15,610	16,288
ROW	793	673	536	516	419	346	552	438	2,252	5,728	7,425	10,078	17,294	19,510	20,216
Total Nd_2O_3	14,704	15,993	15,873	16,649	17,391	16,129	13,645	11,569	14,468	18,623	20,999	24,330	32,225	35,119	36,504
Sm_2O_3	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
China	1,588	1,738	1,839	1,961	2,045	1,888	1,455	1,206	1,324	1,398	1,471	1,545	1,618	1,692	1,765
ROW	75	45	37	37	25	14	14	14	283	648	904	1,306	2,322	2,710	2,862
Total Sm_2O_3	1,663	1,784	1,876	1,998	2,069	1,901	1,469	1,220	1,607	2,046	2,375	2,850	3,941	4,402	4,627
Eu_2O_3	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
China	196	213	221	238	249	235	184	155	170	180	189	199	208	218	227
ROW	2	3	3	3	2	2	2	2	52	110	141	201	348	387	416
Total Eu_2O_3	198	216	223	241	251	237	186	157	223	290	331	400	556	605	643
Gd_2O_3	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
China	1,779	1,894	2,094	2,179	2,220	2,005	1,382	1,117	1,226	1,294	1,362	1,430	1,498	1,566	1,634
ROW	9	11	10	10	6	3	3	3	120	239	353	640	1,249	1,587	1,759
Total Gd_2O_3	1,788	1,905	2,104	2,189	2,226	2,007	1,384	1,119	1,346	1,533	1,715	2,070	2,747	3,153	3,393
Tb_4O_7	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
China	300	322	359	376	385	349	244	195	214	226	238	250	262	274	285
ROW	2	1	1	1	0	0	0	0	12	30	48	88	185	247	279
Total Tb_4O_7	302	323	359	377	386	349	244	195	226	255	286	337	447	520	564
Dy_2O_3	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
China	1,404	1,474	1,666	1,725	1,736	1,564	1,014	807	896	935	984	1,033	1,083	1,132	1,181
ROW	8	3	2	2	1	0	0	0	36	69	165	380	935	1,300	1,495
Total Dy_2O_3	1,412	1,477	1,688	1,728	1,738	1,564	1,014	807	921	1,005	1,149	1,413	2,018	2,432	2,676
Y_2O_3	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
China	12,215	12,698	14,389	14,624	14,580	12,966	8,123	6,420	7,046	7,438	7,829	8,221	8,612	9,003	9,395
ROW	19	10	9	9	5	0	0	0	158	246	623	1,909	5,466	7,898	8,985
Total Y_2O_3	12,234	12,708	14,398	14,632	14,585	12,966	8,123	6,420	7,204	7,683	8,452	10,130	14,078	16,902	18,380
Other	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
China	1,981	2,090	2,337	2,380	2,404	2,135	1,415	1,124	1,233	1,302	1,370	1,439	1,507	1,576	1,644
ROW	1	1	1	1	0	0	0	0	38	61	294	578	1,497	2,039	2,309
Total Other	1,982	2,091	2,338	2,381	2,404	2,135	1,415	1,124	1,271	1,363	1,64	2,017	3,005	3,615	3,953

2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
125,000	130,000	135,000	137,955	139,989	141,058	142,058	143,092	141,822	142,392	140,663	141,162	138,053	138,743	137,434	138,025
143,100	153,750	169,950	188,050	206,050	208,550	224,250	227,150	232,150	233,150	238,150	238,650	238,650	238,650	238,650	238,650
268,100	**283,750**	**304,950**	**326,005**	**346,039**	**349,573**	**366,308**	**370,242**	**373,972**	**375,542**	**378,813**	**379,812**	**376,703**	**377,393**	**376,084**	**376,675**
2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
33,162	34,488	35,814	36,447	36,854	37,000	37,146	37,292	36,843	36,873	36,335	36,364	35,467	35,499	35,033	35,064
34,358	36,917	41,470	45,794	51,084	51,706	55,048	55,793	56,314	56,349	57,724	57,776	57,776	57,776	57,776	57,776
67,520	71,405	77,284	82,241	87,938	88,705	92,194	93,086	93,156	93,222	94,059	94,140	93,242	93,275	92,809	92,839
2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
52,522	54,623	56,723	57,840	58,488	58,632	58,775	58,919	58,646	58,683	58,144	58,180	57,455	57,492	57,083	57,120
61,326	65,588	73,002	79,977	88,175	89,160	94,815	95,801	97,050	97,114	99,214	99,362	99,362	99,362	99,362	99,362
113,847	120,210	129,725	137,817	146,663	147,791	153,591	154,720	155,696	155,797	157,358	157,542	156,816	156,854	156,445	156,482
2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
5,544	5,766	5,988	6,125	6,209	6,240	6,271	6,302	6,209	6,216	6,110	6,117	5,933	5,942	5,848	5,856
6,379	6,783	7,519	8,222	9,007	9,125	9,705	9,766	9,901	9,908	10,118	10,135	10,135	10,135	10,135	10,135
11,923	12,549	13,507	14,346	15,216	15,366	15,976	16,068	16,110	16,124	16,227	16,252	16,069	16,077	15,983	15,991
2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
16,967	17,646	18,324	18,758	19,039	19,162	19,286	19,409	19,050	19,080	18,656	18,684	17,961	17,995	17,626	17,657
21,223	22,557	24,941	27,260	29,695	30,143	32,020	32,217	32,702	32,729	33,374	33,446	33,446	33,446	33,446	33,446
38,190	40,203	43,265	46,018	48,734	49,305	51,305	51,625	51,752	51,809	52,030	52,130	51,407	51,441	51,072	51,103
2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
1,839	1,912	2,041	2,086	2,086	2,121	2,155	2,189	2,129	2,145	2,076	2,090	1,962	1,982	1,925	1,942
2,989	3,178	3,475	3,839	4,102	4,173	4,484	4,486	4,611	4,622	4,702	4,721	4,721	4,721	4,721	4,721
4,828	5,090	5,461	5,881	6,188	6,293	6,639	6,675	6,740	6,767	6,811	6,683	6,703	6,645	6,662	110,000
2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
237	246	256	262	267	270	272	275	266	267	259	259	243	244	237	237
438	489	550	588	642	662	681	686	693	702	707	709	709	709	709	709
675	735	806	851	909	931	953	960	959	969	966	969	953	953	946	946
2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
1,702	1,771	1,839	1,900	1,956	2,007	2,058	2,108	2,077	2,112	2,076	2,107	2,019	2,063	2,041	2,078
1,879	2,032	2,201	2,502	2,631	2,681	2,951	2,960	3,095	3,095	3,139	3,194	3,212	3,212	3,212	3,212
3,582	3,803	4,039	4,402	4,587	4,688	5,009	5,069	5,172	5,251	5,270	5,319	5,231	5,275	5,253	5,290
2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
297	309	321	332	343	353	364	374	368	375	364	370	349	358	351	358
306	336	359	413	437	444	499	513	544	556	566	569	569	569	569	569
603	645	680	745	780	797	863	887	912	930	930	939	918	927	920	927
2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
1,230	1,280	1,329	1,376	1,422	1,467	1,511	1,556	1,538	1,572	1,554	1,583	1,523	1,564	1,557	1,592
1,648	1,832	1,927	2,247	2,349	2,380	2,747	2,841	3,070	3,151	3,206	3,225	3,225	3,225	3,225	3,225
2,879	3,112	3,256	3,623	3,771	3,847	4,258	4,397	4,608	4,722	4,760	4,808	4,748	4,789	4,782	4,817
2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
9,786	10,178	10,569	10,957	11,342	11,724	12,105	12,487	12,515	12,835	12,871	13,145	12,932	13,332	13,454	13,788
10,023	11,109	11,493	13,709	14,169	14,298	16,875	17,259	18,890	19,468	19,853	19,979	19,979	19,979	19,979	19,979
19,809	21,286	22,062	24,666	25,511	26,022	28,981	29,746	31,405	32,303	32,724	33,124	32,911	33,311	33,433	33,767
2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
1,713	1,781	1,850	1,917	1,983	2,048	2,114	2,179	2,181	2,233	2,217	2,262	2,208	2,272	2,278	2,332
2,533	2,932	3,017	3,502	3,762	3,783	4,427	4,833	5,284	5,417	5,497	5,521	5,521	5,521	5,521	5,521
4,245	4,714	4,867	5,418	5,745	5,831	6,541	7,011	7,464	7,650	7,715	7,783	7,729	7,793	7,798	7,852

In the writer's opinion, there are just a small handful of rare earth ventures in development at this time (that is, late November, 2013) outside of China that have any chance of ever going into the production of the mid- and heavy rare earths. Even if they could today produce rare earth mineral concentrates economically, there would be today no place at all for such concentrates to be processed into the fabricated forms necessary for the mass production of consumer, industrial and military high-tech rare earth-enabled devices. This, the creation of a downstream total rare earth supply chain, outside of China, is the opportunity for Malaysia. The creation of the first processing steps alone would make the development of non-Chinese mid- and heavy rare earth mineral concentrates much more likely to be economical. A Malaysian total rare earth supply chain would attract investment globally even without being anchored in a domestic mining industry!

1.3 Global Rare Earth Demand as Raw Materials

Perhaps it is even more important than the geographical distribution of the supply data that the demand data shows that more than 80% of the demand for rare earth mineral concentrates comes from within China where its huge rare earth separation, refining, purification, metal making, and component making industries absorb the rare earth mineral concentrates as raw materials. The most important thing to note is that China's demand for heavy rare earths, as has been said, is larger than its current production of heavy rare earths, because mainly of the dramatic rise of environmentalism in China. China, the only significant producer of heavy rare earths and certainly the only commercial producer of them in history, is now faced with a government-supported crackdown on its "leach, exhaust the deposit, and abandon the operation" methods of extracting heavy rare earths and yttrium from the very low grade, but supposedly radiation-free, ion adsorption clays in southern China's Sichuan and Jiangxi provinces. The total disregard for safety, health, and the environment has been the only thing allowing the Chinese to produce heavy rare earths. This era of production without regard to social or environmental costs has now already ended in China. This means that for the first time since the heavy rare earths became core technology metals:

1. China cannot produce enough heavy rare earths to maintain the growth in domestic demand; and

2. China, having no hard rock deposits of heavy rare earths, must for the first time seek such materials outside of China. It is also of note that there are also ion adsorption clays outside of China in places that include Vietnam, Thailand, Cambodia, Malaysia and the Indonesian archipelago. These clays can be worked safely and in an environmentally friendly way.

The gap between heavy rare earth supply and the growth of the demand for them is a new opportunity for ROW heavy rare earth producers, because for the first time they have attracted Chinese investors. The ROW hard rock and ion adsorption clay deposits from which heavy rare earths could be extracted commercially present a conundrum: It will not be economical to work either hard rock or ion adsorption clays outside of China if the focus is on producing just mixed concentrates of rare earth minerals!

It can only become economical if value is added to the concentrates by taking them downstream to fabricated products suitable for making rare earth enabled devices. BUT if that is done it will be more economical for end-users to utilize the fabricated forms of the rare earths right where they are being produced. This is the Chinese rare earth industry's primary fear; the fear that a total rare earth supply chain will be constructed outside of China that enables the mass production of rare earths-enabled consumer, industrial, and military devices more cheaply than can be done in China and simultaneously out of the control of the Chinese rare earth industry or Government!

The specific categories of demand in the following charts (Figures 2 – 6) are unlikely to change in the next generation. Neither are the relative use percentages with the exception of glass polishing, which is likely to decline as manufacturing engineers improve their ability to produce nanocrystalline powders of substitute materials such as silicon carbide. Optical glasses will still utilize rare earth elements as part of their composition but it is unlikely that polishing, the major use of cerium, will grow, and it is very likely that this use will decline.

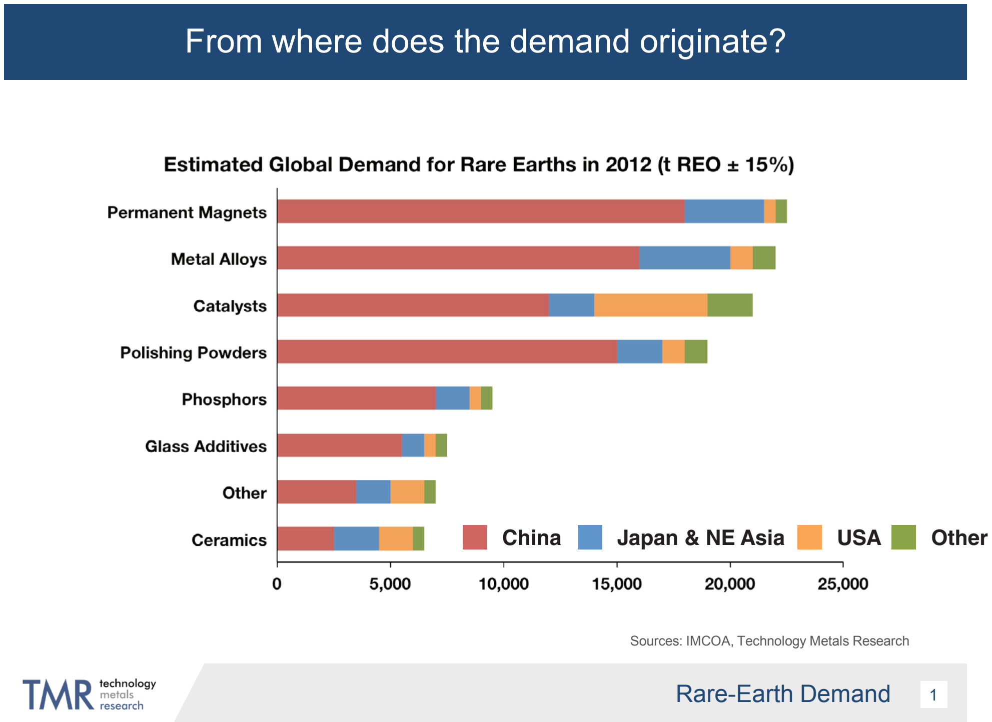


Figure 2. Estimated Global Demand for Rare Earths in 2012 (t REO ± 15%).

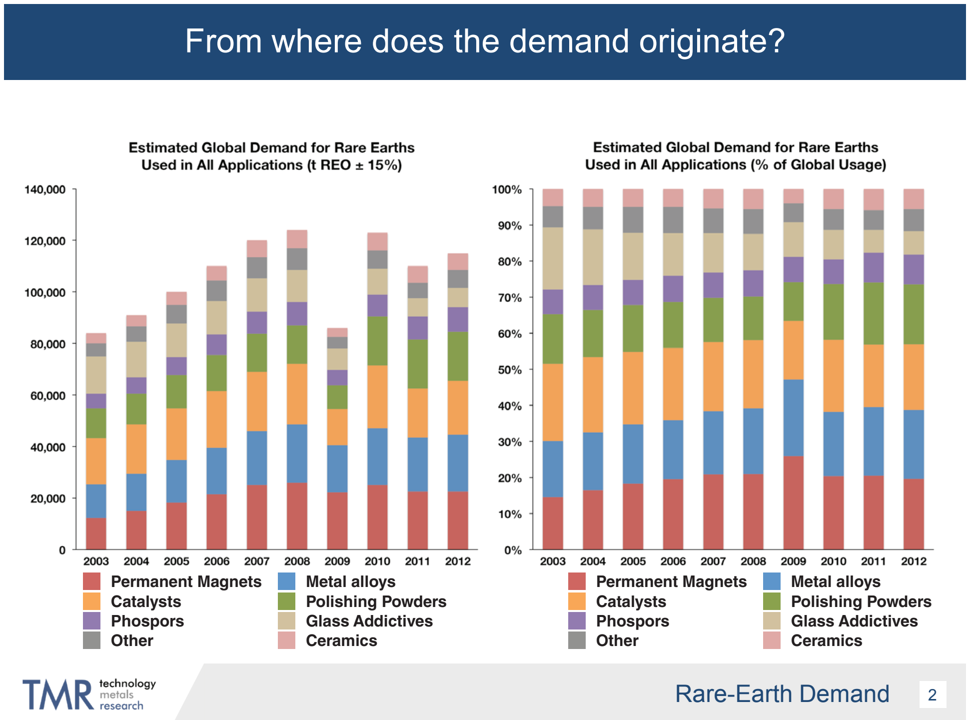


Figure 3. Estimated Global Demand for Rare Earths Used in All Applications (t REO ± 15% and % of Global Usage).

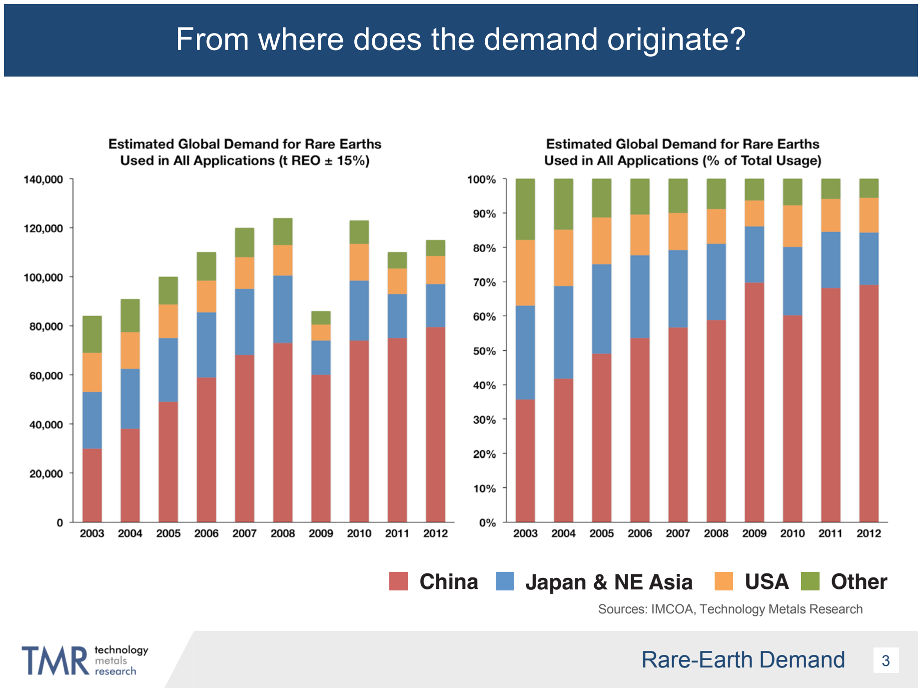


Figure 4. Estimated Global Demand for Rare Earths Used in All Applications (t REO ± 15% and % of Total Usage).

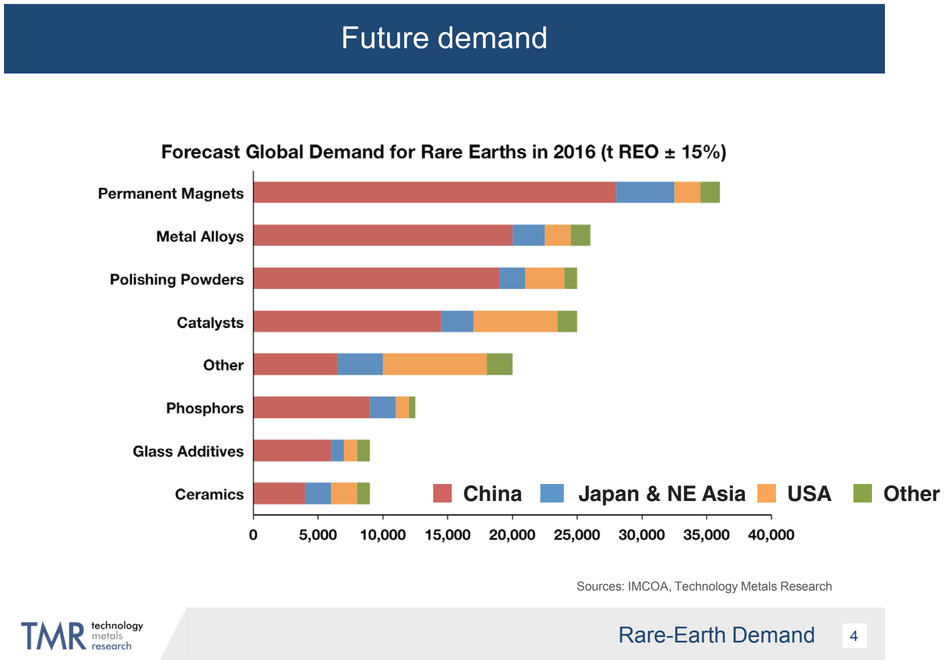


Figure 5. Forecast Global Demand for Rare Earths in 2016 (t REO ± 15%).

Future demand

Forecast for global rare-earth demand in 2016 (t REO ± 20%)

End Use	China	USA	Japan & SE Asia	Others	Total	Market Share
Permanent Magnets	28,000	2,000	4,500	1,500	**36,000**	**22%**
Metal Alloys	20,000	2,000	2,500	1,500	**26,000**	**16%**
Catalysts	14,500	6,500	2,500	1,500	**25,000**	**15%**
Polishing Powders	19,000	3,000	2,000	1,000	**25,000**	**15%**
Phosphors	9,000	1,000	2,000	500	**12,500**	**8%**
Glass Additives	6,000	1,000	1,000	1,000	**9,000**	**6%**
Ceramics	4,000	2,000	2,000	1,000	**9,000**	**6%**
Other	6,500	8,000	3,500	2,000	**20,000**	**12%**
Total Demand	**107,000**	**25,500**	**20,000**	**10,000**	**162,500**	**100%**
Market Share	**66%**	**16%**	**12%**	**7%**	**100%**	

Source: IMCOA

TMR technology metals research — Rare-Earth Demand 5

Figure 6. Forecast Global Demand for Rare Earths in 2016 (t REO ± 15%).

The long-term projection of demand is very difficult. The writer believes, as stated earlier, that the demand for all of the most common rare earths except cerium will increase as the world consumer high-tech economy grows to accommodate personal electronic technologies. He projects and predicts that most of this growth will occur first in southern Asia and then in Africa. Fifty percent of world's population lives in these two regions and, on average, the populations of those regions are younger than those in China, Japan, Europe or North America. The demand for personal entertainment, communication, and data processing devices will ultimately be many times that of the mature demand economies of North America and Europe.

Even if it is assumed that the high-tech economy will only grow at the rate of increase of global GDP, it is estimated that there will be a doubling and a quadrupling of the global demand for the rare earths by 2035. For the critical heavy rare earths, terbium, dysprosium, and yttrium this will not be economically possible unless there is a substantial increase in non-Chinese sourcing of these REEs and the creation of total rare earth supply chain centers outside of China.

Malaysia is uniquely situated to take advantage of this opportunity, and the time to begin Malaysia's transformation into a domestic consumer high tech manufacturing powerhouse is right now.

1.4 Brief History of Rare Earths Supply

In the last six years, there has been a revival of interest in the rare earth elements due primarily to the rapid growth of the East Asian consumer economy, which has resulted in a dramatic increase in the demand for miniaturized electronic devices for communications, data processing and entertainment. During the twenty-five years, the revival of the mining of the rare earth elements moved from being principally in the United States to being almost entirely in the People's Republic of China. This was originally an economic decision driven by low-priced Chinese rare earth ore concentrates. As non-Chinese rare earth mining shut down, the American domestic total rare earth supply chain lost its mining anchor. This drove the refining of the rare earths and the fabricating of rare earth-enabled components to be moved to China so as to have easy access to the necessary rare materials. There then followed logically the outsourcing of the manufacturing of devices using rare earth enabled components from the USA to China.

This outsourcing might not have been of much consequence if it were not for the fact that based on research and development in the late 1970s, the OEM automotive industry began to switch from ferrite- and alnico-based permanent magnet motors and generators to rare earth permanent magnet-based devices in the early 1980s. This was driven by the need to minimize the weight of motor vehicles while losing no efficiency in order to decrease fuel consumption and increase thereby fuel economy.

At the same time, in the early 1980s, the personal computer made its debut in the USA and Europe. Manufacturing engineers soon realized that rare earth permanent magnets could enable a dramatic decrease in the size and weight of the read/write heads on hard disc drives thus allowing for a substantial increase in the memory capacity and operating speed of such devices.

Shortly after that audio and telephone equipment designers realized that rare earth permanent magnets could dramatically reduce the size of speakers without compromising the quality or intensity of sound reproduction.

The rare earth-enabled miniaturization of consumer and industrial devices was underway, but this was after the new production of the rare earths and the refining and fabricating of industrial forms of them had already moved to China.

By 2002, the entirety of the American and most of the European domestic and regional rare earth supply chains had moved to China.

It took only until 2007 for alarms to go off in the USA and Europe when it became obvious that the military needs for rare earth permanent magnets, lasers, and SONAR devices were now totally susceptible to the whims of the People's Republic of China. Wall Street speculators spun this problem completely out of proportion and a one-dimensional approach, the reopening of a former mine and the exploration for new ore bodies, drowned out the common sense that any revival of a non-Chinese rare earth industry would require that the total rare earth supply chain be reconstructed outside of China.

What was also overlooked by Wall Street speculators was the fact that only certain of the rare earths were critical and the most critical of these, dysprosium, had never been produced commercially outside of China. The shameless promotion of a few large deposits of the common light rare earths, lanthanum, cerium, praseodymium and neodymium completely drowned out the fact that sources of the most important rare earths, terbium, dysprosium, and yttrium, were not being developed even though without them there could be no domestic total rare earth supply chain outside of China.

Today, the fervor begun in 2007 for rare earth production has subsided, and a reassessment by long range planners and investors is under way.

It is clear that no single deposit can support a total domestic supply chain for a rare earth industry anywhere. Such a supply chain will require sources of the light rare earths and of the heavy rare earths along with chemical engineering facilities capable of separating large quantities of light rare earths from each other and also capable of separating much smaller quantities of heavy rare eras from each other. In addition, facilities will be needed to produce pure rare earth metals and alloys from the separated chemical forms of all of the rare earths. The next step will be facilities to produce rare earth permanent magnet alloys, lasing chemicals, and phosphor chemicals. Finally, manufacturers of rare earth enabled devices will be needed to fabricate rare earth permanent magnets, lasers, and phosphors for use in consumer, industrial, and military end use products.

All of this is done in one country today only in China.

The Chinese domestic market for rare earth-enabled devices is growing more rapidly than the global market. The Chinese have made it clear that their domestic needs will come first and foremost. China is the only producer today of terbium, dysprosium, and yttrium. If these materials are cut off then there can be no non-Chinese domestic total supply chain anywhere else unless non-Chinese heavy rare-earth production, refining, and fabricating are given immediate priority.

1.5 Rare Earths Pricing

Finally, a word about 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.

The writer predicts that a rare earth total supply chain built outside of China in Malaysia will draw end-use device manufacturers, including both Japanese and Chinese to Malaysia.

He also predicts 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 dollars to the Malaysian economy.

1.6 Conclusion

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 this 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? This 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 so right now", again the answer is emphatically yes.

UPST

TREAM SECTOR

Teoh Lay Hock

UPSTREAM SECTOR

Teoh Lay Hock
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1.0 SUMMARY

In the Upstream Sector, the potential for the development of the rare earths industry in Malaysia can be categorized into four areas according to resource type. These are, in their order of importance,

i. On-shore alluvial xenotime and monazite,
ii. Ion adsorption clays containing rare earths elements (REEs),
iii. Rare Earth (RE) minerals and REEs in marine sediments, and
iv. RE minerals in primary sources.

i. Malaysia is already producing xenotime and monazite from its on-shore alluvial resources as by-products of alluvial tin mining from the processing of *amang*, which is the local term for "tin mining tailings or residues". However, production of *amang* has fallen substantially due to the drastic decline in alluvial tin mining. There are two ways to increase the production of xenotime and monazite from this resource. The first is to revitalize alluvial tin mining by giving incentives for exploration and opening up more areas for alluvial tin mining in a timely manner. The second is to explore for economically mineable alluvial deposits of xenotime and monazite.

ii. There is potential for the discovery of REE-hosted ion adsorption clay deposits in Malaysia as it has the geology and climatic conditions conducive for the development of such deposits. Since this is new territory for Malaysian exploration geologists the search would be best undertaken with the help of, and in collaboration with, researchers and explorers from the more experienced countries such as China, Japan and South Korea. Initial Japanese geological research in Malaysia has recently shown REE-rich ionic adsorption clays to be present.

iii. There are two types of marine rare earth resources which are available for Malaysia to explore. The near-shore shallow marine sediments off the coasts of Peninsular Malaysia could host deposits of detrital xenotime and monazite. In particular, the sediments brought down and deposited by rivers draining the tin fields could be examined from their rare earth potential. The other resource is in the deep-ocean seabed in international waters. These marine sediments are known to host economical concentrations of REEs and could be mined together with the other economical minerals contained therein such as manganese and cobalt. Malaysia could bid for areas to explore and mine. The issue here is whether it has the technology and financial capability to do so.

iv. Based on present knowledge, Malaysia does not have the geology and tectonic settings favourable for the discovery of the traditional alkaline igneous and carbonatite type rare earth deposits. However, a significant part of Sabah and Sarawak is still not geologically mapped in detail. The search for such rock types could form part of the on-going geological mapping and exploration programme. Xenotime and monazite are found as accessory minerals in the tin-

related granites in Peninsular Malaysia. Research could be undertaken to find out if it is possible to extract these minerals from the granites economically.

1.1 Introduction

Malaysia, specifically Peninsular Malaysia, is already well known to be endowed with rare earth (RE) mineral resources. Xenotime and monazite have been produced in the country as by-products of alluvial tin mining for several decades and Malaysia has been exporting xenotime and monazite since the 1960's. However, alluvial tin mining has declined significantly since the 1990s following the collapse of the tin market and accordingly the production and export of xenotime and monazite were also affected.

The United States Geological Survey in their report USGS (2013) listed Malaysia as having 30,000 tonnes of rare earth oxides (REO) reserves in comparison to the following:

Country	REO reserves (tonnes)
United States	13,000,000
Australia	1,600,000
Brazil	36,000
China	55,000,000
India	3,100,000
Malaysia	30,000
Other countries	41,000,000
WORLD TOTAL (rounded)	**110,000,000**

Kingsnorth (2013) estimated (based on USGS reports for 2012 and 2013) that Malaysia has 43,000 tonnes of REO reserves.

The reserve figures for Malaysia mentioned above should be taken with caution as the basis for arriving at those figures was never provided. As far as is known there has never been any country-wide rare earth resource evaluation exercise carried out in Malaysia.

A recent study by the Academy of Sciences Malaysia (ASM, 2013) showed that, apart from alluvial xenotime and monazite, there are other potential sources of REs which are worthwhile investigating.

Based on current knowledge of i) the genesis and typical geological occurrences of RE deposits globally, ii) typical occurrences of xenotime and monazite in Malaysia, and iii) geology and tectonic settings of Malaysia, efforts towards the exploration for, and subsequent mining of, RE resources can be categorized as follows according to resource type:

- On-shore alluvial xenotime and monazite
- Ion adsorption clays containing rare earth elements (REEs)
- RE minerals and REEs in marine sediments
- RE minerals in primary sources (hard-rock)

2.0 ON-SHORE ALLUVIAL XENOTIME AND MONAZITE

2.1 Genesis and typical geological occurrences of detrital xenotime and monazite

Xenotime and monazite are formed during magmatism and metamorphism resulting in their presence in igneous and metamorphic rocks, usually as accessory minerals. When these rocks are exposed and weathered, xenotime and monazite, both being resistant minerals, are released as mineral grains into the environment. These grains are washed down into streams and rivers where they also undergo gravitational sorting and concentration. The sediments containing these and other resistant heavy minerals are finally deposited and form alluvial deposits. The sediments could subsequently be re-sorted and concentrated to form beach placers.

Beach placer (mineral sand) deposits containing commercially mineable concentrations of monazite and to a lesser extent xenotime have been found in several parts of the world including India, Brazil, Australia, USA and several countries in Africa – but so far not in Malaysia.

2.2 Typical occurrences of alluvial xenotime and monazite in Malaysia

Xenotime and monazite grains occur ubiquitously throughout the Malay Peninsula in the stream sediments draining granitic areas and in the alluvium in the valleys and lower reaches of rivers, and in the coastal plains. Although xenotime and monazite have not been found in concentrations high enough to be mined economically by themselves, they are recognized as important RE resources as they have been produced lucratively as by-products of alluvial tin mining.

2.3 Exploration for on-shore alluvial xenotime and monazite

The exploration for on-shore alluvial xenotime and monazite can be undertaken systematically in three stages:

- Compilation, collation and review of currently available relevant information,
- Follow-up exploration - involving delineation of areas with anomalously high concentrations of xenotime and monazite and undertaking additional and more closely spaced surface sampling, and
- Detailed exploration – including augering/drilling to determine grades and reserves.

2.3.1 Compilation, collation and review of currently available information

It has been, and still is, the common practice for geologists in the Minerals and Geoscience Department Malaysia (JMG) undertaking field mapping and exploration programmes to collect panned stream concentrates for examination along streams in their study areas. The results of their studies [referred to as "Quantitative Mineral Examination (QME)" in JMG] are recorded in many forms including originally in "Economic Field Records" and subsequently compiled into published and unpublished memoirs, map bulletins and mineral exploration reports.

Examination of such documents show that three types of information pertaining to RE mineral occurrences are available (differentiated based on the level of confidence of the data):

(i) Record of presence of RE minerals in the stream concentrates but the precise sampling locations were not recorded - such incomplete records are of little value.

(ii) Record of presence of RE minerals in the stream concentrates with the percentages and locations stated but not the tenor*. Such records are useful but only in so far as to show whether RE minerals are present or not in a certain locality.

(iii) Record of presence of RE minerals in the stream concentrates with the percentages, locations and tenors stated. Such records are most valuable as comparisons of potentiality can be made between localities.

* [*"Tenor" is essentially the grade, meaning how much of the mineral by weight is present in a standard volume of alluvium. The tenor can be calculated only if the volume of alluvium from which the panned concentrate is derived from is known. This is done by noting the number of standard "dulang"s (pans) of alluvium panned.*]

While the Economic Field Records represent the best available source of information on xenotime and monazite occurrences, a word of caution is warranted. The quantities of these minerals are based on visual identification and estimation of the detrital mineral grains. Mineral identification is inherently difficult because monazite and xenotime appear similar, not only between the two but also with other minerals, even under the microscope. In addition, the proportions of the minerals in the heavy mineral samples are also at best estimated. Hence, the accuracy of the results is very much dependent on the experience and skill of the analyst.

In this respect, the JMG should ensure that its field mapping and exploration geologists are well-equipped with the tools and knowledge, and have the necessary skills and experience in mineral and rock identification.

2.3.2 Follow-up exploration

Follow-up exploration begins with the processing and evaluation of the available information.

There are several ways to process and evaluate the information. Traditionally, and now with the aid of information technology (IT), the information can be sorted and plotted on maps for digital and visual assessments.

Some examples of such treatments are illustrated below.

Figure 1 shows the locations where RE minerals were noted in the heavy mineral concentrate samples in Peninsular Malaysia. This map merely serves to show where xenotime and monazite occur in relation to the geology, and only where the sampling locations can be identified with GPS coordinates. The sparsity of points in the eastern and central part of the Peninsula is partly due to the lack of QME results and partly due to the location of the points not being recorded in GPS coordinates. There is a dense concentration of monazite occurrences extending from Perak to Selangor down to Negri Sembilan, including the western flanks of Pahang, and since this area also coincides with the tin belt, it should be examined in more detail.

Figure 2 shows the distribution of monazite and Figure 3 shows the distribution of xenotime in the states of Perak, Selangor, Pahang and Negri Sembilan. The maps are plotted using Geographical Information System (GIS). The values are grouped into four randomly (not statistically) defined classes using the GIS built-in package. The range of values is a reflection of the distribution and concentration of elevated values and serves as an important starting point for the development of a statistical method for the delineation of anomalous areas for follow-up exploration. When enough data points become available, meaningful statistical classes can then be made. The values can then be plotted and the statistically anomalous areas identified by contouring.

Follow-up field investigation would involve closer-spaced sampling in the delineated anomalous areas.

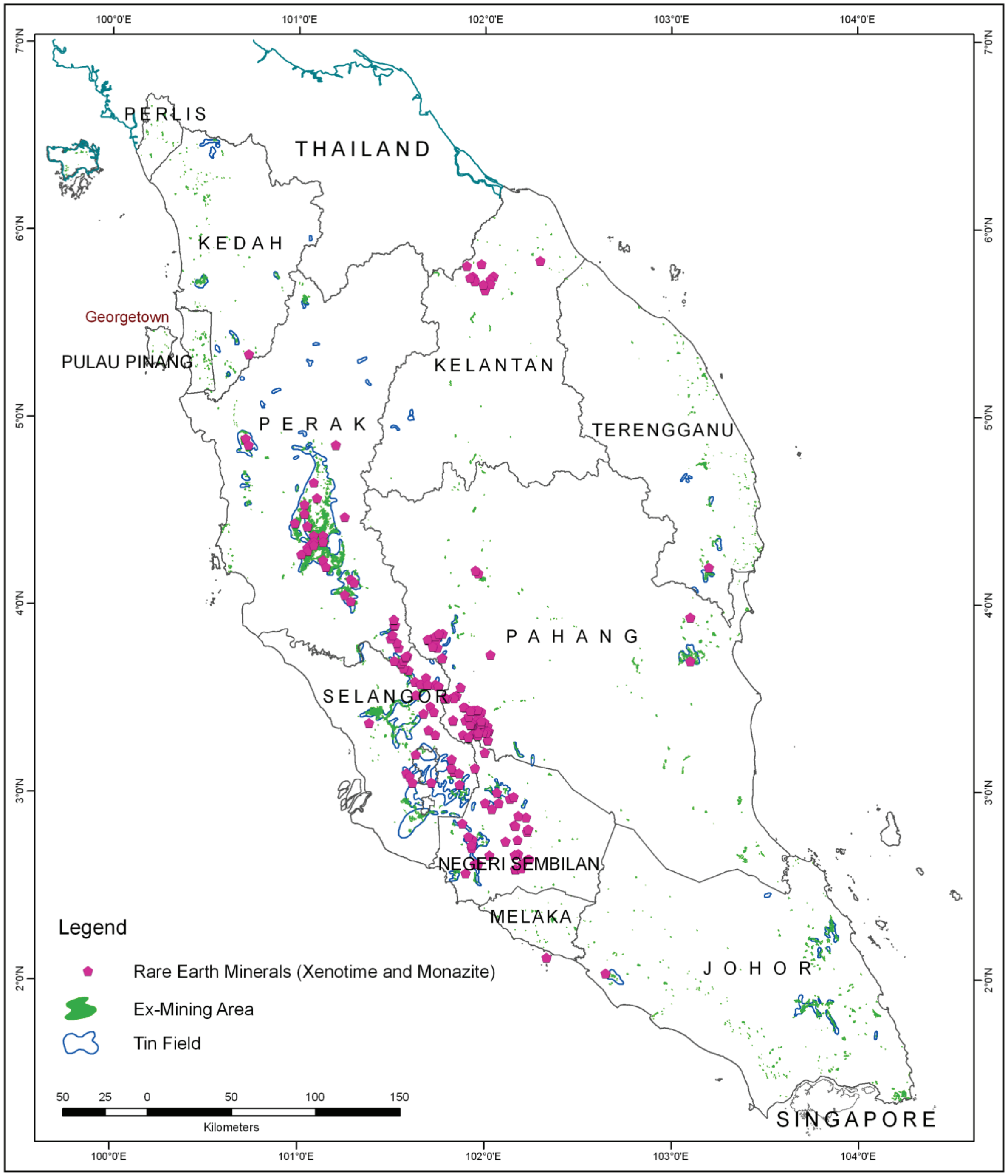


Figure 1: Rare Earth Mineral Occurrences in Heavy Mineral Concentrates, Peninsular Malaysia.

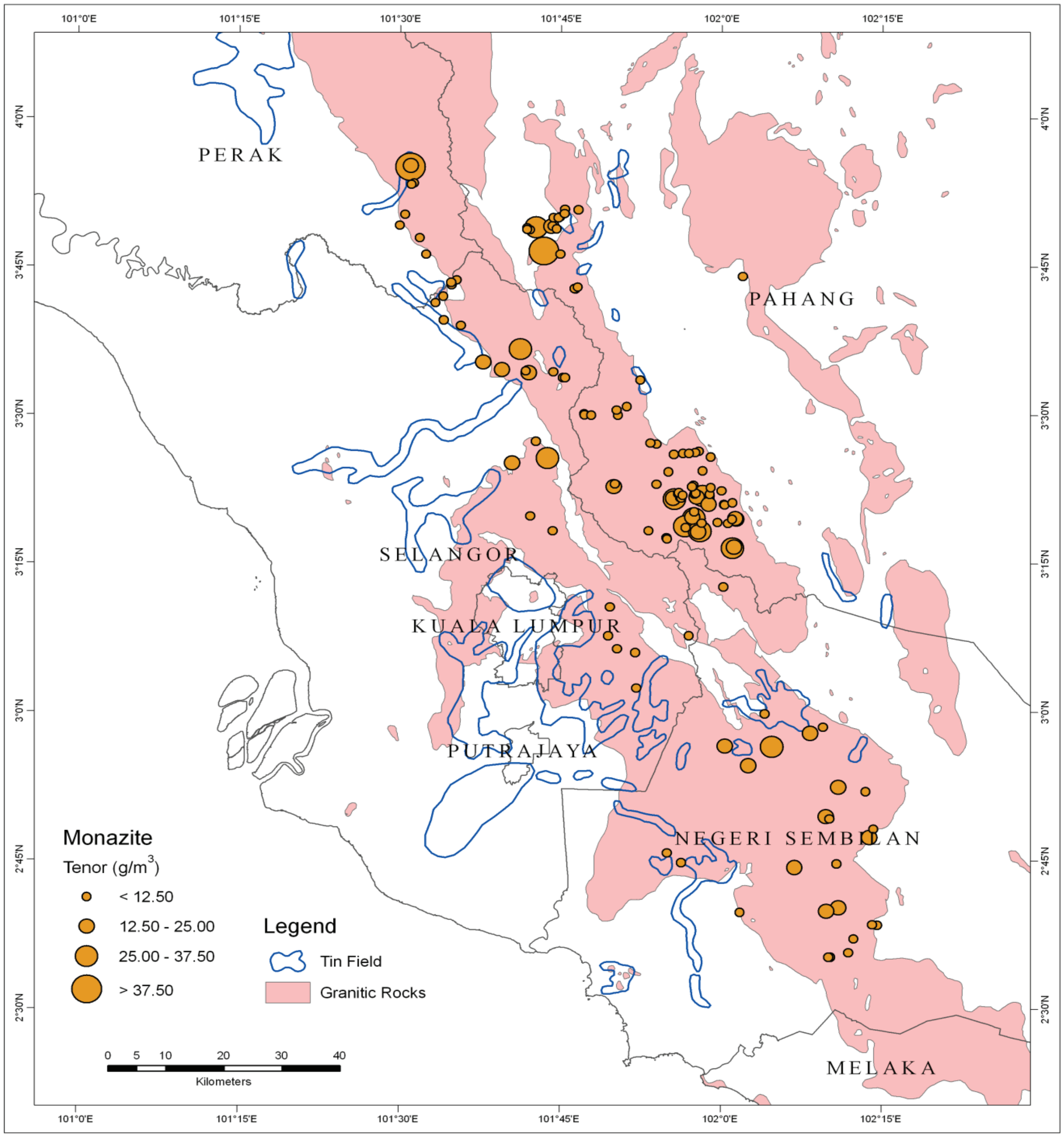


Figure 2: Monazite Tenor Distribution in Perak, Selangor, Pahang and Negeri Sembilan.

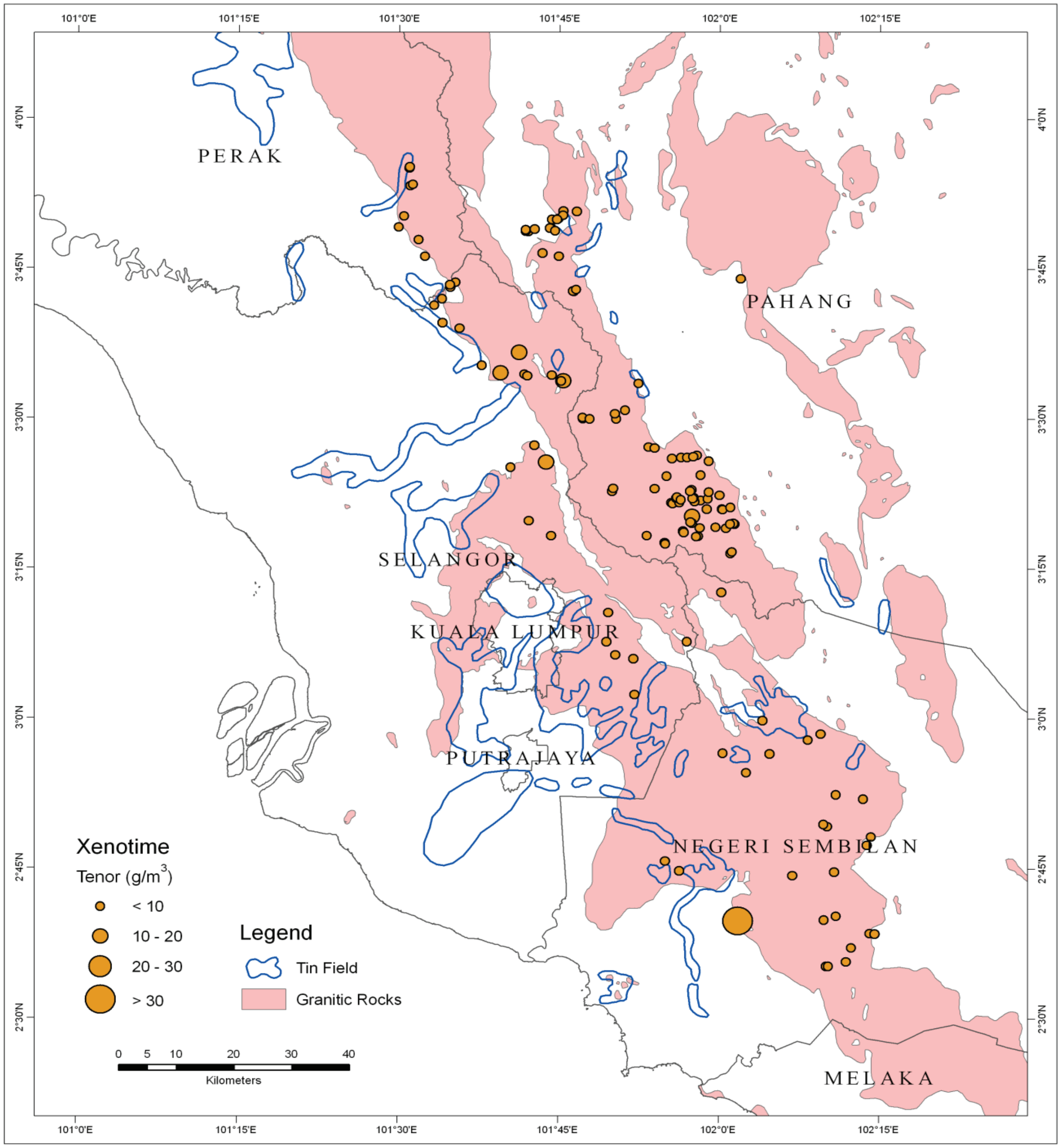


Figure 3: Xenotime Tenor Distribution in Perak, Selangor, Pahang and Negri Sembilan

2.3.3 Detailed exploration

The final stage of detailed exploration is essentially to determine the extent of mineralisation. This would involve augering and drilling at suitable spacing and to depths determined by the exploration geologists based on information obtained from the follow-up exploration. From the depth, grade and volume information it is possible to determine the reserves and accordingly the economic potential of the deposit.

It should be noted that this three-stage exploration method is also applicable for the exploration of all types of economic heavy minerals including cassiterite (tin ore), zircon, ilmenite and niobium/tantalum minerals such as struverite and columbite. In this respect, the exploration for alluvial tin deposits is in itself exploration for xenotime and monazite, although one should not discount the possibility that (in spite of the lack of precedence) in the process one could discover deposits with concentrations of xenotime and monazite which are high enough to be mined by themselves with the other economic minerals (including cassiterite) as by-products.

2.3.4 Estimation of reserves in amang dumps*

Apart from the above exploration efforts to search for and identify the resource of xenotime and monazite, it is worthwhile to note that there is a significant amount of these minerals presently embedded in the *amang* dumps throughout the country. A survey of these *amang* dumps for their xenotime and monazite contents would essentially provide an idea of the “Measured Mineral Resource”** in the country. Once a baseline has been set it would be easy to continually monitor the country’s Measured Mineral Resource of xenotime and monazite using checks and balances on quantities of these minerals produced and sold and the quantities of *amang* stock replenished. The JMG would be the best agency to undertake this task as statistics are provided to them on a regular basis by the *amang* plant operators.

2.4 Mining and Amang Processing

Traditionally, xenotime and monazite have been produced as by-products of tin mining. In the ground, these minerals are found commonly as part of the heavy mineral assemblage together with cassiterite (tin ore) in the alluvial tin deposits (the other minerals include zircon, ilmenite and struverite). Xenotime and monazite are produced from the re-treatment of *amang*. Mining specifically for xenotime and monazite have never been undertaken.

** [“Amang” is a Malaysian term referring to the heaps of heavy minerals discarded after the cassiterite (tin ore) has been separated out in the tin shed or ore treatment plants in a tin mining operation. Also loosely know as tin tailings].*

*** [“Measured Mineral Resource” based on JORC (2012) is defined as that part of a Mineral Resource for which quantity, grade (or quality), densities, shape, and physical characteristics are estimated with confidence sufficient to allow the application of Modifying Factors to support detailed mine planning and final evaluation of the economic viability of the deposit.]*

The processing technology to recover RE minerals from *amang* has not changed much over the years. The only advancement is the addition of a step (in the 1980s) which enabled xenotime to be separated from monazite thereby increasing the value of the RE mineral output. Previously the *amang* plant operators were not able to "pull" out the valuable xenotime and it was sold as part of the monazite concentrates.

Figure 4 shows the flow chart of the processing of *amang* to recover xenotime and m onazite.

The *amang* is first put through a tabling process where the less dense ("light") minerals are separated from the denser ("heavy") minerals through wet gravitational separation. The heavy fraction is dried to remove the moisture and loosen the grains.

The dried heavy fraction is put through a magnetic separator to separate the magnetic from the non-magnetic fraction. The non-magnetic fraction consists of minerals such as cassiterite, zircon, rutile and pyrite. Quartz grains which escaped from the gravitational separation also come out in the non-magnetic fraction. The magnetic fraction consists of ilmenite, monazite, xenotime, tourmaline and garnet.

The magnetic fraction is then put through high-tension (electrostatic) separation during which the conductive minerals are separated from the non-conductive minerals. The conductive ("thrown') fraction usually consists of dark/black minerals such as ilmenite, tourmaline and garnet. Xenotime and monazite come out as the non-conductive ("pin") fraction. The non-conductive fraction is put through a finely tuned magnetic separation whereby the slightly less magnetic monazite is separated from the slightly more magnetic xenotime.

2.5 Production

Table 1 shows the Malaysian production of xenotime and monazite since 1980.

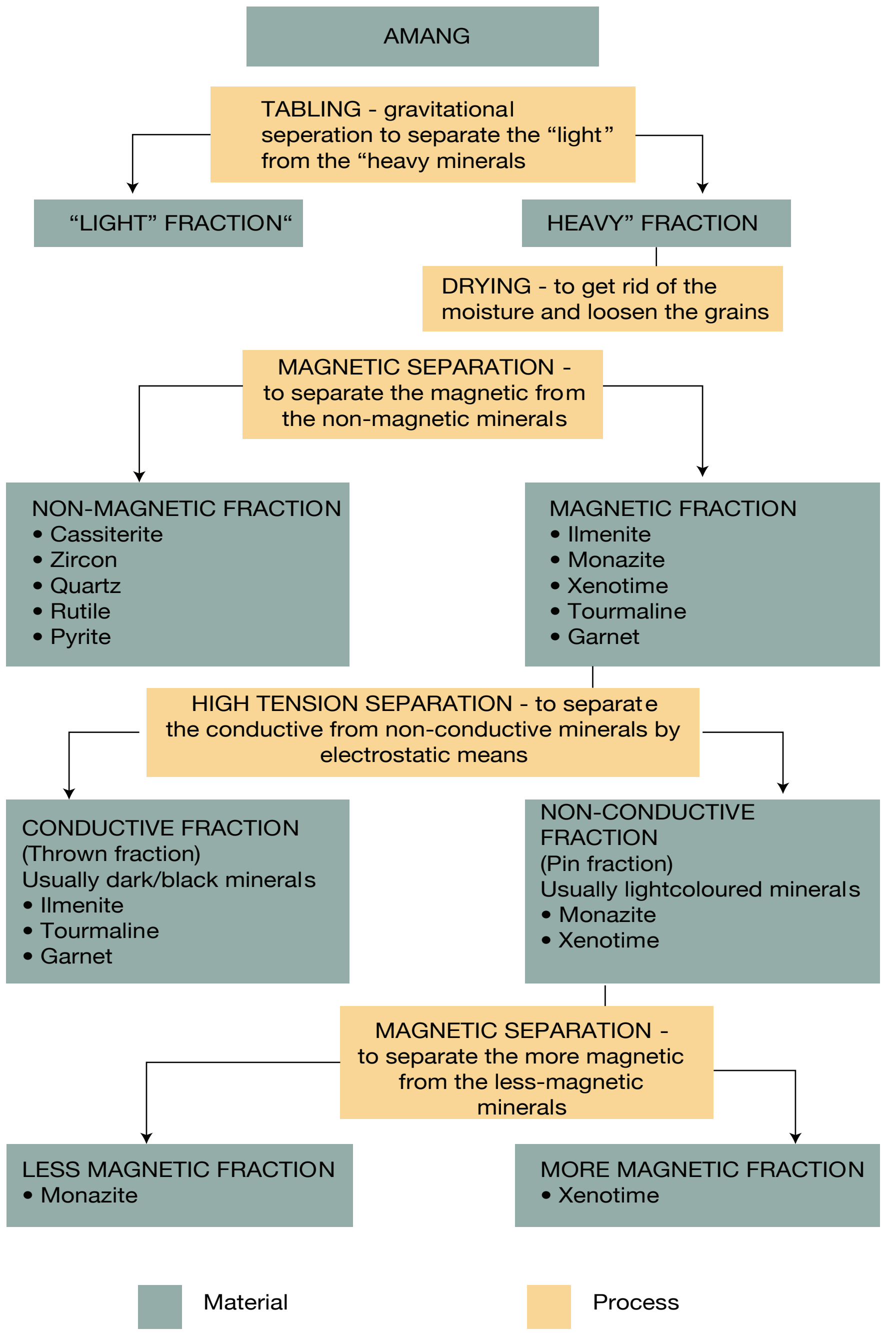
The production of monazite was most significant between 1984 and 1991 during which the annual outputs were in excess of 2,000 tonnes. Since 1992, the annual production of monazite has fallen to below 1,000 tonnes except for two years (1999 and 2004).

Although xenotime is the more attractive mineral in terms of price, production has been erratic with no production recorded during the periods 1998 to 2005 (8 years) and 2007 to 2009 (3 years). However, with the recent high demand and attractive prices for xenotime, 110 tonnes and 208 tonnes were produced in 2010 and 2011, respectively.

2.6 Trade

Table 2 shows the trade data for import and export of xenotime and monazite.

In the past two decades, Malaysia has exported more than 16,000 tonnes of monazite worth some RM25 million and close to 1,000 tonnes of xenotime worth some RM9 million. Most operators would export when the price of the commodity is high and build up stock when it is not lucrative to sell. The highest exports of monazite in the past two decades were between 1995 and 2003. There was no export of xenotime between 1990 and 2002. Malaysia was importing monazite (purpose unknown) until 1992. No import was recorded from 1993 to 2010 but in 2011 records show that 39 tonnes were imported. Imports for xenotime were sporadic.



Source: Teoh Lay Hock

Figure 4: Flow Chart of The Processing of Amang to Recover Xenotime and Monazite

Table 1: Malaysia’s Annual Production of Xenotime & Monazite (Tonnes)

YEAR	XENOTIME	MONAZITE	COMBINED
2011	208	571	779
2010	110	622	732
2009	0	25	25
2008	0	233	233
2007	0	862	862
2006	217	894	1,111
2005	0	320	320
2004	0	1,683	1,683
2003	0	795	795
2002	0	441	441
2001	0	643	643
2000	0	818	818
1999	0	1,147	1,147
1998	0	517	517
1997	79	688	767
1996	0	618	618
1995	8	814	822
1994	1	425	426
1993	22	407	429
1992	13	777	790
1991	5	1,981	1,986
1990	165	3,323	3,488
1989	131	2,948	3,079
1988	47	2,920	2,967
1987	-	-	2,939
1986	-	-	6,104
1985	-	-	6,932
1984	-	-	4,834
1983	-	-	1,051
1982	-	-	618
1981	-	-	344
1980	-	-	327

* Prior to 1988, there were no separate figures for xenotime and monazite production

Source: Minerals and Geoscience Department Malaysia

Table 2: Malaysia's Export/Import of Rare Earth Minerals

	MONAZITE				XENOTIME			
	HS CODE: 2612.20.100				HS CODE: 2530.90.100			
	EXPORT		IMPORT		EXPORT		IMPORT	
YR	TONNES	RM'000	TONNES	RM'000	TONNES	RM'000	TONNES	RM'000
2011 (p)	2209	8490	39	154	362	5536	124	469
2010	630	2675	0	0	306	1667	80	163
2009	105	385	0	0	0	0	3	141
2008	69	696	0	0	48	354	453	198
2007	398	1718	0	0	200	1163	3	13
2006	395	711	0	0	37	145	0	0
2005	33	46	0	0	0	0	0	0
2004	336	416	0	0	2	65	0	0
2003	1075	1122	0	0	20	47	143	317
2002	840	952	0	0	0	0	13	1396
2001	700	971	0	0	0	0	0	0
2000	1225	1366	0	0	0	0	0	0
1999	4245	1672	0	0	0	0	0	0
1998	564	726	0	0	0	0	11	5
1997	1170	871	0	0	0	0	10	8
1996	1033	844	0	0	0	0	0	0
1995	1080	893	0	0	0	0	0	0
1994	178	127	0	0	0	0	0	0
1993	30	116	0	0	0	0	0	0
1992	0	0	119	142	0	0	32	31
1991	0	0	824	912	0	0	6	7
1990	412	794	599	1179	0	0	26	34
1989	560	1074	137	161	100	715	6	27
1988	139	192	62	241	33	26	2	0

Sources: Minerals and Geoscience Department Malaysia Department of Statistics Malaysia

2.7 Importance of alluvial tin mining in increasing production of xenotime and monazite

In terms of feedstock, operators of *amang* re-treatment plants are currently scrapping whatever that is left over from the past alluvial tin mining activities. Occasionally if the opportunity arises they would import *amang* from neighbouring countries such as Myanmar. Increased alluvial tin mining activities will invariably result in the production of more *amang* from which more xenotime and monazite can be extracted. Thus, another way to increase the production of xenotime and monazite is to encourage the exploration for and mining of alluvial tin deposits.

In this respect the (state and federal) government should provide incentives for revitalisation of the alluvial tin mining activities. This could be by way of providing fiscal incentives as well as streamlining the application process to enable more areas to be issued out for exploration and mining.

2.8 R & D relating to exploration and mining of xenotime and monazite

2.8.1 Detection of low concentrations of xenotime and monazite in the natural environment or small samples of rocks and sediment

Hitherto, the detection of the presence of RE minerals at a certain location has been based on manual collection of samples, processing of such samples and visual identification and estimation of the contents. This is a tedious, labour intensive, costly and time-consuming process. Research should be undertaken to find better methods of detecting the presence of RE minerals in field environment which are faster, less labour intensive and cost effective.

2.8.2 Mineral processing methods to produce higher purity xenotime and monazite concentrate

The last break though in the processing of amang to produce RE minerals was in the 1980s when operators were then able to separate xenotime from monazite concentrates. Whilst the present degree of purity of the xenotime and monazite concentrates is acceptable commercially, there is still room for improvement to remove more of the deleterious materials. Research into improving the purity of the mineral concentrates would be of benefit to the industry. Perhaps the research could be extended into finding a method to separate monazite of high thorium contents from low thorium monazite.

2.9 Environmental and safety issues

Environmental and safety issues pertaining to the upstream RE industry are mainly of two types, namely radiological and the non-radiological.

During the exploration and mining stages, radiological safety is not an issue because monazite, although a naturally occurring radioactive material (commonly referred to as NORM), is not present in such an amount and concentration as to be harmful to the workers. There is no specified regulation governing safety at the exploration stage.

At the mining stage, the mining operation (including residues management) and the safety of the workers and the environment are governed by the following legislations which are applicable to mining activities in general:

- Mineral Development Act 1994, enforced by JMG,
- Occupational Safety and Health Act 1994 enforced by Department of Occupational Safety and Health,
- Factories and Machinery Act 1967 (Revised 1974) also enforced by Department of Occupational Safety and Health, and
- Environmental Quality Act 1974 enforced by Department of Environment

At the mineral processing stage in *amang* re-treatment plants, monazite concentrate is produced and this is classified as a technologically enhanced naturally occurring radioactive material (TENORM). Here, radiological safety becomes a concern. In Malaysia, RE-mineral processing is classified as a TENORM activity and is therefore regulated by the Atomic

Energy Licensing Board (AELB), from the siting of the facility to its decommissioning. The following Acts, regulations and guidelines apply.

- Atomic Energy Licensing Act 1984, Act 304;
- Environmental Quality Act, 1974 (Amendment, 1985);
- Environmental Quality Act, 1974 (Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) order 1987);
- Radiation Protection (Licensing) Regulations 1986, P.U. (A) 149;
- Radiation Protection (Basic Safety Standards) Regulations 1988, P.U. (A) 61;
- Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2011, P.U. (A) 46;
- Radiation Protection (Transport) Regulations 1989, P.U. (A) 456;
- Radiation Protection (Transport) Regulations 1989, Corrigendum, P.U. (A) 146;
- Radiation Protection (Transport) (Amendment) Regulations 1991, P.U. (A) 145;
- Guidelines for the Application of Licence from the Atomic Energy Licensing Board for Milling of Materials Containing or Associated with Radioactive Materials, LEM/TEK/28;
- Guidelines for Decommissioning of Facilities Contaminated with Radioactive Materials, LEM/TEK/56, April 2008;
- Guidelines for the Preparation of a Radiation Protection Program for TENORM Activities, LEM/TEK/45 (Part E), April 2011 ;
- Guidelines on Radiological Impact Assessment (RIA) Study Regards TENORM Activities, LEM/TEK 41 (Draft 1) Nov. 2001;
- Radiological Impact Assessment, RIA/EIA---LEM/TEK 30, LEM/TEK 49; and
- Checklist for Application of Class G Licence, LEM/SS/14, 18/02/2010 rev.2.

According to the Atomic Energy Licensing Act 1984, Act 304, any activity related to TENORM handling, such as treatment, reuse, and disposal resulting in a total dose exceeding 0.3 mSv/year shall be licensed. However, under the Atomic Energy Licensing (small *amang* factory) (exemption) Order 1994, small *amang* re-treatment plants where workers are not exposed to greater than an annual dose limit of 50 mSv, need not be licensed, but need only to be registered with AELB and follow its current guidelines.

Presently, the legal framework pertaining to the exploration for, and mining of, xenotime and monazite, and the processing of *amang* is sufficient to ensure that the physical environment and human health are well protected. It is up to the relevant regulatory authorities to ensure that the rules and regulations are properly enforced in a timely manner.

3.0 ION ADSORPTION CLAYS CONTAINING RARE EARTH ELEMENTS

3.1 Genesis and typical geological occurrences

Ion adsorption clays are known to host commercially extractable concentrations of rare earth elements (REEs). In fact, these clay deposits containing high concentrations of REEs are presently the largest source of heavy rare earth elements (HREEs).

Ion adsorption clays containing REEs are formed by chemical weathering of granitic rocks and subsequently chemical adsorption of REEs on kaolinite and halloysite (Yang et al., 1981; Huang et al., 1989, Wu et al., 1990; Murakami & Ishihara, 2008). Bao and Zhao (2008) showed that the parent rocks of these clays are normally I-type and S-type granitic rocks of Chappell & White (1974) with some A-type granitic rocks, and are classified mainly into ilmenite series granitic rocks of Ishihara (1977).

The main characteristics of REE-hosted ion adsorption clay deposits are that it is commonly found in tropical areas with hot and wet climatic conditions and deep weathering. Secondly, they are usually associated with tin-bearing granites. Apart from the deposits found in south China (the only ones presently being exploited commercially), ion adsorption clays hosting significant concentrations of REEs have been found in Vietnam (Mentani et al., 2010), Laos (Sanematsu et al., 2009) and Thailand (Imai, 2012).

3.2 Potential of ion adsorption type clays in Malaysia

Malaysia has similar climatic conditions to south China and the other south-east Asian countries mentioned above. There is also a large expanse of deeply weathered tin-bearing granites in Peninsular Malaysia. The potential of discovering similar types of REE-bearing clays in Peninsular Malaysia is therefore very high.

3.3 Exploration for ion adsorption clays containing REEs in Malaysia

Prior to 2012, no work has ever been done to explore for ion adsorption clays in Malaysia. In early 2013, Watanabe (pers. comm.) collected some soil samples from a weathered granite outcrop in the Bukit Tinggi area for analyses. The REE distribution profiles obtained were found to be promising.

The exploration for REE-hosted ion adsorption clays in Peninsular Malaysia can be undertaken as follows:

3.3.1 Compilation of available technical and scientific information

A comprehensive background research on the technical and scientific literatures on REE-hosted ion adsorption clays should be carried out. The Chinese were the pioneers in this field and have researched and published extensively on the subject (e.g. Chen, 1996; Chi, 1998). Unfortunately, most of the reports are in the Chinese language. However, there are now scientists from other countries, such as Japan, undertaking exploration and research in this field and have published several useful articles.

3.3.2 Identification of initial areas for study

Based on the aforementioned literature research coupled with the knowledge of local geology, in particular locations of tin granites in the Malay Peninsula, suitable areas could be identified for field investigation.

For example, Figure 5 shows the areas in Perak which may be of potential. These areas have been delineated on the basis that they are underlain by tin-related granitic rocks and that the terrain (or geomorphology) looks conducive for the formation of thick soil horizons. Similar areas could be identified in the tin fields elsewhere eg Terengganu and Pahang for investigation.

3.3.3 Field investigation

Reco nnaissance field investigation should involve 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.

The JMG would be the most appropriate agency to undertake this type of investigation as they have the necessary man power with the basic geological and scientific foundation. The government should provide sufficient funds 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 even including excavation for test leaching and evaluation of extractability of the REEs. An assessment of the possible reserves could then be undert

Being new in this field of investigation, JMG could seek technical assistance from other countries with the relevant experience on a G2G basis such as from China and Japan.

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.

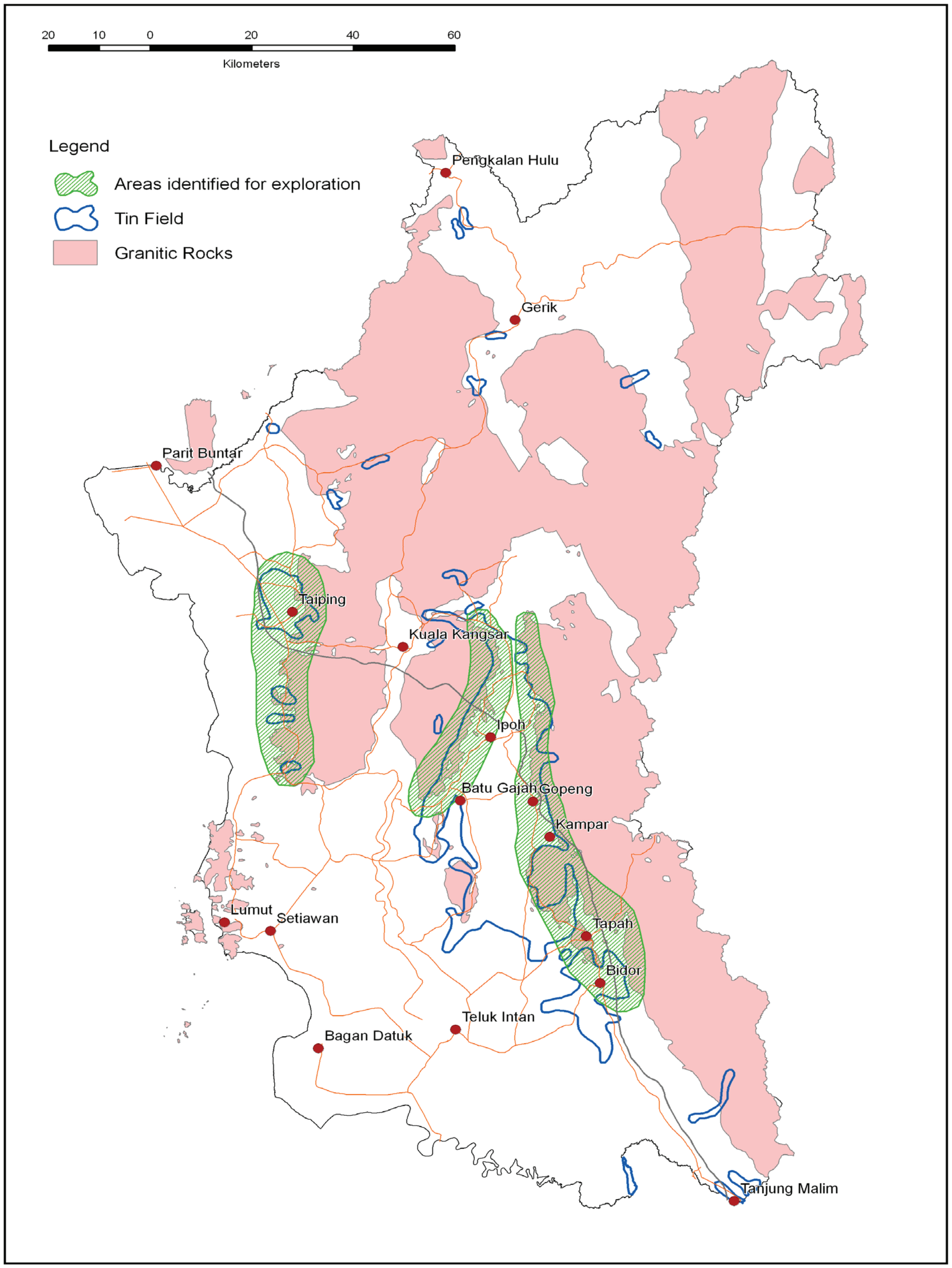


Figure 5: Areas Identified For Exploration Of REE-Hosting Ion Adsorption Clay Deposits In Perak.

3.4 Mining of ion adsorption clay deposits for REEs

To-date, China is the only country where REE-hosted ion adsorption clay deposits have been exploited commercially. Most of the mining operations are in south China. The deposits are located mostly in remote mountainous areas; discovered and mined by local villagers using primitive methods much like artisanal mining in other countries. Nevertheless, collectively they constitute the largest producer of HREEs in the world.

Two types of mining methods are practised in south Chin

The traditional (and more primitive) method of mining involves tank or heap leaching whereby the ore-containing soil is excavated and put into a heap. A solution is passed through which elutes the REEs from the heaped soil. The REE-bearing solution is collected and the REEs precipitated and recovered using an acid solution. The Chinese government has now banned this type of mining method.

The modern method uses in-situ leaching (Figure 6) whereby an electrolyte solution is pumped directly and allowed to permeate into the ore body underground. The solution flows downwards permeating the rocks and eluting the REEs along the way. The REE-rich solution is drained and collected at the bottom. After removing the impurities, the REEs are precipitated by addition of a precipitating agent (eg oxalic acid) and roasted to produce a rare earth mixture containing over 92% REO.

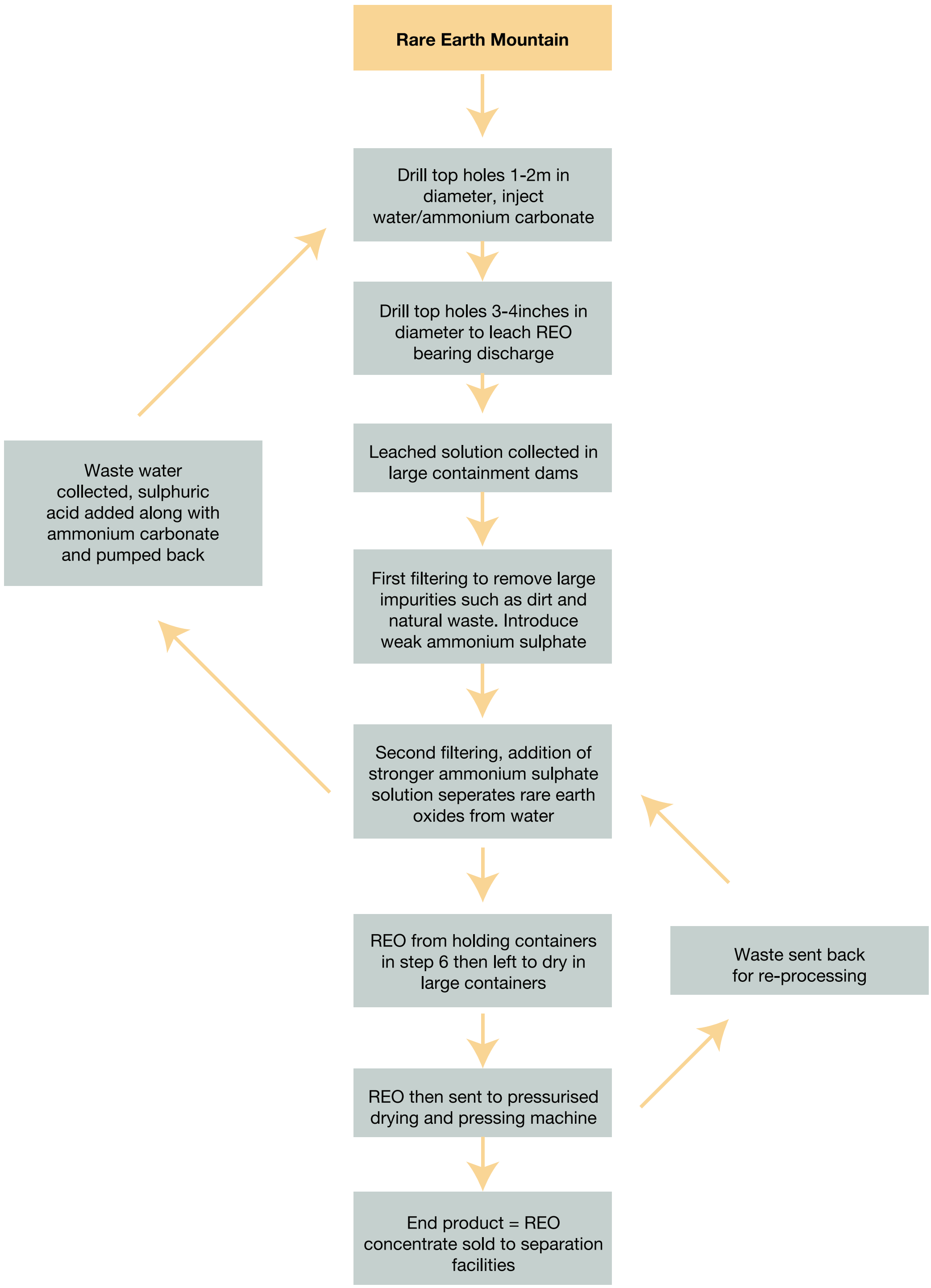
3.5 Environmental issues pertaining to mining and processing of ion adsorption clay for REEs

One of the greater challenges in the mining of ion adsorption clays for REEs is the minimization of damage to the environment. This has been the issue confronting the mining of REE-hosted ion adsorption clays in south China ever since the activity began. Although the mining method has progressed from tank/heap leaching to in-situ leaching, damage to the environment is still a point of contention. According to Hongpo (2012), compared with the traditional method, in-situ leaching "creates less environmental damage" and "is time-efficient and also more cost-effective".

Knowing what has already happened in south China, early steps should be taken to study how best to mitigate possible environmental impact arising from this type of mining. The initial step (pre-empting the discovery and mining of such deposits in Malaysia) would be for the Ministry of Natural Resources and Environment (NRE) which is in charge of both JMG and the Department of Environment (DOE) to initiate a G2G collaborative arrangement with the relevant Chinese authorities to study how the Chinese are addressing the issue. The Chinese government is known to be paying much attention to environmental protection and much can be learnt from them.

3.6 R&D pertaining to ion adsorption clays containing REEs

Several research proposals could be relevant in the search for and mining of REE-hosted ion adsorption clays in Malaysia.



Source: Hongpo (2012)

Figure 6: Flow Chart of an Example of In-Situ Mining of REE-Hosted Ion Adsorption Clay Deposit in South China.

3.6.1 Geochemical behaviour of REEs during the weathering of granitic rocks

An understanding of how the REEs behave during weathering of granitic rocks would help in the search for ion adsorption clays with high concentrations of REEs.

Where do the REEs come from? Are they from minerals such as xenotime and monazite where they are present as a major part of the mineral composition or from other minerals where they are present as trace elements?

How do they get transported? In what form? What kind of conditions is favourable for their transport? What are the physico-chemical conditions under which they are transported; pressure, temperature, pH, redox potential, etc.? How does the ion exchange take place and how best can the REEs be eluted?

How are the RE ions bonded to the lattices of the clay minerals? Do they have preference for a certain type of clay or clay with a certain type of structure?

3.6.2 Pathfinders in the exploration for REE-hosted ion adsorption clays

In geochemical exploration, pathfinders are important in helping to locate the occurrence of the final target minerals or elements. Similarly, this method of approach can be used in the search for REE-hosted ion adsorption clays. The pathfinders need not be confined to trace elements but also the types of clays that are usually associated with such deposits or the signature REE distribution patterns along the soil profiles.

3.6.3 Improved methods for analyzing for REEs in ion adsorption clays

A research project could be undertaken to establish new rapid methods to analyse for the REEs in terms of accuracy and low detection limits.

3.6.4 Improved methods for the mining and extraction of REEs in ion adsorption clays

Research needs to be undertaken to find alternative ways of mining and extraction which will have less damaging effects on the environment. This includes methods that produce less residues or wastes which are less toxic.

The above research proposals would be best undertaken through collaborative efforts amongst the various government departments, government research agencies and institutions of higher learning with relevant research facilities. Collaborative research with foreign institutions should also be encouraged.

Focused research groups could be set up to tackle the various topics of research. To ensure the efforts are well coordinated, a special committee could be set up within a national committee for RE development.

4.0 RARE EARTHS IN MARINE SEDIMENTS

4.1 Genesis and typical geological occurrences

The occurrences of RE minerals and REEs in marine sediments can be categorized into two types based on location.

4.1.1 Near-shore sediments

The first category of occurrence is along the near-shore areas including the continental shelf where the sediment is mainly of terrigeneous origin i.e. from the land which has been eroded and the sediments transported by rivers into the sea. This includes erosion of granitic mounts which were previously exposed when the sea level was lower and subsequently submerged when the sea level rose.

The rare earths in the near-shore sediments occur mainly as minerals. The concentration of RE minerals depends very much on the provenance of the rivers bringing in the sediments.

4.1.2 Deep ocean sediments

Hein (2012) reported that REEs have been found in the very large tonnage deep ocean mineral deposits, specifically in the polymetallic nodules and the cobalt-rich crusts.

Polymetallic nodules are small golf-ball size concretions that sit on the sediment surface in the deep-water (4,500-6,500 metres) abyssal plains. They are composed predominantly of manganese and iron oxides with much lesser amounts of copper, nickel, cobalt, REEs, lithium and molybdenum. The main metals are derived from cold ambient seawater and from pore-waters in the sediment. The minor metals are adsorbed onto the major iron and manganese phases.

Cobalt-rich crusts occur as pavements on the hard-rock substrates on the submarine seamounts and ridges throughout the global ocean. Those of economic interest occur at water depths of about 1,000-2,500 metres. They are composed predominantly of manganese and iron oxide, cobalt, nickel, REEs, tellurium, bismuth, niobium, platinum, and tungsten. The metals of interest are derived from the same sources as those in the polymetallic nodules.

The polymetallic nodules and cobalt-rich crusts in the Pacific Ocean have high proportions of HREEs comparable to those in south China's ion adsorption clays. According to Hein (2012) the REEs in the above deposits can be extracted as by-products during the extraction of copper, nickel, cobalt and manganese. Even though the grades (concentration of REEs) of the marine deposits are generally lower than that of the land-based deposits, the tonnages are much greater.

The two main areas of interests are the Clarion-Clipperton nodule zone in the North-East Pacific in the international seabed area and the prime equatorial Pacific crust zone, which includes both the international seabed area and the Exclusive Economic Zones of the Pacific island countries.

4.2 Malaysian initiatives to explore for and mine REs in marine sediments

4.2.1 Within Malaysian Territorial Waters

Marine sediment surveys have been carried out by JMG (Vijayan, 2001; Yong & Yap, 1974, Oele & Yong, 1975) as well as several other parties (Nor Antonia et al. 2011; Rezaee Ebrahim et al. 2009) along the eastern and western seaboard of Peninsular Malaysia and in the coastal areas of Sabah and Sarawak.

The results of the surveys show that xenotime and monazite do occur in the marine sediments but the concentrations are low and presently not of economic interest. Nevertheless, there are places where the xenotime contents reach up to 18% of the total heavy mineral assemblage.

Malaysia's territorial waters along both the east and west coast of the Malay Peninsula receive considerable amount of sediments from rivers draining the major tin fields where xenotime and monazite are found. It is therefore worthwhile to undertake further investigations in the areas where these sediments are being deposited into the sea. The areas recommended for further investigation are shown in Figure 7.

Off-shore mining of tin has been carried out off the coast of Perak and mineable concentrations of tin have been located off the coast of Melaka. Although the results of the surveys carried out so far show the contents of xenotime and monazite are presently not of economic interest it would be worthwhile to review the results to evaluate the possibility of xenotime and monazite being mined together with tin, gold and other economic minerals. Marine surveys are generally expensive and follow-up marine surveys should be carried out only in areas where there are clear indications of potentials.

4.2.2 International Seabed

Thus far no mining of minerals from international seabed has yet been undertaken. However, under the United Nations Convention on the Law of the Sea (UNCLOS), countries are allowed to apply for “acreage” in the “Area” for exploration and exploitation of seabed minerals following the terms and conditions laid out by the International Sea-Bed Authority (ISBA). Several countries, including Russia, South Korea, India and more recently Singapore as well as several consortia, have applied for such exploration rights and some of them are already undertaking such activities in the Pacific and Indian Oceans.

It is recommended that the Malaysian government bid for such rights as well. The Maritime Institute of Malaysia (MIMA) is presently looking into the policy matter of Malaysia’s participation in international seabed mining. However, in terms of technical and scientific matters, JMG, which has a strong marine geology division, should be involved. This is a strategic decision which Malaysia has to make and take action in a timely manner if it does not want to be left behind.

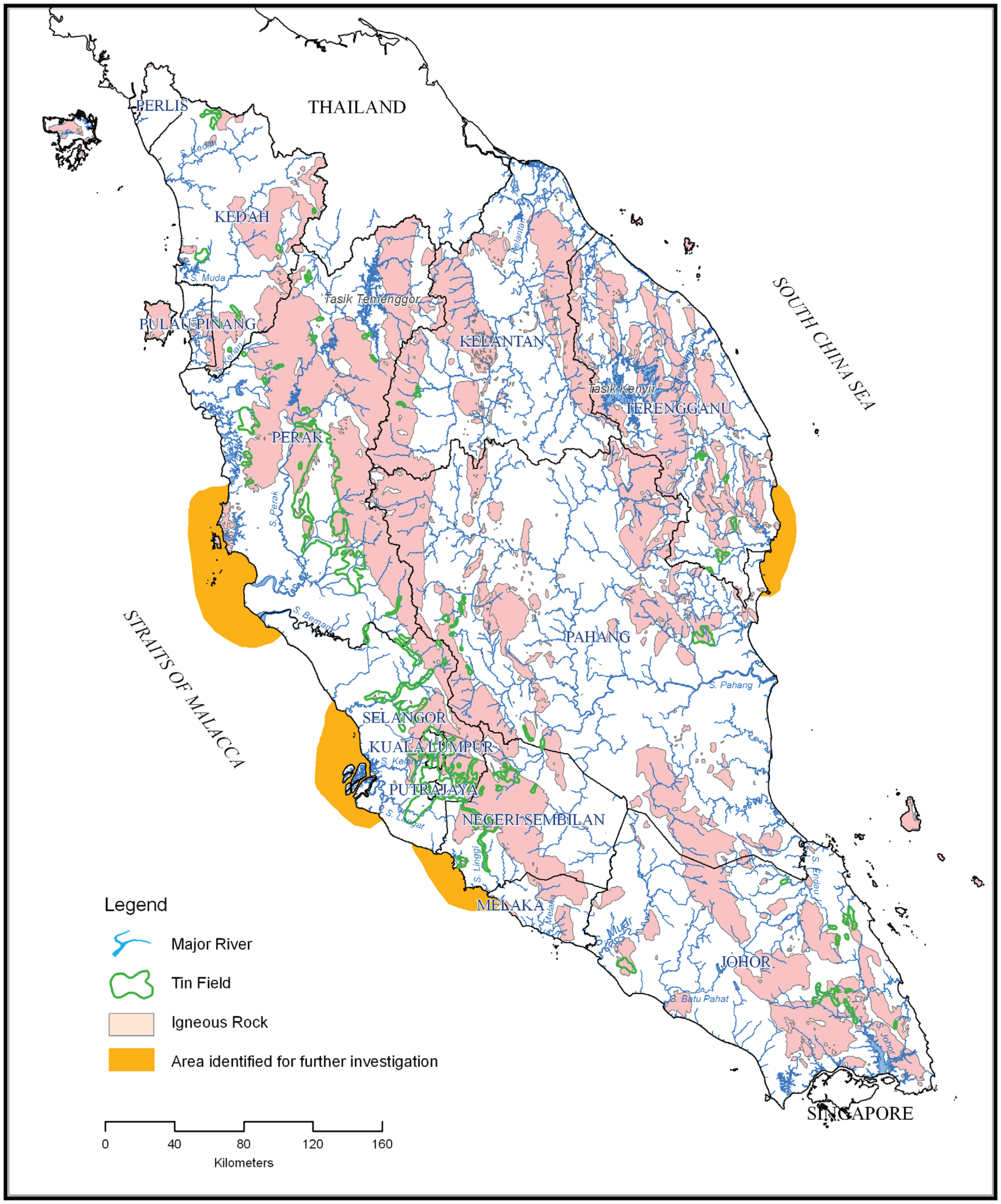


Figure 7: Off-Shore Areas Identified for Further Investigation.

According to Hein (2012), the mining of seabed for REEs has several advantages over hard-rock land-based mining including the following:

- The REEs can be eluted from the seabed ores in a more cost effective method using relatively simple procedures (dilute acid leach).
- The seabed deposits do not contain radioactive components.
- Mining can be done selectively on just the high grade and high tonnage deposits with minimal impact on the seabed.
- The deep-ocean animal population densities are generally low; and
- It leaves little footprint as it does not require removal of overburden.

However, there are still issues concerning mining technology, environment impact and costs to be sorted out.

4.3 Environmental issues

There is always an environmental issue associated with mining in the sea.

The removal of parts of the sea floor during off-shore mining will invariably result in disturbances to the benthic zone as well as cause turbidity to the water. This will affect fish population and other marine life and accordingly those who depend on the sea for a living.

In terms of deep-ocean mining interested parties are still researching on suitable methods of extraction. A major concern is the impact it would have on the marine environment and this has to be sorted out before commercial mining can take off.

4.4 R & D relating to exploration and mining of rare earths in marine sediments

4.4.1 Mining and Extraction of REEs in Marine Sediments

One of the greater challenges in off-shore and deep-ocean mining is to be able to undertake the mining and extraction in a manner that will have minimal impact on the marine environment. Research into this area is important and any success would benefit both the mining industry and environmentalists. The research could be extended to cover rehabilitation of the disturbed environment.

Cost of mining and extraction is also an issue and is a critical component in determining the viability of, in particular, deep-ocean mining. Research into cost effective deep-ocean mining technology is important.

Malaysia on its own may not be ready for this kind of research yet. However, if there is an opportunity for Malaysian researchers to participate in this kind of research which is being undertaken by the more advanced countries or by major mining corporations then such opportunities should be taken up.

5.0 RARE EARTH MINERALS IN PRIMARY SOURCES

5.1 Genesis and typical geological occurrences

The principal concentrations of REEs in hard rocks are associated with uncommon varieties of igneous rocks, namely alkaline igneous rocks and carbonatites.

Alkaline igneous rocks are rocks which have higher concentrations of alkalis than can be accommodated in feldspars alone, the excess appearing as feldspathoids, sodic pyroxenes, sodic amphiboles and other alkali-rich phases (minerals). These rocks are deficient in silica (undersaturated) and/or alumina with respect to alkalis and will have nepheline and/or acmite in their norms. According to Fitton and Upton (1987), volumetrically alkaline igneous rocks account for less than 1% of all igneous rocks. Alkaline igneous rocks are found in three types of tectonic settings, namely continental rift valley magmatism, oceanic and intraplate magmatism without clear tectonic control and alkaline magmatism related to subduction zone processes. They are believed to have been formed from the cooling of magmas derived from small degrees of partial melting of rocks in the Earth's mantle.

Carbonatites are igneous rocks composed of more than 50% carbonate minerals, generally calcite or dolomite. They are silica-deficient but rarely alkali-rich. They are very nearly the last rocks to form during fractional crystallization of the magma at temperatures ranging from 500°C to 600°C. To-date there are only 527 known carbonatites in the world (Wooley and Kjarsgaard, 2008).

Other rock types which have been known to host significant amounts of REES include stratiform phosphates deposits, pegmatites, replacement type deposits, various types of especially high grade metamorphic rocks and prophyries.

5.2 Typical occurrences of rare earth minerals in Malaysian rocks

In terms of geological association, the rock suites in Malaysia and the tectonic settings are not comparable to those where the hard rock RE deposits are typically found. There is no reported occurrence of alkaline igneous rocks or carbonatites in Malaysia. The closest would be the rare occurrences of undersaturated rocks in Johor (Grubb, 1965) and Kalimantan, Indonesia, just beyond the border of Sarawak (van Emmichoven, 1938)

However, in Peninsular Malaysia the streams draining the tin granites and their metamorphic aureoles are known to contain significant amounts of xenotime and monazite. Petrological studies have shown that xenotime and monazite are found as accessory minerals in these granites therefore it is logical to assume that the source of xenotime and monazite in the streams are derived from the granites.

It is worthwhile to note that of all the mines extracting RE minerals from primary sources none are working on granites.

5.3 Exploration for primary rare earth mineral deposits in Malaysia

The exploration for primary RE mineral deposits could be aimed at two targets namely, xenotime and monazite in the tin granites in Peninsular Malaysia and the possible presence of alkaline igneous and carbonatite-type rocks in Sabah or Sarawak as large parts of these states have not been mapped in detailed.

5.3.1 Xenotime and Monazite in the Granites

A reasonable and cost effective method for exploring for economically extractable amounts of xenotime and monazite in the granites is to study the quarry dust produced at the various granite quarries within the major tin fields. The evaluation could involve mineralogical and petrological study of the dust and the host granite, and mineral processing techniques that can be applied to enable cost effective separation of xenotime and monazite or direct extraction of REEs from the dust.

The mineralogical and petrological study could involve identification of minerals as well as their morphology such as grain size, grain shape and form, texture and relationship with the other minerals. The main purpose is to collect information relevant for the subsequent research on mineral processing techniques.

The study of mineral processing techniques could involve the evaluation of the effectiveness of gravity, magnetic, electrostatic, froth flotation and other chemical and non-chemical methods in separating out the RE mineral grains.

The extraction techniques could involve the study of the effectiveness of various solvents and precipitating agents in eluting out the REEs and subsequent recovery from solution.

In view of the preliminary nature of this investigation, the work should rightly be undertaken first as a scientific study in research institutions such as at universities or the Mineral Research Centre of JMG. Some of the above study may have already started in some institutions.

5.3.2 Exploration for REE-Hosted Rocks

Although the present knowledge of the geology and tectonic settings of Malaysia indicate that the presence of RE hard rock deposits is unlikely, the search should not be written off as yet. A large part of the country, especially in the remote areas of Sabah and Sarawak, has yet to be mapped (geologically) in detail.

The focus of the search for RE-hosting rocks such as alkaline igneous rocks and carbonatites should be carried out in the states of Sabah and Sarawak which are still largely unexplored. This exploration exercise could be undertaken as part of JMG's on-going field mapping and mineral exploration programme. However, to be effective, the personnel involved should be knowledgeable on, and be exposed to, exploration techniques relating to the search for RE deposits and be able to recognize geological indications of their likely occurrence. Technical co-operation programmes with foreign institutions to provide the appropriate training would be useful.

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MIDST

TREAM SECTOR

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MIDSTREAM SECTOR

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1.0 INTRODUCTION

In a report by Professor Dudley Kingsnorth in June 2013, he described the complete chain of one of the critical materials i.e. rare earth processing from mining to production of batteries in hybrid vehicle. In those nine steps, step numbers three to five i.e. extraction, separation and oxide to metal can be considered the most crucial steps which is known as the midstream sector in the rare earth chain.

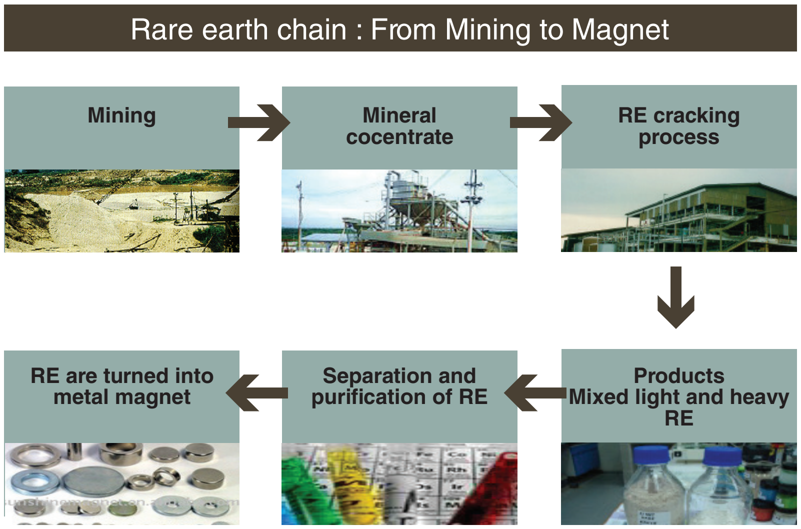


Figure 1. Rare Earth Value Chain.

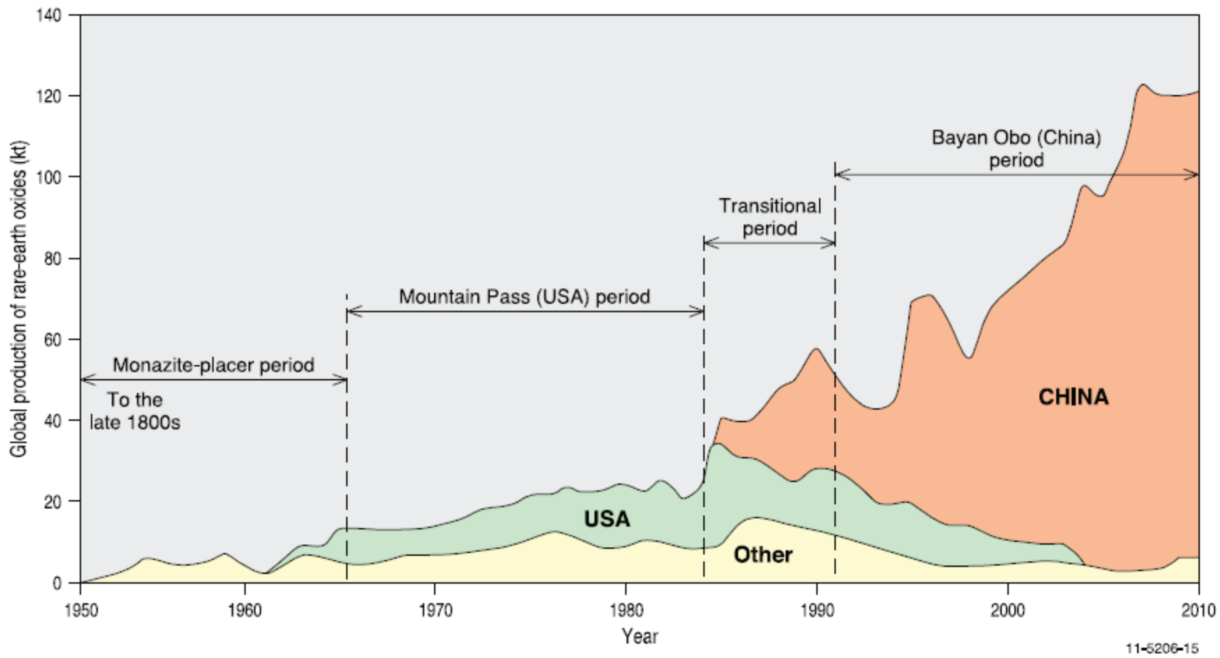
The rare earths (RE) value chain shown in Figure 1 begins from mining of the RE minerals and ends with its industrial applications, such as magnets for car components. The rare earths mineral concentrates produced from the physical beneficiation process or mineral concentrates usually contains around 30-70% of total rare earth oxides (REO), and is used as the starting material for the midstream sector. For the RE to be used in industrial applications, further chemical processing is required. The midstream sector begins with the cracking process, where the RE is recovered from the mineral in the form of mixed light and heavy RE-carbonate compounds. These are intermediate products that require further separation and purification into their individual high purity rare earth elements (REE) if they are to be used in high tech applications. Thus, included in the midstream sector is the separation and purification process that will further separate the individual rare earth elements to a purity of 99.9% - 99.999% (1), depending on its application. The separation of individual high purity REE from intermediate mixed RE is done within the same plant or process via a separate purification plant. In this sector, the radioactive component that is normally associated with the rare earth mineral will be removed and produced as radioactive residues, making this sector unpopular and controversial.

The production of this intermediate product will result in a value-added rate of about 5 times compared to its monazite starting mineral. As we go further down the RE chain, mixed light RE carbonate will then be separated and purified by chemical methods, and this will then produce the high purity individual REE. The purity of the product at this stage is normally 99.9%, and the price is dependent upon the element. Production of the light REE neodymium (Nd) will have a value-added rate of 16 times to that of monazite, while the heavy REE dysprosium (Dy) will gave a much higher value-added rate of 1500 times to that of the monazite starting mineral (2).

1.1 Cracking stage

Cracking or recovering of RE by chemical process began in the late 1800s using monazite as its feed source. Monazite was initially recovered for its thorium content to be used, admixed with cerium oxide, to amplify the light produced by burning natural gas through the incandescence produced when the thoria/ceria mixture was used as a "mantle" around a gas burner but with the introduction of electricity and declining usage of this lamp, the recovery of the RE is now the primary objective of the process. The early RE cracking period from late 1800s to the mid-1960s was identified as the monazite-placer period. In the 1960s, the mineral bastnaesite, obtained mainly from the USA Mountain Pass mine, was introduced as the important alternative source to monazite, with the period from the mid-1960s to mid-1980s identified as the Mountain Pass period. During this period, the USA had become the world's largest producer of RE. China came into the RE cracking scenario in mid-1980s, with the cracking of carbonatites mineral coming mainly from the Bayan Obo mine. The low-cost production from the mines in China has eventually resulted to the decline in usage of both monazite as well as bastnaesite from the Mountain Pass deposits. As of early 2000s, China controls about 97% of the total global RE production, with the period from early 1990s to 2010 identified as the Bayan Oro period (Figure 2).

The RE cracking process involves both alkaline and acid methods (4, 5). In the acid method, concentrated sulphuric acid is used for the dissolution of RE and other elements, including thorium. The liquid RE sulphate will then be further separated into light and heavy RE groupings via a multistage bulk treatment followed by a solvent extraction process. In this process, thorium will be precipitated as thorium phosphate. The alkaline methods normally use caustic soda to break up the mineral, and trisodium phosphate fertilizer will ultimately be produced as a by-product of the process. RE will then be dissolved into solution by leaching with hydrochloric acid, and the RE chloride solution will then move to the solvent extraction stage. Thorium will then be produced and removed as insoluble thorium hydroxide solid (6).



Source: Haridas, T (2011)

Figure 2. RE recovery from different periods (3).

1.2 Separation and Purification Stage

The stage of separation and purification of rare earth processing is the most crucial step in the overall schemes of rare earth project. This stage can make or break the project. In light of this issue, Jack Lifton of Technology Metals Research (2) stated "The production of high-purity metals is as much an art as it is science and engineering. It requires diligent attention to operational details and avoiding mis-steps that can contaminate, and thus ruin the end product… One learns how to purify metals by doing it, not by reading manuals". Due to the complex technologies involved, the costs of the separation and purification processes can become very high when including also costs in building the required expertise and training human capital to run a RE processing facility.

In today's RE processing, the complicated and complex separation and extraction stages such as solvent extraction and ion exchange are known as hydrometallurgy (7). In these processes, via liquid processes i.e. leaching, extraction, and precipitation mineral concentrates are separated into oxides and metals; dissolved and purified into leach solutions. The RE metal or one of its pure compounds is then extracted from the solution using chemical or electrolytic methods (8, 9).

The development of ion exchange, solvent extraction, and other related processes took place in the 20th century although it originated earlier in the 16th century. The methods or techniques include fractional crystallization, ion exchange and solvent extraction.

In order to complete the extraction process, multiple stages are needed. In many cases, hundreds of steps in the form of cascading tanks, mixers, settling tanks, and other equipment such as filtration and evaporation units need to be included due to the RE elements properties which are very close to each other in terms of atomic number. In this regard, solvent extraction has advantage over ion exchange where it can run continuously in a counter-current fashion that constituted many extraction steps which lead to increasing the degree of separation to achieve the required purity (10).

This is why many companies still utilize the traditional solvent extraction methods in their processing facilities. However, the main disadvantage of solvent extraction method is associated with the kinetics (the process reactions are very slow). Also the chemicals used and their by-products, which usually are flammable and thus need handling to dispose, treat or recycle.

The method employed above such as solvent extraction is not always sufficient to purify further to convert to RE metals. It usually requires further refining. Among the methods to produce purer rare earth metals explored by rare earth industry are:-

- Calcination which based on thermal principles
- Sorption, a combination of the two processes – absorption and adsorption
- Vacuum distillation
- Electrolysis
- Gaseous reduction
- Precipitation
- Metallothermic reduction using heat and chemicals to produce metal from RE oxides.

Finally, it is an accepted norm for the rare earth industry that while mining REE material is easy, separation and purification processes are the toughest. This is especially true for refining heavy rare earths such as, terbium, yttrium and dysprosium. It normally will take several years to develop the right and suitable technology for specific minerals and also to develop the expertise required for the related technology. Fortunately a great deal of work has been done on the extractive chemistry and downstream processing and purifying of the rare earths derived from monazite and xenotime. This information is readily available in the open literature and consultants with such experience are available.

1.3 Rare Earth Metals

There are applications, such as magnets, storage devices and batteries, where the rare earths are required to be in metal form. The high purity rare earth oxides produced after the purification stage needs to first be converted into their respective fluorides and are then reduced metallothermically to their metal form at high temperature. This process is known as the Ames Process developed by the US Ames Laboratory and as part of the Manhattan project (11).

Recently, chemists in China have demonstrated that it possible to produce the rare earth metal by the electrochemical reduction of a solid oxide of a heavy rare earth metal into its metallic state (12). The process requires less energy than conventional methods of producing pure rare earth metals and could provide an economically more attractive route to the rare earth metals production. A low melting eutectic is formed by mixing the rare earth oxide with an alkali or alkaline earth oxide and this mixture is melted. As the RE metals form they drop to the bottom of the electrolytic cell and are protected from reactions with air and water by the molten salts just as in the production of aluminum.

Nikolaev Institute of Inorganic Chemistry of Russia developed a method to fabricate rare earth metal using the lithium-hydride technology (13). The technology is based on the method of producing pure rare-earth metals from pure oxides by first chlorination followed by thermal treatment of the chlorides with lithium hydride at a temperature of 700-900^{0}C. The subsequent hydrometallurgical treatment of the reaction mass includes washing with water at room temperature and drying of the metallic hydride powder. Dehydrogenation is performed in vacuum at 800-900^{0}C, resulting in dense metal powders.

2.0 CASE STUDIES OF RE CRACKING IN MALAYSIA

Both monazite and xenotime cracking plants, in the past, were established in Malaysia via the operations of Asian Rare Earths Plant (ARE) and Malaysian Rare Earths Corporation (MAREC), respectively.

2.1 Asian Rare Earths Plant

The Asian Rares Earth (ARE) plant, that was located at Bukit Merah, Lahat Perak, (Figure 3) began its operation in 1982 after obtaining its operating license from the Ministry of Health (MoH). ARE had its operations suspended in 1985 for failing to obtain an operating licence from the Atomic Energy Licensing Board (AELB). The ARE plant, however, was able to begin its operations again in 1987 after it obtained the necessary operating licenses from the AELB. ARE used the alkaline method via caustic soda for its monazite cracking process. Caustic soda is used primarily to separate the phosphate from RE and thorium (14, 15).

In this chemical reaction, the phosphate component is separated from the hydroxides by dissolving it in water. The RE is then dissolved in concentrated hydrochloric acid, while the undissolved thorium is filtered and produced as thorium hydroxide residues. Separation of light and heavy REs is carried out by means of solvent extraction technique, with diethylhexyl phosphoric acid (DEHPA) acting as the solvent (16). The DEHPA used for this purpose was diluted in kerosene to make it more effective in separating the light and heavy RE groups. The final stage of this process is the carbonate precipitation of both light and heavy RE into their respective light and heavy RE carbonate compounds.

As the ARE plant only produced intermediate mixed RE products, these products were then exported to other RE purification plants in Japan and Europe in order to produce high-purity individual REEs, which were then used in different hi-tech applications. The ARE plant, during its peak operation, employed a total of 164 people, with production capacities of 4,000 tons of monazite in a year, producing 4,200 tons of light RE carbonate, 550 tons of heavy RE carbonate, and 4,400 tons of trisodium phosphate annually (15).

Figure 3. Aerial view of ARE plant

Thorium that was present in the monazite feed stock was concentrated and produced as a technically-enhanced naturally occurring radioactive materials (TENORM) from the process. The radioactive issue led to a series of protest and court cases involving ARE and the nearby residents. Among improvements undertaken by the company was to construct a long-term storage facility (LTSF) for the storage of radioactive residues. The LTSF was completed in 1989 at a secluded location on a hill-top on Kledang range, about 5 km from the plant (Figure 4).

Figure 4. Aerial view of LTSF at Kledang range

ARE ceased its operations in January 1994. Reasons for this closure included low RE prices with the entry of China in this sector. The company also incurred losses, as its operating expenses exceeded the price of the RE that it produced. Another factor contributing to this plant was the high cost of plant maintenance, which had to be incurred during the 14 months High Court suspension that it had to endure.

2.2 Malaysian Rare Earths Corporation

The Malaysian Rare Earths Corporation (MAREC) was a xenotime processing plant. Located in the same compound as its sister company, ARE, the plant began operations in 1976, mainly for the production of yttrium oxide concentrate (15). The RM5 million plant had a capacity that was much smaller than that of ARE; at full capacity, it produced only 160 tonnes per annum of yttrium concentrate. The concentrate, which normally contained 60% yttrium oxide, was then exported to Japan, USA, UK and Norway for further separation and purification of valuable HREE. Sulphuric acid digestion method was employed in this plant. The xenotime was first milled to its required particle size before being roasted in a furnace. This was to ensure a good yttrium recovery was obtained in the next stage. In the digestion stage, the YPO_4 present in xenotime was converted to the water-soluble yttrium sulphate. Cold water was used as the leaching medium in the next stage for better recovery. Yttrium was then precipitated as yttrium oxalate, with the addition of oxalic acid. The final stage involved in this process was the calcination of yttrium oxalate into yttrium oxide. MAREC stopped its operation in 1982 when its sister company, ARE, began operations (14).

There is no analysis on the thorium and uranium contents of radioactive residues generated by MAREC. The volume of residues generated by this plant was also unknown. It is presumed that the residues were kept together with the ARE thorium residues at the LTSF.

2.3 Lynas Malaysia Sdn Bhd

Lynas Malaysia Sdn. Bhd. (Lynas), a wholly owned subsidiary of Lynas Corporation Limited (Australia), had constructed and currently operates the Lynas Advanced Materials Plant (LAMP) on privately-owned industrial land located in an area of 100 ha in the Gebeng Industrial Estate (GIE), Kuantan, Pahang.

Based on the company's planning, the plant will process up to 80,000 tonnes per annum (tpa) wet weight basis of lanthanide concentrates (equivalent to 65,000 tpa dry weight basis). The lanthanide concentrates are produced from its processing plant at its mine at Mount Weld, Australia where the lanthanide ore (from the open mine pit) is extracted, crushed and concentrated. The concentrate is then transported from Mt. Weld by road and rail to Port for shipment via sea containers to Port of Kuantan in Pahang. According to their plans, the plant will produce 22,500 tpa (LnO or lanthanide oxide basis) of high-purity lanthanide compounds in the form of a suite of six (6) different products. Figure 5 shows the flow-sheet of the processing of the concentrates to produce the products in LAMP.

PRODUCTION GENERAL INFO

Process Flowsheet

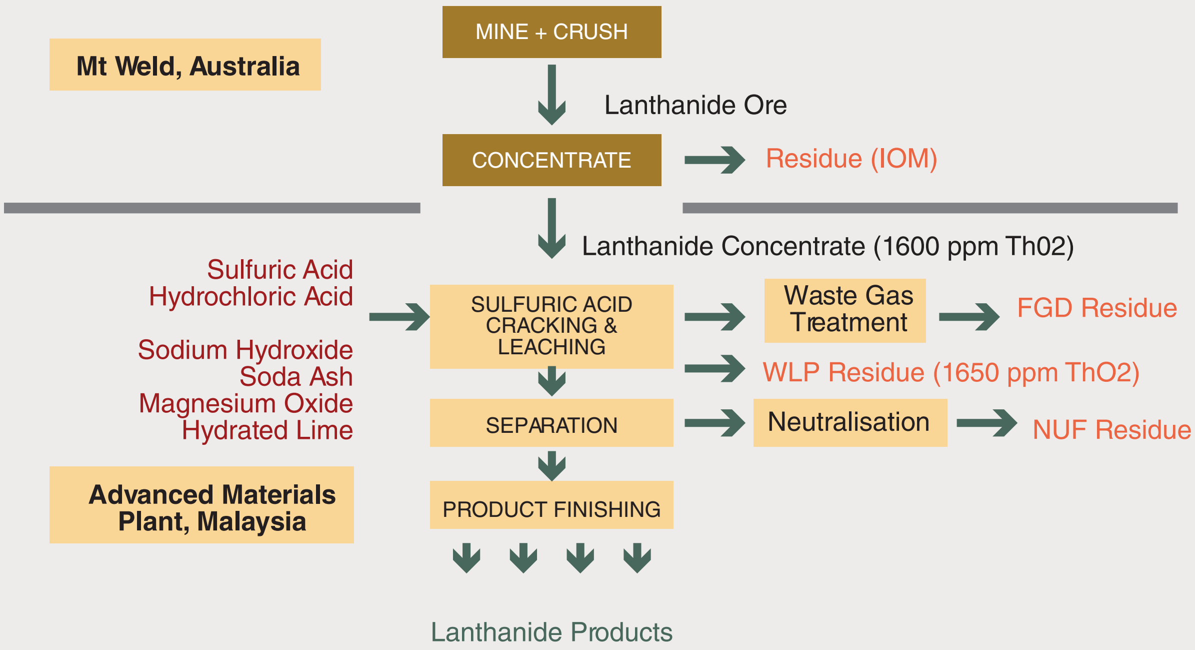


Figure 5. Process Flow-Sheet of LAMP

The list of main products and its application is shown in the Table 1 below :

Table 1 : LAMP Main Products and their Applications

Product	Application
SEG-HRE carbonate	Phosphors for colour screens and energy efficient lighting (e.g. compact fluorescent lights)
LCPN Carbonate	Downstream processing plants for separation into individual lanthanide products
Lanthanum Chloride, Carbonate or Oxide	Fluid Cracking Catalysis (used in oil refining) and to the manufacturers of battery alloy for nickel metal hydride (NiMH) rechargeable batteries
Lanthanum-Cerium Carbonate	Glass polishing powder (plasma TV and LCD TV)
Cerium Chloride, Carbonate or Oxide	Automotive catalysts powders for the automotive industry
Didymium Oxide and Neodymium Oxide	Magnetic alloys, metal production.

These products will be exported to customers in China, Japan, Europe and the USA.

2.4 Management of Radioactive Residues Generated from RE Industry

Thorium and uranium are categorized as naturally occurring radioactive material, otherwise known as NORM. The average content of the element thorium and uranium in the outer crust of the earth is about 12 and 4 grams per ton, respectively. Thorium is a little less abundant than lead, and about three times more abundant than uranium, and is associated with uranium in igneous rocks. The presence of thorium and uranium in the RE minerals is attributed to the same ionic sizes of this NORM and REE. Uranium occurs in the natural form as U^{4+}, and thorium in its natural Th^{4+}, has similar ionic size of 1 angstrom as that of the RE ion (17). Thus, during the mineral formation, these radioactive elements tend to replace the REE, and form as impurities in the crystal lattice. The thorium and uranium contents in monazite vary for deposits of different locality, as shown in Table 2. Malaysian monazite generally has a thorium content of 6.0%, which is much lower than that of monazites found in India, Italy and Sri Lanka.

Radioactive residues generally generated by midstream RE industries include thorium, uranium and their decay products, mainly radium. In a monazite cracking plant, the radium is produced as radium sulphate, and stored in the same storage facility as the thorium hydroxide residues. Two general approaches to radioactive residue management are to `concentrate and contain', or dilute and disperse (19). There are no clear agreements on the acceptable methods for NORM disposal, and the options mentioned below have its own advantages and disadvantages (20).

Table 2: Contents of Th, U and RE in Monazite from Different Countries (18)

Country	ThO_2	U_3O_8	$(RE)_2O_3$
India	8.9	0.35	59.4
Brazil	5.5	0.20	59.2
USA	3.1	0.47	40.7
South Africa	5.9	0.12	46.4
Malaysia	6.0	0.15	46.2
Korea	5.5	0.34	65.0
Italy	11.34	-	35.2
Sri Lanka	14.3	0.10	53.5

ARE had adopted the permanent disposal method for the management of its radioactive residue. Permanent disposal methods are categorized as the dilute and disperse method, and the disposal site identified for the ARE residues was the LTSF site on Kledang range (Figure 6). Two categories of radioactive residues were identified; the first being thorium hydroxide residue. The thorium residue from ARE was analysed for its thorium, uranium and RE contents, which showed a thorium content of 32.0 to 33.5% of ThO_2, 1.1 to 1.4% of U_3O_8, and 27 to 28% of unrecovered RE (22).

It was estimated that there are about 80,000 tons of this residues stored at the LTSF. The second category of residues that need to be disposed is the radioactive contaminated materials from the related equipment and building that had been contaminated, and also land used for the ARE plant. Two different engineering cells were built at the LTSF site for the purpose of burying these radioactive residues. Prior to transportation of the residues to the designated location, decontamination and decommission works were done on the building material and land, where the plant was located. The selection of suitable material used took into account the possible radionuclide radiation exposure pathways that could minimize the impact of radionuclide contamination to water and food cycles. These included the possible radionuclide being contaminated into the surface and ground water systems in the sub-surface as well as possible release of dust particles and radon gas into the atmosphere. Another possible pathway that was taken into account was the possibility for the retrieval of this radioactive material via external factors, including human encroachment. In the ARE case, different layers were laid surrounding the radioactive residues to minimize the five pathways mentioned earlier. The thorium hydroxide was stabilised into a concrete box to reduce its possibility of contaminating the ground water. At the moment, almost 90% of thorium hydroxide residues in ARE had been conditioned and emplaced in the Engineered Cell. The residue was conditioned by means of cementing, which has made the thorium irrecoverable. Thus, the Thorium residue produced by ARE cannot be recovered and utilized any further (22).

There are also several disadvantages of using this option for NORM residues management, amongst it is the high cost required, and the need for continuous monitoring and safeguard of the site.

Figure 6. Part of the permanent engineering cell built at the LTSF site.

Another dilute and disperse approach is to mix the residues with uncontaminated material until the radionuclide concentration reaches a level where it can be released directly to the environment without adverse impacts. Lynas is looking at the possibility of using this technique in the management of its radioactive residue (23). The company hopes to dilute the radioactivity of the residue from 6 Bq/g to the AELB permissible limit of 1 Bq/g. The low radioactivity product will then be turned into basement aggregate for road construction purposes.

The method, however, has a disadvantage of creating a large volume of aggregate that needs to be utilized in lieu of the large dilution factor required. Another important factor that needs to be taken into account is the immobility of thorium in the aggregate material.

2.5 Areas of RE R&D

2.5.1 Management of Radioactive Residues

The safe management of radioactive residues produced from RE cracking plants is one of the important issues to be managed in the Malaysian RE industry. R&D on this topic is based on both the `concentrate and contain' or 'dilute and disperse' approaches. Malaysia had embarked in joint research with other countries to look into the possibility of using residues produced by the RE industry in the production of fuels for a nuclear power programme. The project carried out by the Malaysian Nuclear Agency is supported by the International Atomic Energy Agency (IAEA) (27). For the dilute and disperse approach, research had been carried out to minimize the volume of the diluted residues. One of the methods used was by utilizing a specially synthesized chemical that is capable of selectively bonding to thorium and produce a lower residues volume.

2.5.2 Removal of radioactive elements from rare earth minerals prior the cracking process

Reducing the naturally-occurring radioactive elements in RE minerals is something that should also be looked into. Similar work had been done on zircon, ilmenite and radioactive contaminated soil (28, 29, 30, 31, 32, 33, 34). The treatment enables the production of a higher quality mineral with lower radioactive content using the selective-leaching technique. Previous studies on this subject have used selective leaching method for the purpose of removing the NORM. As shown in Table 3, common chemicals used for this purpose are commercial acid or alkaline. Meor Yusoff (35) from the Malaysian Nuclear Agency had patented a process for the reduction of these radioactive elements by using a leaching solution comprises of recycled carbide residues obtained from acetylene plants. The use of this new leaching enables save costs in the process as the leaching solution contributes to a significant amount of the operating cost.

Table 3: Leaching System Used for Selective Leaching of Th and U

Author/Organization/Year	Leaching System	Sample
Hollit M.J. and Micheal, 1995 (28)	Alkaline Hydroxide	Zirconium Minerals
Eyal et al, 1990 (29)	Carbonate-bicarbonate	Heavy Minerals
Los Alamos, USA, 1993 (30)	HCl	Contaminated Soils
ANSTO, Australia, 1993 (31)	Commercial acids and alkaline	Zircon, Ilmenite,and related minerals
Wimmera Ind. Mineral, Australia, 1993 (32)	Acids and alkaline	Zircon and Ilmenite
CSIRO, Australia, 1994 (33)	Did not disclose	Zircon
Brookhaven National Lab, USA, 1994 (34)	Citric Acid	Contaminated Soils
Meor Yusoff, 2008 (35)	Carbide residues	Zircon, ilmenite

2.5.3 Recovery of RE

Hydrometallurgy is the most common method used in the recovery of RE from minerals and residues. On top of the caustic soda dissolution method used for the cracking process, research had also been done on using alkaline fusion for the same purpose. The use of alkaline fusion is advantageous due to the fact that the need for dilute acid to be used to dissolve RE. Other RE recovery methods that were analyzed includes pyrometallurgy, electrometallurgy, and dry process extraction using hydrogen gas. Research has also been done on recycling rare earth from electronic residues, which includes phosphor lights, magnets, and batteries. Other than electronic residues, research had also been conducted on the recovery of RE from the RE processing industry. Malaysian Nuclear Agency had carried out research regarding the recovery of light and heavy RE from thorium hydroxide residues of ARE (36). Studies have also been done in stripping and recovering RE that is found in the contaminated radioactive organic residues from the ARE (37).

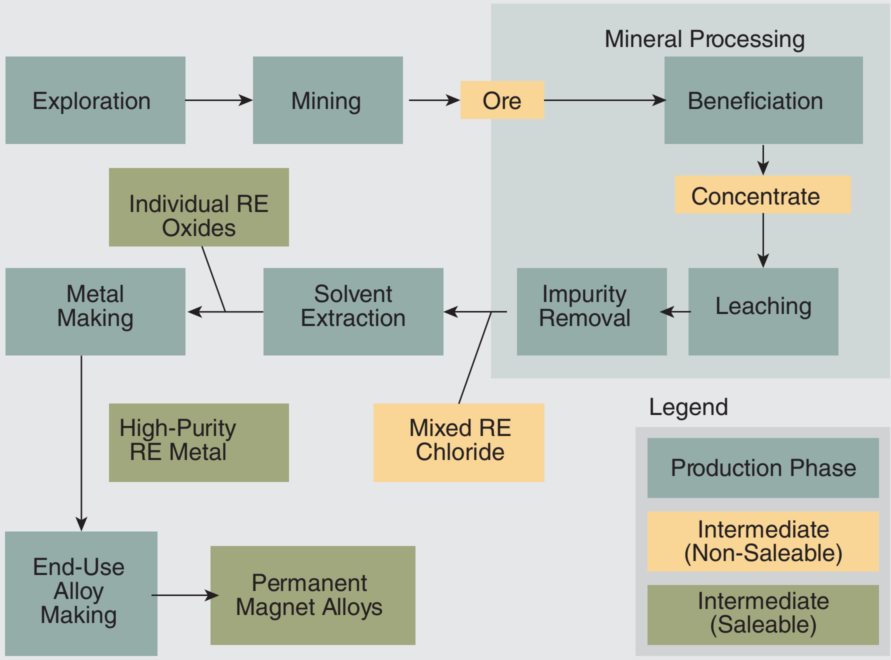
2.5.4 Separation and Purification

Figure 7 shows a more detailed diagram of rare earth processing that deals with metal alloy production which was shown earlier in Figure 1.

In recent years, one of the main challenges of R&D in this area is to improve separation and processing of critical materials. Typically, the current traditional separation technologies are inefficient and unsustainable. Usage of harsh solvents and reagents together with long processing times and high capital cost contribute to this problem. In relation to this, Department of Energy, USA, has initiated several important projects through its national laboratories in improving the separation and purification processes which look at alternatives to the more usual solvent extraction processes.

In addition to the typical solvent extractions, there are several alternative separation techniques being developed. Among them are:

- supercritical fluid extraction,
- biologically inspired approaches,
- ion exchange techniques,



Source: www.gwmg.ca (downloaded on 8 Oct 2014)

Figure 7. Generalized Phases of Rare Earth Processing for Magnet Alloy Production

- redox manipulation,
- crystallization
- electrochemistry

Here are excerpts from the report "Critical Metals Strategy" by Department of Energy in 2011 to illustrate the new initiatives through 3 examples:

1) Supercritical fluid extraction: Several national laboratories are exploring supercritical carbon dioxide (SC CO_2) extraction. A supercritical fluid is a substance at a temperature and pressure above its critical point. In this methodology, the rare earth material (such as an ore) is dissolved in an acid. The dissolved rare earth is contacted with SC CO_2 that contains an extractant. This creates two phases: the acid phase and the SC CO_2 phase. The rare earth metal binds with the extractant and remains in the SC CO_2. The two phases can be separated and the rare earth metal can be isolated by removing the CO_2 (by reducing the pressure or temperature) (Shimizu 2005; Peterson 2011).

2) Biologically Inspired Approaches: Biologically inspired processes are being examined by several organizations. Several academic studies have demonstrated the use of bacteria to concentrate rare earth metals from dilute solutions. One study examined the adsorption of REEs onto bacterial cell walls (Takahashi 2005). In acidic solutions, from an initial concentration of 100 micrograms of an REE mixture per liter, the bacteria preferentially adsorbed REEs onto its cell surface, with europium and samarium seeing the highest enrichment.

3) Electrochemistry: Materials and Electrochemical Research Corporation (MER) received a Small Business Innovation Research (SBIR) 2010 Phase I award to develop an electrochemical route to convert rare earth ore into high-purity metals. Specifically, the work focused on producing refined neodymium oxide. The processing innovation developed in the work yields a magnetic material with a higher energy density. For the work, MER recently won an R&D 100 award. MER has also recently been awarded an SBIR Phase II award to further the R&D effort for the innovative technology.

The above initiatives are expected to contribute to improved separation and processing technologies which will be more efficient and more environmentally friendly. This will lead to lower cost and enhance supply diversification while reducing the impact of mining and processing.

It should be noted here that Technology Metals Research, LLC, of the USA, co-founded by Jack Lifton, has been awarded a contract by the US Dept of Defense to examine and rate the above technologies, among others, in development in the USA that could be used to increase the efficiency and speed of the separation of the rare earths. The results of this research will be available at the end of 2014. The focus of the TMR work is to determine not only the most efficient but also the lowest cost technologies for separating and purifying the rare earths (pers. communication).

3.0 CONCLUSION

For the case of Malaysia, many of these new techniques of separation and purification have been employed by researchers in research institutions and universities but applied to other applications except rare earth. In biotechnology and herbal extraction fields, these techniques are very common.

Therefore, in order to support the establishment of rare earth industry in Malaysia, we need to encourage these researchers to apply their methodology of the techniques in separating and purifying rare earth elements. Many of their developed skilled can be utilised with some modifications suited for rare earth processing. At the Rare Earth Research Center at UMP for example, work has been started to construct a modular pilot plant that can explore different strategies and configuration of those alternative separation and purification processes. In addition, several fundamental works has been initiated such as studying the matching of suitable combination of solvents for different types of rare earth oxides and also separation of rare earth elements using fluidization technique.

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DOWNST

TREAM SECTOR

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DOWNSTREAM SECTOR

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1.0 SUMMARY

In this chapter, an overview and analysis of some important rare earths-related applications and downstream industries have been presented. For each industry sector, an analysis on the various enabling factors has been carried out in context of Malaysia. Recommendations on the development of such sectors in Malaysia have also been made. In the following, a summary of the overall approach and strategy that Malaysia should adopt to develop such industry will be presented.

Rare Earth Related Downstream Industry, Technology and Research: The Way Forward

Overall, Malaysia has the following advantages for the development of rare earths-related downstream industries:

- Availability of certain rare earth oxides from a local rare earths processing plant.
- Existence of some local industries which are related and consuming rare earths as raw materials directly or indirectly through parts and components. For example, automobile, lightings, oil refining, etc.
- Potential supply of rare earths and other rare metals from untapped mineral deposits in the country.
- Existence of manufacturing experience, expertise, know-how and technical workforce in a wide range of industry sectors which can be adopted or adapted into some new rare earths-related industries.

However, we have certain weaknesses as follows.

- There is still lack of research work being carried out in rare earths application and related areas that can lead to commercial implementation. There is still a lack of IPs in such areas in Malaysia.
- There is still lack of human resource in R&D to support such kind of industrial development.

Therefore, the best strategy for Malaysia is to attract foreign companies to invest and start manufacturing plants in some rare earths-related downstream industries as presented above. Through such FDIs, we can jump start new industries and achieve technology transfer through the corresponding industrial operations. While doing so, the country should start to focus on R&D activities related to the industries. Related R&D projects should be started with the hope that the R&D manpower in the areas can be developed to support transition of the industries up their value chains. For R&D, a national research institute focusing on advanced materials should be set up. Such institutes have been set up overseas e.g. National Institute for Material Science (NIMS) of Japan, Korea Institute for Rare Metals (KIRAM) of South Korea, General Research Institute for Nonferrous Metals of China, etc. With such a national institute in Malaysia, we should be able to pool resources to focus on certain research areas of strategic importance to the industrial development of the nation.

2.0 INTRODUCTION

Rare earth elements are a group of seventeen elements in the periodic table. They are the lanthanide (consists of fifteen elements), scandium and yttrium. Over the years, numerous unique applications of these elements have been found. In many of these applications, rare earth elements are used because of their unique chemical or physical characteristics and properties of which alternatives have been scarce. This is the main reason why rare earth elements have become so strategically important to many industries and countries.

Lanthanide elements have unique electronic structure whereby when they form compounds where the ions involved have loss of outer orbital electrons (6s) and this leaves the inner orbital electrons (4f) left 'buried' inside the atoms shielded from the atoms' environment by other orbital electrons (4d and 5p). As a result of this, the chemistry of the elements is largely determined by their atom size. [1]

All lanthanide ions (except Lu3+, Yb3+ and Ce 4+) are paramagnetic. This is mainly due to the unpaired 4f orbitals lying too deep in the atoms which results in magnetic moment contributed by orbital electrons not able to interact and quenched by the electric fields of the environment. [2]

Due to their unique chemical and physical properties described above rare earth elements have been applied in some industry processes, equipment and consumer products. A list of some of the major applications of rare earth elements is given in Table 1.

Table 1. Some important applications of rare earth elements

Z	Symbol	Element	Applications	Usage level	Other info.
21	Sc	Scandium	• Additive in metal-halide lamps and mercury-vapor lamps [3][4]	• Moderate: the adoption of the application in products. • High: the adoption of the element in the application • Low: material quantity used in the application.	Key industrial players: GE, OSRAM, Phillips
39	Y	Yttrium	• Energy-efficient light bulbs [5][6]	• Moderate: the adoption of the application in products. • High: the adoption of the element in the application • Low: material quantity used in the application.	Key industrial players: Philips, Osram.
57	La	Lanthanum*	• High refractive index and alkali-resistant glass, camera lenses, lanthanum flint glass [7][8]	• High: the adoption of the application in products. • High: the adoption of the element in the application • Low: material quantity used in the application.	Key industrial players: Canon, Nikon, Corning, Zeiss, Hoya, etc.
			• Battery-electrodes (NiMH battery) [9][10][11]	• High: the adoption of the application in products (HEV). • High: the adoption of the element in the application • Moderate: material quantity used in the application.	Key industrial players: Toyota, Honda, Panasonic, NEC, etc.
			• Fluid catalytic cracking catalyst for oil refineries [12][13]	• High: the adoption of the application in products (petrochemical industry). • High: the adoption of the element in the application • Low to moderate: material quantity used in the application.	BASF, Sinopec, Advanced Refining Technologies (Grace-Chevron), Albemarle etc. [14]

58	Ce	Cerium*	• Polishing powder / abrasive [15][16][17]	• High: the adoption of the application in products (glass polishing). • High: the adoption of the element in the application • High: material quantity used in the application.	There are many suppliers especially from China (due to local supply of rare earth oxides).
			• Fluid catalytic cracking catalyst for oil refineries [18][19]	• High: the adoption of the application in products (petrochemical industry). • High: the adoption of the element in the application • Low to moderate: material quantity used in the application.	BASF, Sinopec, Advanced Refining Technologies (Grace-Chevron), Albemarle etc. [14]
59	Pr	Praseodymium	• Rare-earth magnets [20][21]	• High: the adoption of the application in products (high-performance permanent magnets). • Moderate: the adoption of the element in the application • Moderate: material quantity used in the application.	Rare earth magnet production is a relatively specialized area where there are different manufacturers with different product specifications. China manufacturers have emerged to be a major supply source in recent years.
60	Nd	Neodymium*	• Rare-earth magnets [22][23][24]	• High: the adoption of the application in products (high-performance permanent magnets). • High: the adoption of the element in the application • High: material quantity used in the application.	Rare earth magnet production is a relatively specialized area where there are different manufacturers with different product specifications. China manufacturers have emerged to be a major supply source in recent years.
62	Sm	Samarium	• Rare-earth magnets [25]	• Moderate: the adoption of the application in products (high temperature operating environment) • Moderate: the adoption of the element in the application • Low: material quantity used in the application.	Rare earth magnet production is a relatively specialized area where there are different manufacturers with different product specifications. China manufacturers have emerged to be a major supply source in recent years.

63	Eu	Europium	• Red and blue phosphors, Fluorescent lamps [26][27][28]	• High: the adoption of the application in products (divalent europium blue phosphors and trivalent europium red phosphors are used with terbium “green” phosphors to provide the “trichromatic” lighting technology) • High: the adoption of the element in the application • Moderate: material quantity used in the application.	Fluorescent lamps are increasingly used for lighting due to their higher energy efficiencies. Key players: Osram, Philips, etc. In recent years, production of the product in China has increased significantly due to rare earth supply.
65	Tb	Terbium	• Green phosphors, Fluorescent lamps [29][30]	• High: the adoption of the application in products (terbium “green” phosphors are used with divalent europium blue phosphors and trivalent europium red phosphors to provide the “trichromatic” lighting technology) • High: the adoption of the element in the application • Moderate: material quantity used in the application	Fluorescent lamps are increasingly used for lighting due to their higher energy efficiencies. Key players: Osram, Philips, etc. In recent years, production of the product in China has increased significantly due to rare earth supply.
66	Dy	Dysprosium	• Rare-earth magnets	• High: the adoption of the application in products (NdFeB magnets in electrical and hybrid vehicles) • High: the adoption of the element in the application (applied in NdFeB replacing Nd at about 6% to enhance coercivity) • High: material quantity used in the application.	Rare earth magnet production is a relatively specialized area where there are different manufacturers with different product specifications. China manufacturers have emerged to be a major supply source in recent years.
68	Er	Erbium	• Fiber-optic technology [32]	• Moderate: the adoption of the application in products (Erbium doped fiber amplifier [EDFA] is the most commonly used optical amplifier used in telecommunications) • High: the adoption of the element in the application • Low: material quantity used in the application	This is a niche area application. Key players such as Finisar, etc. have operation in Malaysia.

3.0 RARE EARTHS-RELATED TECHNOLOGY AND INDUSTRY

Some of the uses of rare earth elements have been in place for long time while others are relatively recent. Many of the industries using rare earth elements are considered as high-technology industries where much of the know-how has been protected as IPs or trade secrets.

For a developing country like Malaysia to develop rare earths-related downstream industries, a well thought-through strategy and plan have to be devised and implemented with full commitment. This chapter intends to provide some information, analyses and recommendations on the strategy and plan that Malaysia should pursue if the rare earths-related industries is to be ventured into.

Certain criteria have been set to determine the application areas of rare earth that Malaysia should focus on in developing its rare earths-related downstream industries. They are as follows.

C1. Market size and potential – areas which have medium or large economic values naturally attract more attention from industry and investors.

C2. Existing related industries – areas in which there are local related industries should attract more attention because these industries may serve as suppliers, customers or complementary industries to the intended rare earths industries.

C3. Competency in local industry, universities and research institutions which may be applicable directly or indirectly to rare earth related downstream industry – high level of such competency locally would be beneficial to the development of the industry.

C4. Local supply or easy access of raw materials (e.g. rare earth metal oxides, etc.) for industry.

Based on the above criteria the following areas in Table 2 have been identified.

Table 2. Analysis on industries of some important rare earth related applications

Application areas of rare earths	C1 (Market)	C2 (Related industries)	C3 (Local competency)	C4 (Raw materials)
Magnets	H	M	M	H
Batteries	H	M	M	H
Lighting	H	M	M	M
Catalysts	H	H	M	H
Glass / lens / polishing powder	H	M	M	H

H – High, M – Medium, L – Low

Technology, industry and research are closely interrelated to each other. As a medium size developing country, Malaysia needs to be selective in spending its resources on research and technology development. Such effort should be highly oriented towards optimum socio-economic impact to the country.

The same applied to the emerging green technology area related to rare earth. In this chapter an attempt is made to analyse the current research and technological development in some selected application areas related to rare earth. Recommendations will in turn be made on how the related industry can be initiated or further developed.

Being a developing country that is still playing a catching-up role as far as research and technology development are concerned we should approach R&D not only to develop new knowledge frontier but more importantly as a platform to develop human resources needed for the related industries to be established or further developed here especially those involving higher value-added activities.

In the following sub-sections, coverage on selected application areas of rare earths, related industries (listed in Table 2) and recommended approach and strategy for Malaysia will be presented. In each sub-section, an overview of an application area and the technology development and research involved followed by recommendation on approach and strategy that can be pursued by Malaysia will be presented.

3.1 Permanent Magnets

Lanthanide elements (except Lu, Yb and Ce) are paramagnetic due to their partially occupied f electron shells which contain unpaired electrons that are too deep in the orbits which experience little cancellation of their magnetic moment by interaction with electric fields of the environment. The spin of these electrons when aligned can produce very strong magnetic fields. They thus make up high-strength compact magnets. The most common types of rare-earth magnets are samarium-cobalt (SmCo) and neodymium-iron-boron (NdFeB) magnets.

Rare earths-based magnets are magnets which have significantly higher energy densities compared to other types of magnets. These high-performance magnets have found important usage in many applications. Among them are compact high-performance motors in hard disks, vehicles / cars, etc. Also, such magnets are widely used in wind turbines and compact speakers in handheld gadgets and devices like mobile phones. Demand for such magnets has been on a steep rise in recent years mainly due to the global trend of increasing use of smart phones and tablets, hybrid and electric cars and wind power generators.

3.1.1 Rare Earths-Based Magnets: Properties and Fabrication

For NdFeB magnets besides neodymium (Nd) other rare earth elements may be added to enhance certain properties of the magnets e.g. dysprosium (Dy) and praseodymium (Pr) are added in place of some neodymium to improve the corrosion resistance and to improve the intrinsic coercivity of the magnets. An example of NdFeB magnet composition is given in Table 3.

Table 3. An example of the ingredients of NdFeB magnet [33]

Elements	Percentage by weight (%)
Neodymium (Nd)	29% - 32%
Iron (Fe)	64% - 68%
Boron (B)	1% - 2%
Aluminum (Al)	0.2% - 0.4%
Niobium (Nb)	0.5% - 1%
Dysprosium (Dy)	0.8% - 1.2%

A permanent magnet material is normally characterized by its maximum energy density (BH_{max}) which is the product of remanence (B) and coercivity (H). Remanence is the magnetization left behind in a ferromagnetic material after an external magnetic field is removed. Coercivity of a ferromagnetic material is the intensity of the applied magnetic field required to reduce the magnetization of that material to zero after the magnetization of the sample has been driven to saturation. Fig. 1 shows the evolution of maximum energy density of various ferromagnetic materials [33].

Research has been focused mainly to increase the coercivity (H) by adjusting the alloy composition and by producing better microstructures (smaller grain size results in higher coercivity). A high residual induction may be achieved by producing small crystallites and aligning them perfectly parallel to gain the best anisotropy.

Rare earths-based magnetic materials have thus far been shown to exhibit higher energy density compared to other types of material (Fig. 2) [33].

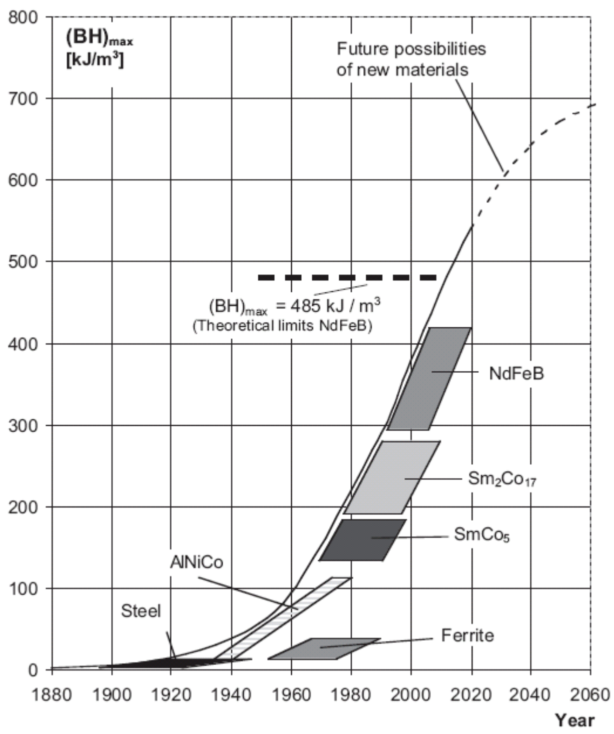


Figure 1. Evolution of the maximum energy densities of permanent magnets [33]

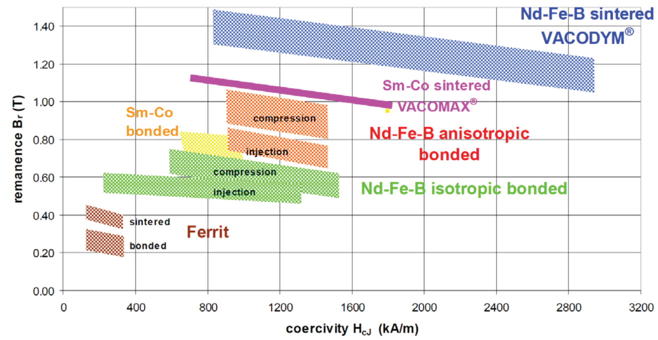


Figure 2. Energy densities of different magnetic materials [33]

For a long time, permanent magnets have been adopted in many different applications, ranging from magnetic tape, cassettes, hard disks for data storage to wind turbine, electric motors for hybrid and electrical vehicles.

Fig. 3 illustrates fabrication process of rare earths-based magnets [34].

Rare earths-based magnet fabrication consists of the following major aspects:

- Chemical composition of alloys used as magnet material
- The mechanical and machining techniques used in each stage of the fabrication process above

The important know-how and IP involved are mainly in the formulation of the alloy composition and the combination of techniques and processes in each stage of the fabrication. This is usually the result of R&D carried out by companies and research institutions.

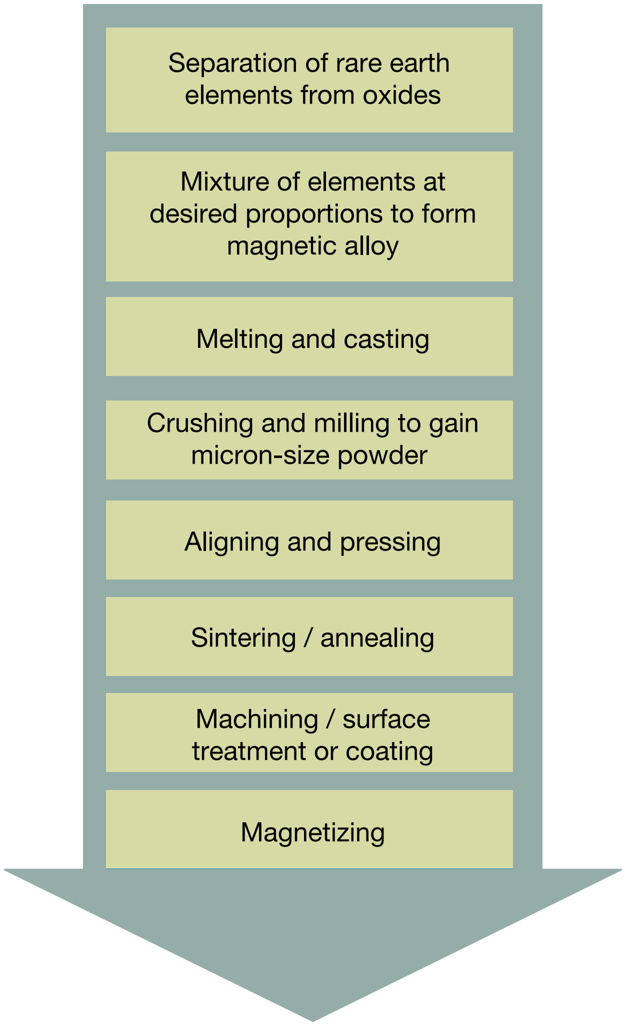


Figure. 3 Fabrication process of rare earths-based magnets [34]

3.1.2 Rare Earths-Based Magnets: Major Applications

Rare earths-based magnets are widely used in the following applications:

- Hybrid and electric vehicles' motors / generators
- Wind turbines
- Hard disk motors
- Miniature speakers in electronic appliances including mobile phones, tablets, laptops, earphones, etc.

Most of the above applications are currently rising fast in terms of demand for high-performance permanent magnets mainly due to the global trend in lifestyle, energy and environment conservation. One emerging trend which is going to have high impact on the demand and utilization of rare earths in permanent magnets is the increasing adoption of hybrid and electric vehicles by the public especially in developed and some developing countries including Malaysia.

3.1.3 Rare Earths-Based Magnets: Hybrid and Electric Cars

Generally, there are two major types of vehicles that are electrically driven.

- Hybrid electric vehicle (HEV)
- Electric vehicle (EV)

The adoption of hybrid personal vehicles is still small globally. In the USA, the adoption rate was about 3% of new cars in 2012 and while in Japan it was 17% of new cars in 2011 [35][36].

Various forecasts have been made on the market size of HEVs and EVs. One example is the forecast made by Exxon Mobil as shown in Fig. 4. It is estimated that HEVs and EVs will make up close to 50% of global car sales by 2040. Generally, HEVs and EVs sales have been growing at an accelerating rate in the past few years and the growth rate is expected to go even higher in future. Along with the growth of the adoption of HEVs and EVs is the growth in demand for high performance, compact permanent magnets which are thus far been mostly rare earths-based magnets [37].

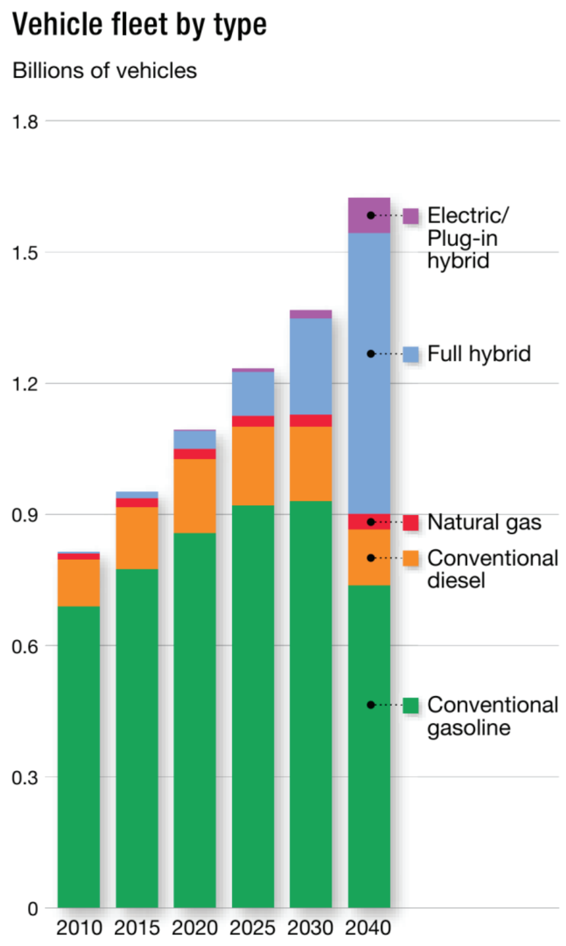


Figure. 4 A forecast on the vehicle types and quantities (year 2010 – 2040) [37]

It is estimated that each conventional car uses about 400g of rare earth elements for its magnets while each HEV uses about 1kg of rare earth elements for its magnets, especially those in the electric motor. Supply of rare earth elements i.e. neodymium (Nd) and dysprosium (Dy), is therefore critical for the magnet and HEV and EV industry based on the current technology developed in the industry. Malaysia, with its rare earths processing plant already operational, would have advantage in this respect [38].

Another component of HEV and EV that is closely related to rare earth elements is the battery. This will be discussed in details in the next section.

3.1.4 Rare Earths-Based Magnets: Recommendations on R&D and Technology Development

Malaysia should explore the possibility of developing high-performance permanent magnet industry due to the following reasons:

- Supply of key rare earth elements which are crucial for the fabrication of high-performance compact magnets especially neodymium (Nd) from the local rare earth processing plant.
- Demand for such magnets is growing rapidly in the automobile industry due to increasing adoption of HEVs and EVs.
- Established local automobile industry will have fast increasing demand for such magnets in the production of HEVs' and EVs' electric motors.

As the industry is relatively new in Malaysia the following strategy should be adopted.

- Foreign direct investment (FDI) by global key players to set up high-performance magnet fabrication plants in Malaysia should be targeted by the Malaysian Investment Development Authority (MIDA).
- Enhance the undergraduate programme in material science, metallurgy, manufacturing engineering such that students are trained in areas relevant to the industry and ready to meet the human resource needs of such industry.
- Encourage or set up more R&D projects related to high-performance magnetic material composition and fabrication process such that more research manpower relevant to the industry can be produced and thus supporting the industry to move up to higher value-added activities such as R&D.

3.2 Battery

3.2.1 Battery: Use in Vehicles

In this section, we are primarily focused on heavy-duty batteries used in HEVs and EVs to drive the vehicles. For such vehicles, a rare earths-bearing type of battery used is the nickel metal-hydride (NiMH) battery. Battery technologies used currently by automobile manufacturers are listed in Table 4 [39].

3.2.2 Nickel metal-hydride (NiMH) battery

NiMH battery is a type of rechargeable battery. It uses positive electrodes made of nickel oxyhydroxide (NiOOH), similar to nickel–cadmium cell (NiCd), but its negative electrodes are made of a hydrogen-absorbing alloy compared to cadmium in the case of NiCd cells. The energy density of NiMH battery is a few times higher than equivalent sized NiCd cells.

The energy density of NiMH battery depends on the hydrogen storage capacity of the negative electrodes. The materials used for the alloy is the key factor. Thus far, the most common alloy materials are based on the AB_5 type where A is a rare earth mixture of lanthanum, cerium, neodymium, praseodymium and B is nickel, cobalt, manganese, and/or aluminium [40][41][42].

3.2.3 NiMH and Li-ion Battery: Comparison

A simple comparison between NiMH and Li-ion batteries for use in HEVs and EVs is given in Table 5. [45]

Table 4. Battery technologies for HEVs and EVs adopted by automobile companies [39].

Company	Country	Vehicle Model	Battery Technology
GM	USA	Chevy-Volt Saturn Vue Hybrid	Li-ion NiMH
Ford	USA	Escape, Fusion, MKZ HEV Escape PHEV	NiMH Li-ion
Toyota	Japan	Prius, Lexus	NiMH
Honda	Japan	Civic, Insight	NiMH
Hyundai	South Korea	Sonata	Lithium polymer
Chrysler	USA	Chrysler 200C EV	Li-on
BMW	Germany	X6 Mini E (2012)	NiMH Li-on
BYD	China	E6	Li-on
Daimler Benz	Germany	ML450, S400 Smart EV (2010)	NiMH Li-on
Mitsubitshi	Japan	iMiEV (2010)	Li-on
Nissan	Japan	Altima Leaf EV (2010)	NiMH Li-on
Tesla	USA	Roadster (2009)	Li-on
Think	Norway	Think EV	Li-on, Sodium/Metal Chloride

Table 5. A comparison between NiMH and Li-ion batteries for use in HEVs and EVs [45]

	NiMH	Li-ion
Energy density	Lower	Higher
Operating temperature	Can operate at higher temperature	Need lower temperature for operation
Technology maturity	Higher	Lower
Manufacturing maturity	Higher	Lower
Cost of production	Lower	Higher

Although the major automobile manufacturers, such as Toyota and Honda, are still producing most of their HEVs with NiMH batteries thus far, it is anticipated that a gradual shift to Li-ion battery will happen soon as the technology, manufacturing and cost of production improve. The main reason is that the higher energy density of Li-ion battery enables HEVs and EVs to increase their range for the same battery capacity and charge. [46]

3.2.4 Fuel Cell

Another battery technology that has a high potential to be used in HEVs and EVs is the fuel cell. A fuel cell operates based on the chemical reaction between a fuel and oxygen in which the chemical energy of the fuel is converted into electricity. Hydrogen is the most common fuel. Fuel cells are different from batteries as they require a constant supply of fuel and oxygen for the chemical reaction to be sustained.

Most of major auto manufacturers have researched into fuel cells and their application in EVs. Active and intense R&D on the topic is ongoing and it is anticipated that fuel cell-powered EVs will be commercially available in the next few years. Yttria-stabilized zirconia (YSZ) is one of the most commonly used electrolyte materials in fuel cells and such material is produced using yttrium oxide as stabilizer. [47]

3.2.5 Recommendations on R&D and Technology Development for Battery used in HEVs and EVs

Malaysia should explore into the development of HEV and EV battery industry due to the following reasons.

- Established local automobile industry which will have fast increasing demand for compact high performance batteries for HEVs and EVs.
- Local supply of key elements used in NiMH battery from local rare earth processing plant (especially lanthanum and cerium).

As the industry is relatively new in Malaysia the following strategy should be adopted.

- Foreign direct investment (FDI) by global key players to set up HEV / EV battery fabrication plants in Malaysia should be targeted by MIDA.
- Enhance university undergraduate programmes in material science / engineering and chemistry such that students are trained in areas relevant to the industry and thus the human resource needs of such industry can be supported.
- Encourage or set up more R&D projects related to material composition and fabrication process of the different battery types such that more research manpower relevant to the industry can be produced and thus supporting the industry to move up the value chain to carry out R&D in Malaysia.

3.3 Lighting

3.3.1 Lighting Technology, Usage and Industry: An Overview

A phosphor, a material used in lighting technology, is a substance that exhibits luminescence. Luminescence is the emission of light by a substance not due to heat. It is caused by some other reasons such as chemical reactions, electrical energy, subatomic motions, or stress on a crystal. Emission of light due to heat is called incandescence.

Phosphors include phosphorescent materials (show slow decay in brightness, longer than 1ms) and fluorescent materials (emission decays last over tens of ns). Phosphorescent materials are used in radar screens and glow-in-the-dark toys. Fluorescent materials are used in cathode ray tube (CRT) and plasma display screens, sensors and white light-emitting diodes (LEDs). Phosphors are usually transition metal or rare earth compounds. [48]

Phosphors normally consist of a suitable host material with an added activator. An inorganic phosphor luminesces at emission centers where inhomogeneities in the crystal structure of host material are created usually by addition of a trace amount of dopants or activators. The wavelength emitted by the emission center is dependent on the atom itself, and the surrounding crystal structure. Not all phosphors contain REEs, but many do.

The host materials are typically oxides, nitrides and oxynitrides, sulphides, selenides, halides or silicates of zinc, cadmium, manganese, aluminium, silicon, or various rare earth metals. Common materials for activators are copper, silver, europium, cerium and thallium. [49]

The world consumption of rare earth oxides for phosphors is given in Fig. 5. In 2008, 9,000t of REOs was used in making phosphors, of which yttrium oxide contributed 69 percent; cerium oxide, 11 percent; lanthanum oxide, 8.5 percent; europium oxide, 4.9 percent; terbium oxide, 4.6 percent; and gadolinium oxide, 1.8 percent. [50]

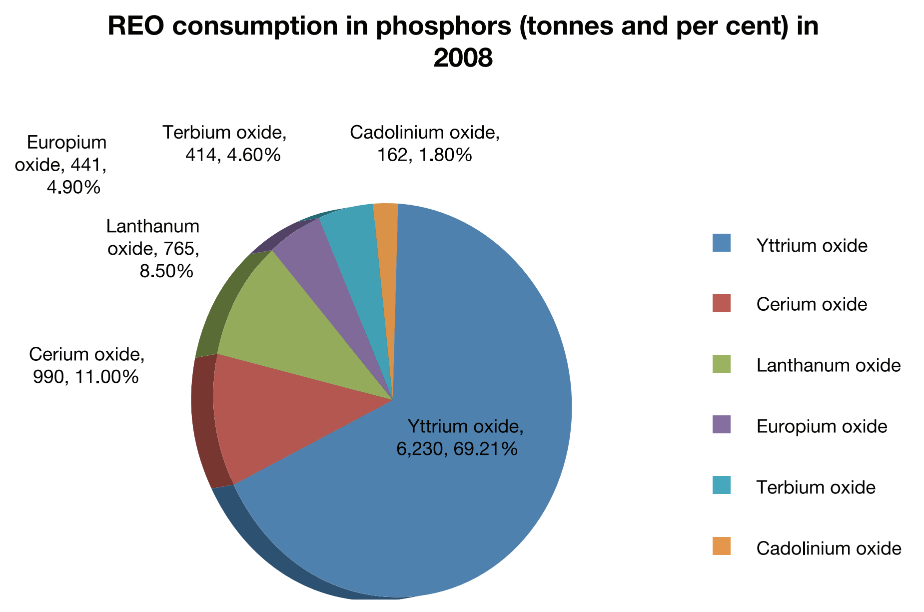


Figure 5. Rare earth consumption in phosphors (year 2008)

Lighting is one of the major applications that consume energy. It consumes up to 19% of global electricity in 2005 [51]. The low energy-efficient incandescent light bulbs are still in widespread use in the United States and many parts of the world today.

However, today modern technologies provide opportunities to significantly reduce energy demand from lighting. Some countries have introduced rules, regulation and programmes that restrict or discourage the production and usage of incandescent light bulbs. Globally, there is gradual movement towards energy saving through the adoption of energy-efficient lightings. Energy-efficient lightings, such as compact fluorescent lights (CFL) and light emitting diodes (LED), are now gradually replacing the traditional incandescent light bulbs globally. Table 6 illustrates the energy efficiencies of various lighting lamps [52].

Table 6. Energy efficiencies of various lighting lamps [52]

Type of lamp	Efficiency (lumens/watt)	Typical lifespan (hours)
Incandescent	10 – 17	750 – 2,500
Fluorescent tube lamp	30 – 100	7,000 – 24,000
Compact fluorescent lamp (CFL)	50 – 70	8,000 – 10,000
LED (phosphor based)	50 – 100	50,000

Currently, demand for fluorescent lights is growing rapidly worldwide. In the coming years, other energy-efficient lighting alternatives, such as LEDs and halogen incandescent lights, will grow in usage as well and these are likely to replace fluorescent lights in certain applications.

Production of fluorescent light bulbs involves phosphors made from terbium, europium and yttrium. Thus, demand for these rare earth elements is currently high in the lighting industry. In fact, there has been concern in the industry on the supply adequacy of these elements. However, as other lighting alternatives are adopted more widely, the demand for rare earth elements from the industry may subside as these alternatives require either less or no rare earth elements in their production. For example, LEDs use much less rare earth contents than fluorescent light bulbs, while organic light-emitting diodes (OLEDs) and halogen incandescent use no rare earths. In addition to that, demand for rare earths in the lighting industry may also be relieved through phosphor recycling in future. Thus far, attempts have been made to recycle phosphors from used light bulbs.

3.3.2 Lighting Industry: Manufacturing

Malaysia currently has some lighting manufacturing plants. The major ones are operated by world industry leaders, such as Osram and Philips Lumileds.

Generally, the manufacturing process of compact fluorescent lamps (CFL) is not a high-tech process. The production consists of major four stages and is highly automated [53]:

1. Mount making
2. Glass tube preparation (including preparation of fluorescent powder, its coating onto the glass tube, oven heating and then cooling)
3. Base preparation
4. Assembly

Phosphor-based LED lights are made by assembling LED light bulbs in a glass coated with phosphors. Thus, there are similarities between the manufacturing process of CFL and phosphor-based LED lights. This is currently the most popular way of making LED lighting bulbs due to simplicity of making phosphors [54][55].

3.3.3 Recommendations on R&D and Technology Development for Lighting Industry

Malaysia should explore into the further development of lighting industry due to the following reasons.

- The existence of lights manufacturing plants in Malaysia e.g. Osram and Philips Lumileds.
- Local supply of key elements used in phosphors from local rare earth processing plant (especially lanthanum and cerium).
- Demand for energy-efficient lightings is expected to grow more rapidly as the less efficient incandescent light bulbs are being replaced

As the industry is relatively new in Malaysia the following strategy should be adopted.

- Foreign direct investment (FDI) by global key players to set up more CFL and LED bulb fabrication plants in Malaysia should be targeted by MIDA.
- Enhance the undergraduate programme in material science / engineering, chemistry, such that students are trained in areas relevant to the industry.
- Encourage or set up more R&D projects related to material composition and fabrication process of different phosphors such that more research manpower relevant to the industry can be produced and thus supporting the industry to move to higher value added activities such as R&D.

3.4 Catalysts

3.4.1 Fluid Catalytic Cracking (FCC) and the use of Rare Earths in Catalysts

In petroleum refining, the main objective is to process crude oil into more useful and valuable products such as petroleum naphtha, gasoline, diesel fuel, asphalt base, heating oil, kerosene, and liquefied petroleum gas. One key process in petroleum refineries is fluid catalytic cracking (FCC).

FCC basically converts high-temperature boiling and high-molecular weight hydrocarbon fractions of crude oils to more higher-valued gasoline, olefinic gases and other products. In FCC, crude oil with high boiling point (above 300 °C) and average molecular weight of 200 to 600 or higher is vaporized and thus broken into much shorter molecules through the contact with fluidized powdered catalyst. [56]

Rare earths are used in FCC as catalysts mainly because of the need for more active and hydrothermally stable products and better yield performance. This is achieved by rare earth oxides (REOs) through catalytic activity enhancement and prevention of loss of acid sites during operation. Lanthanum (La) and cerium (Ce) are the most commonly used rare earth elements in FCC catalysts.

Formulation and production of FCC catalysts is a relatively specialized industry. Manufacturers formulate catalysts with various compositions which include varying the levels of rare earths with the aim of optimizing performance in accordance to the operational severity, targets and product objectives of the refineries. The increase in demand for gasoline refiners has gradually increased the proportion of rare earths in the catalysts used over the years. By the end of 2010, catalysts used in FCC have averaged 3% rare earths content [57].

3.4.2 Fluid Catalytic Cracking (FCC) Catalysts Industry

FCC catalyst manufacturing is a relatively specialized industry. The industry is closely related to the oil industry. In recent years, due to global oil demand and supply trends, the world has witnessed closure of some FCC plants in Europe and North America but the opening of new ones in the Middle East and in the other parts of Asia (high-growth economies). It is estimated that the FCC catalyst market will grow at a rate of 3% per year and refineries faced with stricter environmental regulations and enforcement are under more pressure to source for high-performance catalysts (HPC) which normally contain higher rare earth contents [57][58].

Currently, there are few key players in the industry: BASF, Sinopec, Advanced Refining Technologies (Grace-Chevron), Albemarle, etc. Sinopec and other Chinese catalysts manufacturers have been enjoying the advantage of rare earths supply and thus price advantage over competitors outside of China, especially for the past few years when prices of rare earths were high. But, the advantage has been gradually diminishing. Non-Chinese manufacturers have been competing on technology by focusing on HPC.

With shale gas extraction and processing activities being rapidly developed in various parts of the world recently it is expected that these will boost ethylene margins, but severely cut propylene output. This will drive demand for more propylene output from FCC plants. Also, demand for diesel is expected to grow significantly in future. This provides challenges and opportunity for catalysts manufacturers. Catalyst manufacturers outside China have also been focusing on FCC catalysts with low or zero rare earths content in response to the high and uncertain prices of rare earths. Thus far, significant progress has been made on this. It is expected the trend and focus will continue in the industry. [59][60]

3.4.3 Recommendations on R&D and Technology Development for FCC catalyst industry

Malaysia should explore into the further development of FCC catalyst manufacturing industry due to the following reasons.

- Existence of well-established petrochemical industry especially oil refineries in Malaysia.

- Local supply of key elements used in FCC catalysts from local rare earth processing plant (especially lanthanum and cerium).

As the industry is relatively new in Malaysia the following strategy should be adopted.

- Foreign direct investment (FDI) by global key players to set up FCC catalyst manufacturing plant in Malaysia should be targeted by MIDA.

- Enhance the undergraduate programme in material science, chemistry, chemical engineering such that students are trained in areas relevant to the industry.

- Encourage or set up more R&D projects related to material composition and fabrication process of different FCC catalysts such that more research manpower relevant to the industry can be produced and thus supporting the industry to move to higher value added activities such as R&D.

3.5 Glass, Lens and Polishing Powder

3.5.1 Glass and lens

Optical glasses containing the oxides of rare earths such as lanthanum to impart a very high refractive Index combined with a low dispersive power. Such types of glass are normally doped with oxides of rare earth elements, such as lanthanum and cerium, are highly suitable for the fabrication of high-performance camera lenses.

Rare earth elements are also added into glass materials used to make glass filters. For example, filter glasses are made by doping samarium, holmium and neodymium oxides into the glass materials. [61]

3.5.2 Polishing powder

Cerium oxide is a widely used ingredient in glass polish powder. It is highly used in the making of high precision polishing powder which is used in many industrial sectors, in particular glass and lens manufacturing, gemstones carving and polishing, wafer polishing, etc. An alternative to this is the aluminium oxide-based polishing powder.

Making of the polishing powder is not a high technology industry. Many of the suppliers are from China, probably due to the large quantity and low cost supply of cerium oxide locally. [62][63]

Malaysia has some industries that use substantial amount of high-precision polishing powder. For example, wafer processing, solar cell manufacturing, glass lens production plants.

3.5.3 Recommendations on R&D and Technology Development for Glass, Lens and Polishing Powder Industry

Malaysia should explore into the further development of glass / lens / polishing powder industry due to the following reasons.

- Existence of some local industries which are using substantial amount of polishing powder in Malaysia.
- Local supply of key elements used in high refractive index, performance glass and lenses and polishing powder from local rare earth processing plant (especially lanthanum and cerium).

As the industry is relatively new in Malaysia the following strategy should be adopted.

- Foreign direct investment (FDI) by global key players to set up glass, lens and polishing powder plants in Malaysia should be targeted by MITI.
- Enhance the undergraduate programme in material science / engineering, optics, such that students are trained in areas relevant to the industry.
- Encourage or set up more R&D projects related to material composition and fabrication process of high refractive index, performance glass and lenses and polishing powder such that more research manpower relevant to the industry can be produced and thus supporting the industry to move to higher value added activities such as R&D.

3.6 Rare Metal Recycling

3.6.1 Rare metal recycling: the global trend and need

Demand for metals correlates strongly with per capita gross domestic product (GDP). The demand increases in developing countries due to industrialization. Demand grows in developed countries due to the development of metal-intensive technology and products which are essential in meeting the needs of modern lifestyles. If the emerging economies adopt the similar lifestyles as in OECD countries the global metal demand would be 3 to 9 times larger all the metals currently used in the world. Taking into consideration the long-term growth trend in population and prosperity, the global stock of metals in-use is expected to be 5 to 10 times of today's level. [64]

The increasing worldwide stock of metals in-use has become too significant in quantity to be ignored in metal production. Therefore, 'urban mining' will be a significant part of future metal production. Besides the quantity factor such trend is expected to intensify due to other factors as follows.

- Supply from mining activities: supplies of metals from the natural sources are subjected to various uncertainties and the long term declining mineral deposits which may result in supply disruption, increased cost, etc. This is especially true for some rare metals e.g. rare earth elements.

- Sustainability of metal production: mining, ore processing and metal extraction activities consume significant energy. Metal production constitutes about 8% of global energy consumption and thus similar percentage in terms of fossil-fuel related carbon dioxide (CO_2) emissions. Recycling can reduce the ‘footprint’ is carried out properly. It is less energy-consuming to re-melt and extract metals from end-of-life products than the conventional metal production. Besides energy consumption, other environmental impacts e.g. water usage, residues, processing and discharge, etc. may be less in metal recycling than the conventional production process.

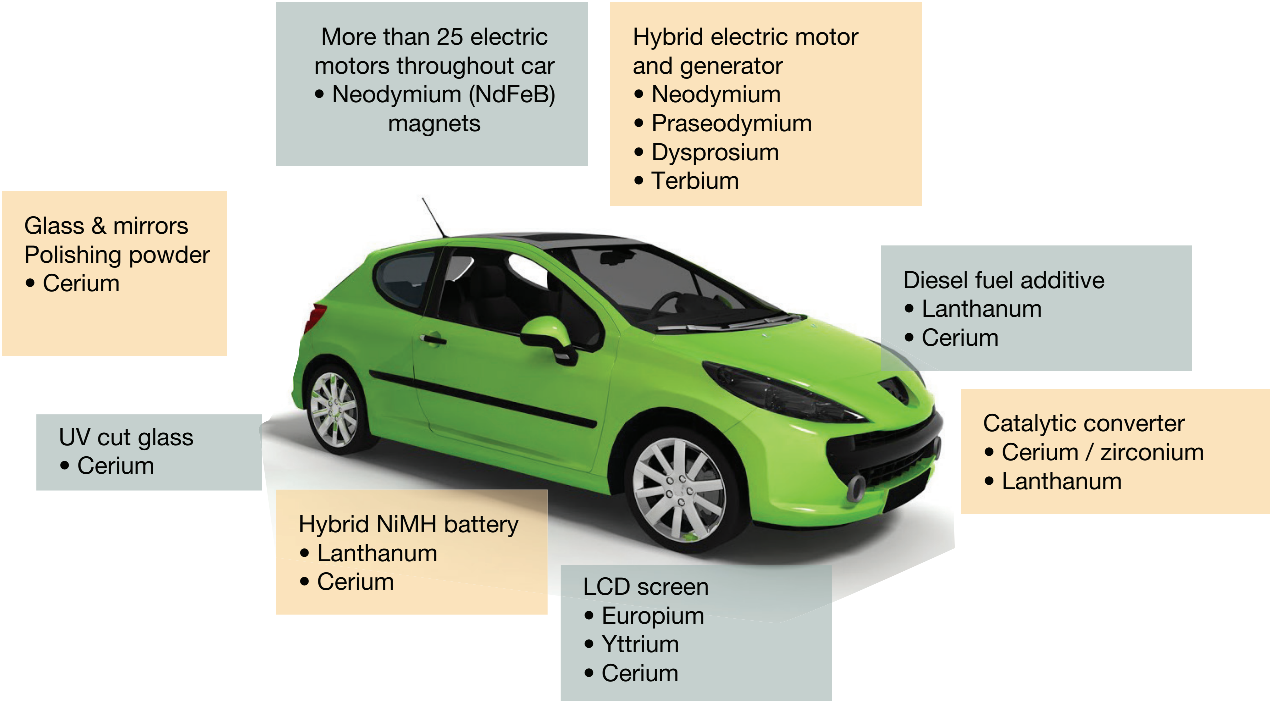
Despite all the factors above, the bottom line for the whole metal recycling industry is still down to one major factor: economic viability. Common commodity metals, such as steel, manganese and copper, have been widely recovered from end-of-life products. The technology involved is relatively advanced with high recovery rates and thus making recycling economically viable. Recovering such metals from end-of-life products is also relatively easy due to the simple applications of such metals in certain products.

However, certain products, especially those which are now increasingly in demand in modern lifestyles, are much more complex in their use of metals and thus making metal recycling on such products much more challenging. Examples of such products are:

- Mobile phones: there are more than 40 elements in them including base metals such as copper and tin, special metals such as cobalt, indium and antimony, and precious and platinum-group metals including silver, gold, palladium, tungsten and yttrium.

- Modern cars which contain commodity materials (pure metal, alloys and compounds, such as steel, copper, aluminium, zinc and nickel), plastics, rubber, and rare earth elements used in the increasingly used hybrid cars (neodymium, lanthanum, cerium, etc.) (Fig. 6).

- Fluorescent lamps which contain various materials and elements (including rare earth elements – yttrium, lanthanum, cerium).



Source: www.cbt.com.my (downloaded on 8 Oct 2014)

Figure 6. Rare earth elements used in a modern hybrid-engine car

Recycling for such products is not straightforward at all. The conventional material and metal-centric (MMC) approach is not suitable for such products due to the wide range of materials and metals used and their complex integration in the products. A new approach is needed: a product-centric approach. In this new approach, the players in the entire product value chain will need to be involved. For example, recyclers at the downstream end will need the more established know-how and expertise of upstream ore processing and metal extraction industry to be applied in the downstream recycling process. Recovery rates and costs in recycling processes can be significantly improved by incorporating material recoverability aspect in product design and production.

The industry increasingly is paying more focus on the recycling of rare metals. For example, Honda successfully recycled rare earth elements used in 386 hybrid cars that became unusable due to the Great East Japan Earthquake. [65]

Also, much research on rare metal recycling is actively being carried out in research institutions and universities especially in developed countries such as Japan, US and Europe. The rare metal recycling industry is still at initial stage of development but great potential is anticipated considering all the enabling factors mentioned above.

3.6.2 *Recommendations on R&D and Technology Development for Rare Metal Recycling Industry*

Malaysia should explore into the development of rare metal recycling industry due to the following reasons.

- Existence of local industry e.g. electronic and car industries which are large potential users of rare metals in Malaysia.

- The expected development of know-how in rare earth processing due to the setting up of Lynas' rare earth processing plant may be applicable to rare metal recycling.

As this is an emerging industry Malaysia should adopt the following strategy.

- Foreign direct investment (FDI) by leading players in the industry to set up recycling facilities and operation in Malaysia should be targeted by MIDA.
- Enhance the undergraduate programme in material science / engineering, chemistry, such that students are trained in areas relevant to the industry.
- Encourage or set up more R&D projects related to material and metal extraction / separation such that more research manpower relevant to the industry can be produced and thus supporting the industry to move to higher value added activities such as R&D.

4.0 RARE EARTH RELATED DOWNSTREAM INDUSTRY, TECHNOLOGY AND RESEARCH: THE WAY FORWARD

Overall, Malaysia has the following advantages for the development of rare related downstream industry:

- Availability of certain rare earth oxides from local rare earths processing plant. See Table 7.
- Existence of some local industries which are related and consuming rare earths as raw materials directly or indirectly through parts and components. For example, automobile, lightings, oil refining, etc.
- Potential supply of rare earths and other rare metals from untapped mineral deposits in the country.
- Existence of manufacturing experience, expertise, know-how and technical workforce in a wide range of industry sectors which can be adopted or adapted into some new rare earths-related industries.

Table 7. Composition of rare earth ores from Mount Weld used in the Lynas rare earth processing plant in Kuantan.

Rare earth oxides	Mount Weld composition by weight
Lanthanum Oxide	25.50%
Cerium Oxide	46.74%
Praseodymium Oxide	5.32%
Neodymium Oxide	18.50%
Samarium Oxide	2.27%
Dysprosium Oxide	0.12%
Europium Oxide	0.44%
Terbium Oxide	0.07%

However, we have certain weaknesses as follows.

- There is still lack of research work being carried out in rare earths application, product manufacture and related areas that has led to commercial implementation. There is still a lack of IPs in such areas in Malaysia.
- There is still lack of human resource in R&D to support such kind of industrial development.

Therefore, the best strategy for Malaysia is to attract foreign companies to invest and start manufacturing plants in some rare earths-related downstream industries as presented above. Through such FDIs we can jump start new industries and achieve technology transfer through the corresponding industrial operations. While doing so, the country should start to focus on R&D activities related to the industries. Related R&D projects should be started with the hope that the R&D manpower in the areas can be developed to support transition of the industries up their value chains. For R&D, a national research institute focusing on advanced materials should be set up. Such institutes have been set up overseas e.g. National Institute for Material Science (NIMS) of Japan, Korea Institute for Rare Metals (KIRAM) of South Korea, General Research Institute for Nonferrous Metals of China, etc. With such national institute in Malaysia we should be able to pool resources to focus on certain research areas of strategic importance to the industrial development of the nation.

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1.0 SUMMARY

Although the Rare Earths mining industry is still at the nascent stage in Malaysia, it is imperative that steps be put in place to ensure sufficient human capital is prepared at the University Level for Rare Earths industries in the upstream, midstream and downstream activities. Currently, engineers produced by Malaysian Universities are generally buyers, users and providers of maintenance of equipment with few realizing that some of the products they use contain rare earth elements. Therefore, Malaysia needs to develop a **Rare Earth Human Capital Strategy** focusing on demand creation in Rare Earths activities covering the full ecosystem Malaysian professional and semi-professionals to have the necessary innovative capacity and capabilities.

For demand creation to be able to ascertain the human capital requirements for Rare Earth product innovation, it is proposed that Malaysia should adopt the following **Strategic Imperatives:**

- Re-strategize its FDI policies and to attract REE product development and innovation companies into Malaysia.
- Make REEs resources as strategic and any disruption in the supply will hamper the FDI initiative.
- Attract Electric and Hybrid Car Manufacturers to invest in Malaysia as the REE components are substantial.
- Develop innovative capacity to create REE product innovations in Malaysia through international collaboration with Centre of Excellence.
- Designate Rare Earth Universities for downstream, midstream and upstream in Malaysia similar to Korea and Japan (with the necessary funding).

The demand creation **Strategic Imperatives** would provide sustainable human capital for Rare Earth innovative product development and at the same time Malaysia will be able to attract new investments in Rare Earth industry into Malaysia.

It is also proposed that the downstream REE product innovations are designated to the **Malaysian Technical University Network (MTUN)** to have the necessary infrastructure to build capacity and future knowledge in rare earth applications and innovations.

As the Rare Earths mining industry involves risks, as is inherent in any industry, there is a need for rigorous safety features typically deployed in the working environment (as is addressed in Chapters 6 and 8). Automation is one way to improve Occupational Health and Safety in the mining industry. Skills in Automation such as Automation Technician, Mechatronics Engineer and Operations Optimization Manager are required. **It is proposed that Universiti Teknologi Melaka (UTeM) provides a comprehensive TVET courses in Automation for the mining industry.**

For the upstream (mining) and midstream (extraction and processing), Malaysia has limited human resources with some courses available at local universities. However, there is a gap if compared with Australian universities. **There is a need to narrow the gap in terms of the courses offered and it is recommended that local universities collaborate with Australian universities especially with University of Queensland, University of Western Australia, Curtin University and Murdoch University.**

As parts of Peninsular Malaysia have reserves of xenotime and monazite (which contain the Heavy Rare Earths Elements (HREE) and potential reserves of ion-adsorption clays (all yet to be assessed - Chapter 2), **it is therefore proposed that manpower be trained to undertake exploration using the latest technologies thus enabling the Malaysian Rare Earths reserves to be determined with great urgency.**

In order to ensure that Rare Earths, a resource of strategic importance, can become an engine of economic growth for Malaysia, it **is proposed the setting up of the Malaysian Rare Earths Research Institute for upstream, midstream and downstream research activities to develop research competences and expertise.**

At the Vocational Level, in order to revitalize rare earths and other mining-related industries in Malaysia, vocational-skilled individuals or sub-professionals need to be properly developed because of shortage of experienced and skilled workers.

Some of the vocational skills needed are specific to mining and rare earths-related industry but most competencies required are fortunately common with others. Existing government polytechnics and training institutes are able to produce skilled individuals needed.

These established polytechnics and institutes can also be extended to offer mining related courses in the future. **Mining needs to be given attention because of the absence of formal technical training courses, while the mining industry is still showing a growth trend. In states like Pahang and Perak, where most mining workers in Malaysia are employed currently, institutes there can be upgraded**. Assuming 10% growth based on current data, about 150 technical sub-professionals and 600 semi-skilled/ unskilled new workers are needed in a year.

Sighted education and training carried out in Western Australia with its established mining industry can be adopted on a smaller scale in Malaysia. **Collaboration with the Australian government agencies, universities and training organizations may jumpstart our efforts.**

The above proposal can only be realized with a high degree of success with the necessary governmental support and financial resources behind such an ambitious program for demand creation, vocational skilled training, exploration and the necessary capabilities for Malaysia to become innovative product developers in rare earths applications and to become the next growth area for Malaysia.

2.0 INTRODUCTION

As the global population grows and the demand for natural resources increases, there will be a shortage in many commodities including strategic elements. Without strategic elements, such as platinum group elements, ***rare earth metals*** and other critical metals, maintaining the global economy becomes exceedingly difficult.

The demand is projected to increase at an alarmingly rate in the near future, which will hamper the progress of energy-critical technologies as well as many consumer products. For example, a global REE shortage would prove disastrous to the future of many existing consumer and green technology products. Over the past decade, there has been an increase in the use of highly efficient permanent magnets (especially in green energy production). This increased demand for efficient permanent magnets has directly led to increase in the demand for dysprosium and neodymium, strategic metals that are used in the production of permanent magnets ([1] Alonso et al., 2012). For example, neodymium is projected to become a limiting factor for the production of hybrid car models, due to its use in permanent neodymium alloy (NdFeB) magnets ([5]Shaw, 2012). Demand for permanent rare earth magnets used in developing energy technologies is expected to increase by 60% by 2017 and will accelerate to 200% of current demand by 2020. World demand for heavy REEs used in consumer-grade products with phosphors and pigments is set to increase by 50% by 2017. In addition, the use of dysprosium in heat-resistant alloys, which are present in wind turbines, means that the demand for dysprosium will increase with the use of wind energy ([3] Moss, 2011) ([4] Roskill Estimates, 2012). Analysts predict that the demand for dysprosium will outstrip existing production levels within 25 years (Alonso, 2012). A potential disturbance in the supply of REEs would threaten not only modern technology, but also the advancement of innovative technology.

The cost of inaction on declining supply of REE is particularly concerning. If the world does not quickly take steps to change how REE is consumed, conduct research to find alternative sources, the global economy will become considerably more difficult with limited innovation to produce new products based on Rare Earth Metals.

Malaysia has experienced a major decline in the mining industry especially tin for decades and getting graduates in metallurgy and skilled sub-professionals locally is difficult. In recent years however, mining industry has shown some very positive growth, according to Malaysian Mining Industry's latest yearly report [5]. This shall lead to rising demands for sub-professionals fresh from technical institutes due to efforts by the government to raise their training capacities. However, the fact remains that Malaysia still has a shortage of experienced workers in mining and there are no specific mining courses offered in training institutes currently [9].

The shortage of technical expertise is further compounded by the lack of competent technical trainers or instructors in those required fields (mining and minerals, especially rare earths) and their appropriate laboratories for practical or hands-on training to help support the industry's manpower growth. In order to build momentum, appropriate infrastructure investments are necessary to create the necessary manpower needed for the mining industry.

3.0 CURRENT STATISTICS OF THE MINING INDUSTRY IN MALAYSIA

According to Minerals and Geosciences Department [5], the total number of workers employed in mining sector has increased dramatically from 5,719 in 2010 to 7,053 in 2011. This increase of 23% is due to the opening of new mines in a few states. The number of mines and the mineral types and their respective employment figures for 2011 is as shown in Table 1.

Table 1: Employment by type of minerals and number of mines in Malaysia, 2011

No	Mineral Type	No. of mines	No. of workers
1.	Iron ore	79	2,205
2.	Gold	16	1,569
3.	Tin	13	1,448
4.	Coal	9	1,029
5.	Kaolin	17	268
6.	Manganese	10	200
7.	Silica	5	195
8.	Other types	10	139
	TOTAL	**159**	**7,053**

From Table 1, it is clear that Malaysia is rich in minerals with open-cast mining being carried out. The iron ore mining industry employs the highest number of workers, followed by the gold sector, tin, and coal. From Table 2, out of the total 7,053 workers employed by the end of 2011, 615 are engineers and professionals, 1,191 are in sub-professional technical area while 4,890 are in semi-skilled/unskilled category.

Table 2: Employment by mining job category, 2011

No.	Job Category	No. of Workers
1.	Semi-skilled and unskilled	4,890
2.	Technical	1,191
3.	Managerial and professional	615
4.	Clerical	357
	TOTAL	**7,053**

With relatively significant number of workers in technical and semi-skilled category compared to others, it is evident that sub-professionals education and training have to be proportionally strengthened if the industry is to be revitalized.

Pahang is where most of the mining workers are employed in, at more than 40%. It is followed by Perak, Sarawak, Kelantan, Johor, and Terengganu. The rest of the states employ less than 200 workers in total. The details are as shown in Table 3 below:

Table 3: Employment by States, 2011

No.	State	No. of Workers	%
1.	Pahang	2,992	42.4
2.	Perak	1,491	21.1
3.	Sarawak	1,161	16.5
4.	Kelantan	437	6.2
5.	Johor	395	5.6
6.	Terengganu	388	5.5
7.	Other states	189	2.7
	TOTAL	**7,053**	**100**

As the number of people employed in the mining industry is highest in states like Pahang and Perak, it is proposed that these states have higher preferences in providing university and vocational training at universities and polytechnics and technical institutes on rare earth and mining related courses.

4.0 HUMAN CAPITAL REQUIREMENT FOR DOWNSTREAM REE APPLICATIONS

Most Engineering Faculties in Universities in Malaysia may not have realized that the down-stream products normally used by them contain REEs, from cameras, LCD TVs, to hybrid cars. The use of polishing powder to polish silicon wafers also contains cerium oxide and to prevent pollution, the catalytic converters use lanthanum and cerium.

However, Malaysian engineers do not have the opportunity to be involved in product development like their counterparts in Korea, Japan, US, UK and Germany and, as such, the downstream REE applications are developed in these countries. These countries view REEs as strategic because REEs are a major constituent of many advanced materials, especially in the high tech and green energy sectors. Any potential disturbance in the supply of REEs would threaten the advancement of innovative technology and innovative products.

It can be safely assumed that Malaysian engineers who graduated from the local universities are trained as either process engineers, plant engineers or product engineers. Process engineers are trained to ensure that the production processes are efficient with high yield using statistical process control whereas the plant engineers are effectively the one who oversea the overall running of the entire plant or factory. Product engineers are focused in ensuring that a particular product produced by the plant is manufactured from raw materials, assembly and final product with the lowest defect rate. It is unfortunate that Malaysia attracts foreign direct investments (FDI) with the objective of providing employment for our graduates. FDI in REE product development is almost non-existent and although some MNCs have moved up the value chain, these MNCs are involved in design activities mainly in the semiconductor sectors.

As rare earths are a strategic source of economic growth for the country, it is therefore imperative that Malaysia develops the needed the human capital for the REE down-stream applications. For instance, the use of NdFeB, praseodymium and dysprosium is known to produce the strongest permanent magnets for wind turbines and other electrical power generators yet Malaysia are mere buyers and users of these permanent magnets.

Japan, for example, has a very well-defined strategy for rare earths research with the Rare Metal Substitution Project starting in 2007. Organizations, such as National Institute for Material Science (NIMS) and RIKEN, are involved in Strategic Research while the National Institute of Advanced Industrial Science and Technology (AIST) are involved in Applied RE Research. Japan is developing permanent magnets with less dependence on dysprosium (Dy) in collaboration with Toyota, Tohoku University and NIMS. In 2008, Toyota funded NIMS-Toyota Research Centre for Dy-free permanent magnet and all solid Li-Ion battery research. For the Malaysian human capital development, collaboration with Japanese research organization will develop capacity for Malaysian to be at the forefront of innovative downstream REE product development.

Korea, for instance, has a strategy for Rare Metal Industry Development. By 2018, Korea would be 80% self sufficiency in strategic rare metals by securing resources either in Korea or elsewhere, 95% technical competency in developing R&D and create 100 companies. The 2018 Strategy would mean that the current product innovation already uses a high percentage of Rare Earth materials in their products. The structure for driving the Rare Metal Strategy includes the creation of Rare Metals Advisory Committee, establishment of the Korea Institute for Rare Metals (KIRAM), and Local Rare Metal Commercialization Centre. KIRAM has designated Rare Metal Specialized Universities in Korea such as Konju National University, Sooncheon University, Hanyang University, Chungnam National University and Incheon National University. KIRAM also established international collaboration with MCGill University, Osaka University and the AMES Laboratory in the USA. The memorandum establishes a framework for the AMES Laboratory and KITECH to work together to make advancements in rare-earth processing techniques, to transfer rare-earth discoveries to industrial applications and to educate the next generation of rare-earth scientists and engineers.

Korea has demonstrated their seriousness in pursuing the 2018 Rare Metal Strategy and has established the necessary infrastructure to achieve their goals and objectives. **Malaysia also needs a long term strategy for rare metals and establish international collaboration to build R&D and innovative capacity in rare metals.**

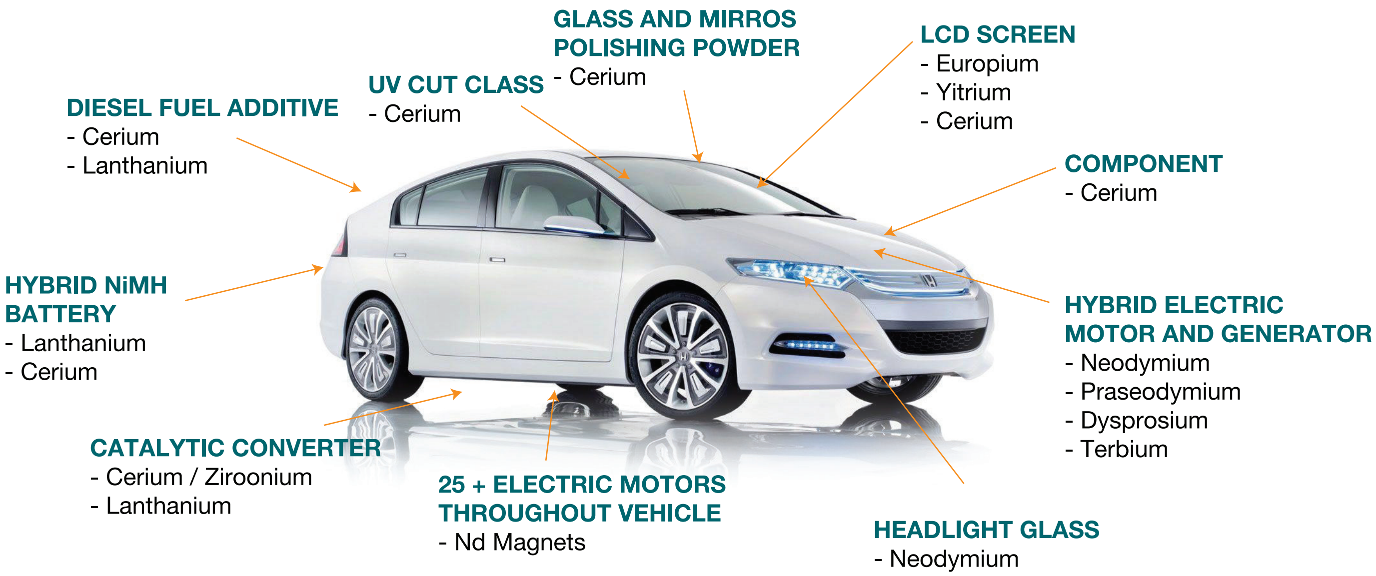
In essence, the demand creation is necessary to be able to ascertain the supply of human capital for REE product development.

The following are the short-term **Strategic Imperatives** for Malaysia:

- Re-strategize its FDI policies and to attract REE product development and innovation companies into Malaysia.
- Make REEs resources as strategic and any disruption in the supply will hamper the FDI initiative.
- Attract Electric and Hybrid Car Manufacturers to invest in Malaysia as the REE components are substantial.
- Develop innovative capacity to create REE product innovations in Malaysia through international collaboration with Centre of Excellence.
- Designate rare earths research Universities for downstream, midstream and upstream in Malaysia similar to Korea and Japan (with the necessary funding).

For example, Electric and hybrid cars can contain 20-25 pounds of rare earths. The battery itself is made from several pounds of rare earth compounds. REEs are also used in regenerative braking systems and electric traction motors. The motors consist of powerful magnets made from neodymium and dysprosium. Fig. 1 depicts the use of substantial REE components of a hybrid car.

One thing for sure, all engineering faculties in the local universities which are focused in the areas of electrical, electronics, optics, power electronics, mechanical and mechatronics, automotive engineering, materials engineering and chemical engineering would be required in downstream



Source: www.cent-anni.com (downloaded on 8 Oct 2014)

Figure 1: Substantial use of Rare Earths in Hybrid Cars

REE product innovation. **It is proposed that the human capital requirements for downstream REE innovations are designated to the Malaysian Technical University Network (MTUN).** However, there is a need to strategise in order for the MTUNs to have the necessary capacity and future knowledge in Rare Earth Applications and the necessary research to be conducted in collaboration with Japanese and Korean Universities.

Malaysia has no option but to adopt the strategic imperatives as part of demand creation to ensure that our graduate engineers, vocational and technical skilled personnel are given the exposure in REE product innovation and applications.

To develop the innovative capacity of creating REE product innovation, it is necessary that our rare earths research universities collaborate with institutions involved in downstream REE product development particularly in Korea, Japan and Australia. Malaysian Universities should also become members of the Rare Earth Technology Alliance or RETA, which is an international organization representing a wide coalition of organizations that produce, use, and study rare earths.

In support for downstream rare earth strategies and activities mentioned in this section, vocational and technical support is necessary. There is a need for technical and vocational skill in advanced chemical processing or further separation of mixed-element concentrates into individual element and other metallurgical processes to produce commercially utilizable products in the form of rare earth oxides, metals, or alloys for downstream applications. This would require skilful handling of advanced processing plant and machinery to produce rare earth elements for downstream applications.

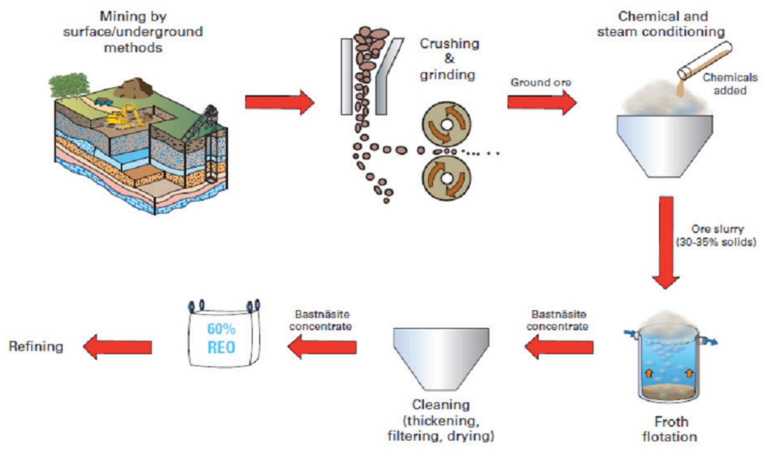
Therefore, Malaysia needs to develop a Rare Earth Human Capital Strategy for downstream applications both at university and technical and vocational levels to become innovative product developer for rare earth applications beyond permanent magnets and Li-ion or NiMh batteries. Such strategy would not only develop REE human capital for new Rare Earth applications but also would attract new investments in downstream rare earth products into Malaysia with the availability of human capital at both at the university, technical and vocational levels. The demand creation would provide sustainable human capital for Rare Earth innovative product development and the necessary technical support and the necessary resources for attracting investments in Rare Earth industry into Malaysia.

The Rare Earth Human Capital Strategy and the adoption of the Strategic Initiatives would need political will as well as putting financial resources behind such an ambitious program to create and develop the necessary capabilities for Malaysian engineers, technical and vocational skill-sets to become Rare Earth application developers to position this industry as the next engine of growth for Malaysia.

5.0 HUMAN CAPITAL REQUIREMENT FOR UPSTREAM AND MIDSTREAM PROCESSES

5.1 Up-Stream (Exploration and Mining) Human Capital Requrements

Mining activities use large-scale techniques involving drilling, blasting and hauling. Mining involves removing mineralized rock from the ground through open-pit or underground methods. Typically, excavators pull huge clumps of dirt from the earth, depositing them into equally giant haulers. These machines pull some fresh ore from the ground and the rocks are hauled to a massive crushing facility, a warren of tubes and conveyer belts that ultimately lead to a silo where the ore gets pounded into pieces about three-eighths of inch wide. These pebbles then move via conveyer belt to a mill and get mixed with water and dumped into a giant cylinder with large steel balls. The mixture turns into slurry that moves to a so-called hot floatation facility with chemicals added and the slurry heated up. The rare-earth minerals rise with the bubbles that float to the top and are skimmed off as shown in Fig 2.

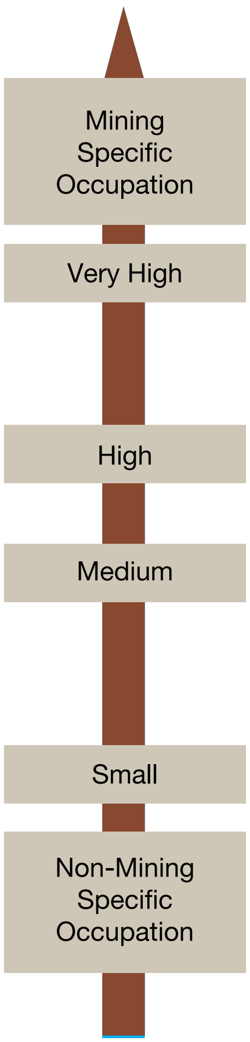


Source: Mackowski, S (2012)

Figure 2: Mining and the Associated Processes

In terms of human capital requirements, mining jobs requiring university degrees are mostly in Geology including Environmental Geology, Geophysics, Geochemist, Mining Engineering and Metallurgical & Materials Engineering, Civil Engineering programs although Chemistry, Surveying, Geography and Biology are related to the mining industry. At the Degree Level, Technical Level and Semi Professional Level, the entire value chain of the human capital requirements of the mining and upstream activities is shown in Table 4. At the top, mining specific occupations are very high while at the bottom, it is much smaller which means that these jobs, though important, are not completely indispensible.

Table 4: Value Chain of HCD Requirements of the Mining Sector



Degree Level	Technical Level	Semi Professionals
• Mining engineers	• Central control processes and operators, mineral and metal processing • Mine workers	• Underground service and support workers • Machine operators, mineral and metal processing • Supervisors, mining and quarrying • Production and development miners
• "Other" professional occupations in physical sciences	• Primary production managers	• Supervisors mineral and metal processing • Workers in mineral and metal processing
• Geological engineers • Metallurgical and materials engineers	• Geological and mineral technologists and technicians • Geoscientists	• Construction millwrights and industrial mechanics • Crane operators • Heavy-duty equipment mechanics • Drillers and blaster • Steamfitters, pipefitters and sprinkler system installers • Contractors and supervisors, mechanic trades
• Chemists • Civil engineers • Chemical engineers • Industrial and manufacturing engineers • Biologists and related scientists	• Land surveyors • Financial auditors and accountants • Electrical and electronics engineers • Industrial engineers • Construction managers and estimators • Mechanical engineering technologists and technicians	• Secretaries (except legal and medical) • Human resources managers • Truck drivers • Welders • Materials handlers • Inspectors and testers • Carpenters • Financial managers • Cooks

Source: Mining Industry Human Resources Council, Canada 2013

Table 5 below depicts the vocational and semi-skilled human capital development of the upstream sector which involves obtaining the minerals and has three major areas, namely exploration, mining, and mineral processing. Some of the semi-professional skills required in each area are common to all.

Exploration focuses on searching for rare earth elements that are economically viable to mine whereas mining and quarrying is basically to extract the rare earth minerals from the ground. Rare earth mineral processing involves processing and upgrading the raw minerals to concentrates. Plant and machines need to be operated and maintained by skilled and experienced personnel. Some of the processes involved are magnetic, electrostatic, or gravity separation.

Table 5: Vocational and Semi Skilled Requirements of the Upstream Mining Sector

Exploration	Mining and Quarrying	Mineral Processing
Vocational skilled persons typically required	Semi-professional individuals required are:	Skilled and experienced personnel required
• Drill rig operators	• Mine-machine operators	• Mineral processing machine operators
• Electrical maintenance technicians	• Electrical maintenance technicians	• Electrical maintenance technicians
• Mechanical maintenance technicians	• Mechanical maintenance technicians	• Mechanical maintenance technicians
• Geological, geochemical, and geophysical field technicians	• Environment technicians	• Mineral processing/ analytical laboratory technicians
• Analytical chemistry technicians	• Mine maintenance technicians	• Civil maintenance technicians
• Civil maintenance technicians	• Civil maintenance technicians	• C&I maintenance technicians
• C&I (control & instrumentation) technicians	• C&I maintenance technicians	• IT/computer technicians
• Survey technicians		• Environment technicians

5.2 Mid-Stream (Extraction and Separation) Human Resources Requirements

Obviously, the expertise needed for the extraction and separation of rare earths-bearing minerals are in the areas of geochemistry, solution chemistry, analytical chemistry, inorganic and organic chemistry, fluid dynamics, mineralogy, biochemistry and environmental impact analysis.

However, the presence of thorium, particularly in monazite extraction would require safety in handling radioactive compounds and the courses in the management of radioactive residues would be necessary (Chapter 8). Expertise in Environmental Science and Management offered by local universities will be necessary to ensure that radioactive materials are handled with utmost care.

Fundamental training in handling rare earth-bearing minerals is critical here, not only to ensure high-quality products, but also because of the radioactive by-products that might be present. Fortunately, in Malaysia, radiation and radioactive handling are also common to other local industries and training programs are to a certain extent, readily available.

The Vocational and Semi-professional level for the midstream sector focuses on cracking the mineral concentrates to produce mixed rare earth elements. The human capital requirement for midstream activities at university, technical and vocational including semi-professional levels is shown in Table 6.

Table 6: The Expertise needed for Midstream Extraction and separation at Degree levels and Vocational and Semi-professional Technician for Midstream activities

Midstream degree level expertise needed for extraction and separation	Vocational and Semi-professional level for midstream activities such as leaching, cracking and separation
• Geochemistry	• Processing machine operators
• Analytical Chemistry & Bio Chemistry	• Electrical maintenance technicians
• Inorganic and Organic Chemistry	• Mechanical maintenance technicians
• Fluid Dynamics	• Radioactive-handling technicians
• Mineralogy & Metallurgists	• Environment technicians
• Environmental Impact Analysis	• Civil maintenance technicians
• Environmental Science and Management	• Chemical-handling technicians

6.0 COMPARISON BETWEEN AUSTRALIAN UNIVERSITIES AND MALAYSIAN UNIVERSITIES FOR UPSTREAM AND MIDSTREAM COURSES

Compared to Japan and Korea, Australia has huge mineral reserves some of which are rare earth minerals. Western Australia is fortunate to be endowed with extraordinary mineral wealth, providing it with the opportunity to prosper from this endowment well into the future. The Western Australian minerals industry is a significant contributor to the Western Australian and Australian economy. This includes a number of multi-national mining companies, including the world's two largest mining companies, BHP Billiton and Rio Tinto, which have a considerable portion of their respective minerals production portfolios located in Western Australia. Innovation in the minerals industry will become more critical in the future as the industry cost curve steepens as a result of the emergence of scale operations in low cost structure jurisdictions, the lowering of trade barriers, the dominance of large multi-national minerals companies with significant production and marketing economies of scale and more technically challenging exploration, extraction and processing environments [7].

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is the most significant public sector minerals research organisation in Australia with approximately 400 research staff (270 FTEs) from across Australia of which 47% are Process Science and Engineering and 39% are Earth Science and Engineering. The majority of minerals research activity undertaken at CSIRO occurs in the principal mining states of Western Australia and Queensland. The research topics by CSIRO can be found in [7].

The single most significant and immediate challenge facing the expansion of the Western Australian minerals industry is the rapidly growing critical shortage of skilled labour, particularly in the geosciences and mining engineering profession.

The comparison between Australian Universities and Malaysian Universities for upstream and midstream courses is summarized in Table 7.

Table 7: Comparison between Australian Universities and Malaysian Universities

AUSTRALIAN UNIVERSITIES [8]		MALAYSIAN UNIVERSITIES [9]	
University	Courses and Centre of Excellence	University	Courses and Centre of Excellence
University of Queensland	Centre for Integrated Resources Management Division of Mining and Metallurgical Engineering Environmental Management Centre School of Earth Sciences Sustainable Minerals Institute Julius Kruttschnitt Minerals Research Centre WH Bryan Mining Geology Research Centre Centre for Mined Land Rehabilitation Minerals Industry Safety and Health Centre Centre of Social Responsibility in Mining Centre for Water in the Minerals Industry	Universiti Malaya	Applied Geology and Geology Chemistry Mechanical Engineering Environmental Engineering Electrical Engineering Chemical Engineering
University of Adelaide	School of Chemical Engineering School of Chemistry and Physics School of Civil, Environmental and Mining Engineering School or Earth and Environmental Sciences	Universiti Kebangsaan Malaysia	Geology Chemistry Environmental Science Chemical Technology Mechanical Engineering Civil and Environment Engineering
Murdoch University	School of Chemical and Mathematical Science School of Engineering and Energy Sustainable Ecosystems Research Institute	Universiti Teknologi MARA	Chemistry Applied Chemistry Mechanical Engineering Chemical Engineering Electrical Engineering
University of Western Australia	Australian Centre for Geomechanics (Joint Centre with Curtin University) School of Civil and Resources Engineering School of Mechanical Engineering School of Earth and the Environment Centre for Exploration Targeting (Joint Centre with Curtin University) Centre for Land Rehabilitation School of Environmental Systems Engineering	Universiti Sains Malaysia	Pure Chemistry Applied Chemistry Physics Mineral Resource Engineering Materials Engineering Mechanical Engineering Chemical Engineering
Curtin University	Institute for Geosciences Research Western Australian School of Mines Department of Exploration Geophysics Rio Tinto Centre for Materials and Sensing in Mining Department of Applied Geology Minerals Engineering and Extractive Metallurgy Mining Engineering Department of Spatial Sciences	Universiti Malaysia Sabah	Geology Environmental Science Industrial Chemistry Electrical & Electronics Engineering Chemical Engineering Mechanical Engineering

Table 7: Comparison between Australian Universities and Malaysian Universities (contd.)

The Australian National University	College of Engineering and Computer Science College of Physical Science	Universiti Malaysia Kelantan	Geoscience Resource Chemistry
University of Newcastle	Centre of Advanced Particle Processing Geotechnical and Materials Modelling	Universiti Malaysia Sarawak	Resource Chemistry
University of Sydney	School of Chemistry School of Geosciences	Universiti Putra Malaysia	Mechanical Engineering Chemical Engineering Electrical & Electronic Engineering Material Science Environmental Science & Technology Environmental Management
University of Melbourne	School of Earth Sciences School of Engineering	Universiti Tunku Abdul Rahman	Chemistry Mechanical Engineering Electrical & Electronic Engineering Chemical Engineering Mechatronics

It is obvious from Table 7 above that Malaysian Universities are offering courses in traditional Engineering and Sciences with some universities offering courses on Geology, Geological Sciences, Mineral Resource Engineering, Applied Geology, Material Engineering and Applied and Resource Chemistry. These courses are relevant for upstream and midstream activities. Other Engineering such as Mechanical, Electrical & Electronic Engineering courses and Mechatronics are relevant for downstream activities.

It is observed that there are significant gaps between courses offered by Australian Universities compared with Malaysian Universities for upstream and midstream related courses. Of particular interest are minerals research activities at Western Australian universities undertaken by University of Western Australia, Curtin University and Murdoch University. Mineral research activities for upstream and midstream processes in Malaysian Universities are very limited compared to Australian Universities. For instance, the specific minerals research capabilities of University of Western Australia, Curtin University and Murdoch University, together with joint centres is summarized in Table 8.

Table 8: Capabilities of University of Western Australia, Curtin University and Murdoch University

<table>
<tr><th>University of Western Australia</th><th>Curtin University</th><th>Murdoch University</th></tr>
<tr>
<td>• School of Civil and Resources Engineering
• School of Mechanical Engineering
• School of Earth and Environment
• Centre of Land Rehabilitation
• School of Environmental System Engineering
• School of Indigenous Studies
• Eureka Archaeological Research and Consulting
• Centre for Regional Development
• Business School
• School of Civil Resources Engineering
• School of Mechanical Engineering
• School of Civil Resources Engineering
• School of Mechanical Engineering</td>
<td>• School of Civil and Mechanical Engineering
• Western Australian School of Mines:
- Department of Applied Geology
- Department of Exploration Geophysics
- Metallurgical and Minerals Engineering
- Mining Engineering
- Department of Spatial Sciences
• Centre for Industrial Modelling and Opportunity
• WA Organic and Isotope Geochemistry Centre
• Centre of Rock Characterisation
• Water Quality Research Centre
• Centre for Aboriginal Studies
• Centre for Research on Energy and Mineral Economics</td>
<td>• School of Chemical and Mathematical Science
• School of Engineering and Energy
• Sustainable Ecosystems Research Institute</td>
</tr>
<tr><td colspan="2">Autralian Centre for Geomechanics</td><td></td></tr>
<tr><td colspan="2">Centre of Exploration Targeting</td><td></td></tr>
</table>

Malaysian Universities described in the ASM Study Report 1/2013 ("Revitalising the Rare Earth Mineral Programme in Peninsular Malaysia as a Strategic Industry") [10] will need to narrow the gap in term of courses offered and research activities for upstream and midstream processes. It is therefore recommended that Malaysian Universities collaborate with the Australian Universities especially with University of Queensland, University of Western Australia, Curtin University and Murdoch University to enhance and narrow the gap of human capital needed for upstream and midstream processes and activities.

Western Australia has recently established in June 2013 the Western Australia Mineral Research Institute (WAMRI) [10] with the focus on research and development needed to ensure that the mineral industry remains the engine for economic growth for Western Australia. In the same breadth, Malaysia also needs to focus of Rare Earth based research by setting up the proposed **Malaysia Rare Earth Research Institute** for upstream, midstream and downstream research activities to develop competencies and expertise in Rare Earth. This institute should collaborate with local universities described in [9] and provide the conduit for collaboration with CSIRO for joint industry research activities in mineralogy and mineral exploration.

In addition, the proposed **Malaysian Rare Earth Research Institute** should also collaborate with the Baotou Research Institute of Rare Earths (BRIRE) in North China (Inner Mongolia). BRIRE was established in 1963, under the direct administration of former Ministry of Metallurgy Industry and today, BRIRE has been developed into the largest rare earths technological R & D institution specialized on rare earths in China. BRIRE is an integrated research institute covering the fields of rare earth metallurgy, environmental protection, new rare earths performance materials, application of rare earths in traditional industry, rare earths assay and inspection and rare earths information. BRIRE has more than 700 employees today and engineering technicians represent more than half of the employees. The Institute has the first-class research team with strong technical back-up, led by many national and provincial technical experts who have made outstanding contributions to rare earths industry with 680 technological achievements, among which more than 200 ones were awarded national invention prizes and various provincial technological prizes.

7.0 TECHNICAL AND VOCATIONAL TRAINING PROGRAMS

While some semi-professional job positions would require special training for rare earth minerals and handling, most of the others such as electricians or manufacturing plant and machinery maintenance technicians do not. They can undergo standard vocational education offered by various accredited institutions in electrical, mechanical, civil engineering, and instrumentation fields, and once employed, be trained in-house on specific programs or machineries and given on-the-job training (OJT).

Specific technical education and training on rare earth related areas are needed only for those prospective mining technicians and machinery operators who extensively handle these minerals. These programs, even if they are not yet available in Malaysia, are readily available with established and customizable short courses, as seen abroad in Korea Institute for Rare Metals, South Korea, and Central Institute of Technology, Australia.

7.1 Vocational Training in South Korea

Korea Institute for Rare Metals (KIRAM) was set up by South Korean government to specifically focus on rare metals industry. It conducts research, tertiary-level education, and training, while promoting rare metals development and collaboration domestically and internationally.

Close relation with KITECH (Korea Institute of Industrial Technology) gives KIRAM access to large network of domestic SMEs (small and medium-sized enterprises), since KITECH develops wide range and area of technologies for the industries. KIRAM also benefits from KITECH's international ties with foreign research institutes and the exchange of technology know-how.

KIRAM offers a customizable training program specifically on rare metals processing technology. It is a hands-on course involving lab work in its research and training facilities. Training period can be as short as 2 weeks for basic handling and processing [13]. Their government agencies and private organizations' individuals involved in rare metals there are the usual participants of this training.

7.2 Vocational Training in Australia

It is known that Australia has an established mining industry, mainly in Western Australia. Also, its formal human capital development programs for mining and related fields are well in place.

Central Institute of Technology (Central) offers certificate, diploma, and advanced diploma level programs on underground and surface mining. They range from basic drilling to mine management, covering environmental, surveying, mining, and lab operational aspects [13].

A customized training programs on underground mines may take 8 weeks, to prepare new workers for a new mine site. These workers already have vocational qualification in required fields such as electrical or mechanical, and need to be prepared and conditioned for mining jobs. The institute also have an underground mine simulator, to introduce and train prospective workers on realistic underground mine situations.

Similar certificate-level programs in surface mining are also offered by Polytechnic West. Tailored programs are also possible designed to meet specific needs, if required.

7.3 Vocational Training in Malaysia

Although vocational programs focusing on rare earths and mining are still not available in Malaysia, other related skills mentioned earlier such as electrical, mechanical, chemical, material, civil engineering, environment, and so forth have been established for decades, supporting Malaysian industrialization efforts.

Various government and private technical and vocational training institutes have been producing skilled sub-professionals in various areas. With the country's target to increase highly skilled workers from 23% to 37% by 2015, major efforts have been put up to achieve it [14].

Some of the government's skills institutes are as shown below in Table 9.

Table 9: Government Ministries with their respective institutes

Ministry	Institute
Human Resource	• Advanced Technology Training Centres (ADTEC) • Industrial Training Institutes (ILP)
Education	• Polytechnics • Community colleges
Youth and Sports	• National Youth Skills Institutes (IKBN)

The Ministry of Human Resource has 23 ILPs and 8 ADTECs all over the country. The Ministry of Education currently operates 32 polytechnics offering various technical programs. 85,435 students enrol in certificate and diploma level vocational skills courses such as electrical, mechanical, civil, IT, and automotive engineering, among others, in various government institutions for 2012/2013 sessions. This is an increase of 8.4% over the past year [15].

Hence, good development and growth trend are expected for prospective young sub-professionals currently in Malaysia, with evidently strong government support and commitment. For fast-track implementation, only specific training on mining and rare earth mineral handling and processing shall be needed for them to familiarize with and adapt to the real tasks. This is also the modus operandi of training in some of the mines in Pahang, giving fresh-intake workers from technical institutes, on-site and on-the-job training (OJT).

For specific task such as drilling, it is usually outsourced by the mining companies. A drilling contractor visited informs that fresh local intake starts first as an off-sider (unskilled helper), before becoming a drill trainee/assistant (semi-skilled). Training is on the job, and this can further pave the way for the trainee to become drill specialist if he stays on. Unfortunately, the contractor's records show that many local workers lack the discipline required, do not prefer the working conditions and environment, and leave before long. Hence the contractor employs most skilled workers from Indonesia, Philippines, and Australia. Out of 21 current skilled drillers there, only 2 are Malaysians.

7.4 Prospective Vocational and Technical Training Institutions

Given the current growth in the mining industry in Malaysia as shown in Table 3 based on employment and number of mines, Pahang is the first choice for developing future mining-related vocational training. Existing government training institutes in Pahang that can be expanded to include subjects related to mining and rare earth. The second state where most mining workers are employed, Perak, also has a number of established government-sponsored training institutes.

For other states, such as Sarawak, Kelantan, Johor and Terengganu, where mining activities are found hiring mining employees some of their respective institutes that have great potential in offering mining related courses in the future.

Table 10 shows the potential Vocational and Technical Training Institutes which could be developed given their proximity to mining activities in the respective states.

8.0 FUTURE POTENTIAL

Data and recent trends on mining labour force in Malaysia suggest a positive outlook. From a total of 5,719 workers in 2010, the number has increased to more than 8,600 in 2013 [17]. As this already translates to more than 50% increase in 3 years, restarting mining for rare earths shall warrant some attention and effort on supplying more skilled local individuals.

Assuming the growth continues at about 10%, coupled with proposed efforts on rare earth mining, about 150 technical sub-professionals and 600 semi-skilled/unskilled workers are needed every year from 2014 in various skills of mining.

Table 10 The potential Vocational and Technical Training Institutes by State

Pahang	Perak	Sarawak	Kelantan	Johor	Terengganu
Sultan Ahmad Shah Polytechnic Kuantan	Ungku Omar Polytechnic	ILP Miri	Kota Bharu Polytechnic	ADTEC Batu Pahat	Kuala Terengganu Polytechnic
Muadzam Shah Polytechnic	Sultan Azlan Shah Polytechnic	ILP Kota Samarahan	Jeli Polytechnic	ILP Mersing	Sultan Mizan Zainal Abidin Polytechnic
ILP Gebeng	ADTEC Taiping		ILP Kota Bharu	ILP Ledang	ILP Kuala Terengganu
IKBN Temerloh	ILP Ipoh		IKBN Bachok	ILP Pasir Gudang	ILP Marang
	IKBN Seri Iskandar			IKBN Pagoh	IKBN Wakaf Tapai

Therefore, the proposed extension of a training institute in Pahang to include upstream mining and rare earths technical courses is quite justified.

Projecting these numbers to 2030 when the total rare earths supply chain is expected to be in place in the country, it is expected that some 14,000 workers would be employed (Figure 3).

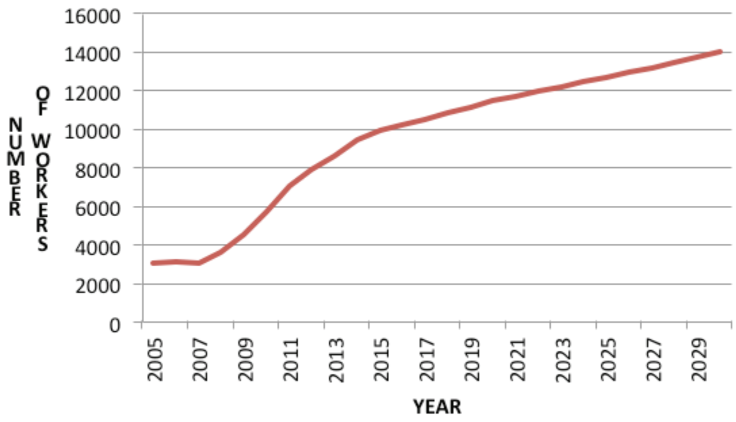


Figure 3. Projections of Number of Workers to 2030

The on-going practices by mining companies of giving only OJTs to fresh intakes and hiring skilled foreign workers are not sufficient for the country's proper human capital development. The setbacks of short-cut OJTs for unskilled or semi-skilled fresh intakes are that proper knowledge/ skills foundation, systematic training facilitation, and safety considerations, are normally lacking. These can be done much more effectively through formal training.

For midstream and downstream, there are no foreseeable shortages of prospective technical sub-professionals. With the increasing number of youth trained in various institutes, it shall be able to meet correlating demands as rare earth industry revitalizes. Familiarization with specific plant and machinery can be carried out through OJTs.

8.1 Automation And Workforce Structure for the Upstream, Midstream and Downstream Sectors [12]

Automation can be broadly defined as the intelligent management of a system, using appropriate technology solutions, so that operations of that system can occur without direct human involvement either in risky mining environment or to improve efficiency of mining industry.

Specific technologies that typically comprise an automation system in a mineral industry operation include:

- Sensor technologies
- Database and data fusion technologies
- Logic software technologies
- Visualisation and simulation technologies
- Collaboration technologies
- Networking technologies
- Mechatronic technologies

These technologies are used where there is a need for rigorous safety features and are typically deployed in harsh environmental conditions to improve Occupational Health and Safety in the mining industry.

There is no doubt that automation will render certain roles in mineral operations redundant as it has in other industries. Some unskilled and semi-skilled roles may also be replaced by automation.

The change in skills, culture and workforce structure that results from automation will be felt most profoundly in the minerals industry. As automation and remote control technology is increasingly adopted by the minerals industry, its workforce will increasingly resemble that of the oil and gas industry workforce, with a smaller portion of unskilled and semi-skilled labour and a larger portion of technicians and technical professionals working in a process oriented culture.

There is general consensus among operators that the following three roles that are not usually associated with resources industry, particularly mining operations, but are commonplace in other automated environments, will become increasingly important operational roles in the resources industry.

• ***Automation Technician***

The role of an automation technician is to build, install and maintain automated machinery and equipment. It is largely a systems integration role, with electrical tradespersons still being required to perform functions such as wiring and mechanical tradespersons still required to address mechanical issues. If deployed on an operating environment today, it is expected that an Automation Technician would be heavily reliant on support or direction from other experts (engineers and tradespersons) to perform many of the tasks.

• ***Mechatronics Engineer***

Mechatronic technologies are central to field robotics and the application of automated and remote control systems to resources industry operations. Mechatronics engineering is a multidisciplinary field that combines electrical, mechanical, computing and software engineering to create expertise in designing, building, deploying and maintaining electromechancial devices such as robotics. A particular skill set that is common to mechatronics engineer that is crucial to many resources operations automation programs is data fusion expertise. Because highly automated resources industry operations produce enormous volumes of data from heterogeneous data streams, the ability to write software code that can interpret and integrate those heterogeneous data streams is critical to not only the operation of automated systems, but also optimizing their benefits.

• ***Operations Optimisation Manager***

As resources operations become more automated and the immediate benefits of the automation program are realized, significant additional benefits can be attained through optimization, as has been the experience of other largely manual processes that have achieved high levels of automation. This role applies expertise in logistics and process optimization to achieve optimal whole of operations productivity and other benefits, and is performed by an operations optimization manager.

In Australia, its Resources Industry Training Council highlights the implication for vocational education and training in the inevitable adoption of automation technology [11]. The new workforce needs to be prepared for multi-skilling, new operating environment as well as new technologies. As the cost of labour escalates, the drive for automation increases.

All these developments and changes observed in Australia may translate into setting up of training institutes in Malaysia which have programs that provide good wide-range fundamentals, need to be flexible enough, and ready for change as required by technological climate and conditions in Malaysian mining industry.

The readiness and capacity of the TVET with polytechnics to deliver automation to the mining industry is of utmost importance. Malaysia is well positioned and UTeM together with partner polytechnics could provide a very comprehensive TVET Courses offered by the Faculty of Engineering Technology.

8.2 Implications for Higher and Vocational Education

Universities, particularly the universities with robust, multi-disciplinary engineering schools should have adequate capability to be quite flexible in course offerings such that the professional engineering needs of a more automated resources industry can be met.

In Australia, some institutions report that mechatronic engineers are highly sought after by the mining industry primarily as a result of their somewhat unique expertise in data fusion that is required for the assembly, interrogation and analysis of heterogeneous data sets and streams that are inherent to automated mining systems

In higher education, the requirement for automation in the minerals industry would require expertise in the following areas:

• ***Mechatronics Engineering In Resources Undergraduate Degree***

It would seem that the main challenge that mineral companies face in employing a mechatronics engineering graduate is the lack of expertise in mining or hydrocarbon production processes possessed by the graduate, as conventional mechanical and electrical engineering can be harnessed by employing mechanical or electrical engineers.

Mechatronic technologies incorporate electronic and mechanical functions into a single device to perform robotic actions. It represents an interdisciplinary area of engineering that integrates mechanical and electrical engineering with computer science. A typical mechatronic technology is a device that receives a signal from a sensor, processes that signal through a software algorithm that then commands a mechanical device to perform an action.

- ***Electrical and Electronics Engineering & Mechanical Engineering***

Apart from Mechatronics Engineering, the next sought-after courses in Mineral Industry automation are Electrical & Electronic is Engineering and Mechanical Engineering. In all cases, the electrical and electronic engineering curricula most closely resembles that of the mechatronics curricula, noting that in some cases, a limited number of subjects more typically taught as part of a mechatronics or electrical engineering degree are also taught in the mechanical engineering degree. This implies that electrical & electronic engineers are more likely to have more of the expertise required to work with automated systems than other non-mechatronics engineering graduates and that mining and petroleum engineering graduates are likely to have the least appropriate technical background, other than their understanding of resources processes. However, dual-undergraduate qualifications or an appropriate post-graduate qualification could be developed to deliver the required complete set of expertise.

The above courses are already offered in most local universities and polytechnics. As such Malaysia is well positioned to introduce automation in the mining industry as much as the already automated semiconductor industry.

The implementation of extensive automation systems in a resources operation that is based on conventional operational methods requires a significant exercise in organizational change and development, as its impacts pervade the entire operation. Key changes include the following:

- ***New Roles***

Most automated systems will result in a reduction in the number of manual, repetitive, heavy labour and/or hazardous jobs, and an increase in the number knowledge worker and technician roles. This implies, not only a shift in the skills profile of the workforce but the demographic of the workforce.

- ***Workforce Retraining and Professional Development***

Developing the required skills, including soft-skills that will be required within the workforce will likely involve reasonable investment in workforce training and professional development across all tiers of the organization. This is likely to involve external training providers as well as internally developed operations policy programs.

9.0 CONCLUSION

This chapter has highlighted the Human Capital Development requirement for the downstream, midstream and upstream processes.

For the rare earths downstream innovation and product application development, Malaysia would need to enhance the availability of the needed professional and sub-professional capacity. Initially, there is a need to collaborate with rare earths products development either with institutions in Korea, Japan or Australia to produce engineers with the application of rare earths product development capacity and capabilities. There is therefore a need for demand creation in rare earths innovative product development for the Malaysian graduate engineers to have the necessary innovative capacity and capabilities.

For the upstream and midstream activities, Malaysian Universities need to narrow the gap and to collaborate with the Australian National Universities especially with University of Queensland, University of Western Australia, Curtin University and Murdoch University to enhance the human capital needed for upstream and midstream processes and activities. It is also proposed the setting up **Institute of Critical Materials Technology Malaysia (ICMTM)** (Chapter 10) for upstream, midstream and downstream research activities to develop competencies and expertise in Rare Earths and to collaborate with CSIRO in Australia, KIRAM and KIGAM in Korea, NIMS in Japan and BRIRE in North China. Malaysia should also designate some Universities as Rare Earth Universities similar to Korea.

The future of the mining industry particularly the Rare Earth Industry depends on Automation where there is a need for rigorous safety features typically deployed in harsh environmental conditions to improve Occupational Health and Safety. Mechatronics Engineering, Electrical and Electronic Engineering and Mechanical Engineering are very much sought after for the Mining Industry Automation. Malaysia is well positioned to take advantage of automation in the mining industry as most local universities offer these courses.

The human capital development at the University Level for downstream innovative product development activities and for future mining automation can be met by the existing courses available at most local universities. However, for midstream and upstream activities, collaboration with known institutions identified may be required to narrow the gap of human resources constraints.

At the vocational level, most technical skills needed by the mining industry are available domestically, only those specific to mining and rare earth mineral processing will need to be developed in line with demand and growth. Formal training on mining is still not available locally. Current practice of fresh intakes only undergoing OJT at the mine site is not sufficient for proper well-rounded technical human capital development.

The proposed way forward is by sending prospective vocational instructors or trainers overseas on customized rare earth and mining programs, and then setting up the curriculum, the required labs and equipment in the existing institutions that are deemed suitable. Australian education and training on mineral mining may be adopted.

It is proposed that intensive rare earth training overseas for prospective trainers with good teaching ability and technical background may take up to 6 months for each of mining and rare earth mineral processing area, and another 6 months to set up the required syllabus in collaboration with the overseas provider.

Concurrently, about 12 months are required to setup and equip selected training institutions with lab and equipment. An additional 6-month period is needed to finalize the class theory synchronization with actual lab equipment and obtain approval and accreditation. Hence about 18 months of lead time is required to first establish a vocational program on rare earth industries in Malaysia, once the overseas customized programs are ready, and existing training institutes (probably one or two institutes in Pahang or Perak) could be equipped with the necessary trained teaching staff.

In conclusion, the above proposal can only be realized with high degree of success with political will and financial resources behind such an ambitious program for demand creation, vocational skilled training, exploration and the necessary capabilities for Malaysian to become innovative product developers in rare earth applications, strong in rare earth extraction and processing capabilities and able to determine the rare earth reserves through the use of mining technologies in order for it to become the next growth area for Malaysia.

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SOCIAL AND
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Saleem H. Ali

SOCIAL AND ENVIRONMENTAL IMPACT OF RARE EARTH INDUSTRIES SECTOR

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1.0 INTRODUCTION

The rare earths sector has come under intense public scrutiny in recent years because of a convergence of environmental narratives around natural resource extraction. First, there has been a growth of social movements around mining extraction more broadly which are predicated in resource nationalism as well as environmental activism. Second, there is a growing concern about any materials which have even a remote connection to radioactive pollution. Finally, a legacy of past projects has also played a role in further enhancing distrust between the community and the site developers of such projects.

Malaysian environmentalism around the rare earth sector has been amplified by these aforementioned factors in addition to distrust which emanates from political tensions within the country between various ethnic groups and the transition towards pluralistic democracy. The Asian Rare Earths site which was operated by Mitsubishi at Bukit Merah twenty years ago sensitized the country to rare earth environmental concerns because of mismanagement of various aspects of community relations at the site (Ichihara and Harding, 1995). Although the claims of environmental health damage were initially upheld by the courts, and then eventually refuted by Malaysia's highest court, the absence of a community engagement process led to immense public distrust of environmental regulation and enforcement.

Even though current rare earth mining and processing technologies are very different from the case in Bukit Merah which involved old tailings with monazite from tin mining operations, there is a tendency to conflate the past and the present given the negative history of minimal engagement. The aim of this chapter is to highlight how environmental aspects of rare earth processing is socially constructed by communities and to provide a Blueprint for differentiating risk in socially appropriate ways for Malaysians.

2.0 RARE EARTHS MINING

The mining process itself for rare earths often depends on the kind of ore being processed and the range of accompanying elements which will also be mined. For example, the world's largest and best known rare earths mine in China, Bayan Obo, was originally discovered as an iron ore mine in 1927 and is also one of the world's largest fluorite extraction sites (Zhonxin etal, 1992). The large footprint of mines such as Bayan Obo can clearly have major ecological impact and there is little doubt that environmental concerns have been real and present in this context and been documented. The reduced production by China on environmental grounds during the past 3 years which has been questioned by the United States, Japan and Europe deserves further research but there is little doubt that the scale of the operations in Bayan Obo needed environmental remediation.

An independent research article by the French Newspaper *Le Monde* which was subsequently published in *The Guardian* in 2012 documented through interviews with farmers and local residents of the town of Baotou that the scale of the mining had irrevocably changed the lifestyles of residents. In the village of Xinguang Sancun farmers have abandoned fields and stopped planting anything but wheat and corn and the population has declined from 2000 to 300 within the past 10 years. A study by the municipal environmental protection agency showed that rare-earth minerals were the source of their problems (The Guardian, 2012). The Chinese government has committed $4 billion Yuan ($600 million) to clean-up the damage caused by the rare earths sector in this region according. In 2012, Su Bo, the vice minister for industry and information technology noted publicly that the Chinese authorities were ''absolutely not willing to sacrifice the environment in order to develop the rare earths industry" (Cai and Wilkinson, 2012).

The Mountain Pass rare earths mine in California also faced environmental compliance cost challenges which led to its closure during the 1990s, allowing for the Chinese industry to flourish soon thereafter. However, the environmental issues with reference to Mountain Pass involved leakage of a particular piping system used to carry waste water to an evaporation system. A federal investigation found 60 spills - some unreported - occurred between 1984 and 1998, when the pipeline was shut down. In all, about 600,000 gallons of waste water flowed onto the desert floor. The mine's operator at the time was sued by the San Bernardino County district attorney's and paid more than $1.4 million in fines and settlements. However, since then the current management of the company has changed the waste water system completely and through new technologies tailings will be managed much closer to the mine site with a paste-tailings system to avoid piping of waste water. A field visit by the author to the surrounding areas in January 2013 including interviews with various environmental regulators revealed general satisfaction with the processes being proposed for the site. There is thus far minimal environmental opposition to this site's reopening.

Additional rare earth mining comes from ion-adsorbed clay deposits, particularly in Southern China which also have a considerable environmental footprint in the province of Jiangxi. In 2010 there were 88 rare-earth producers in the province's capital Ganzhou but according to a USGS study 90% of them ceased their operations because of weak prices. Jiangxi Province had a reserve of 2.3 Mt of the ion-adsorption rare earths (Tse, 2011). An interesting development in this sector involves the Aluminum Corporation of China (Chinalco) signing an agreement with the government of Jiangxi Province to allow the company to consolidate the local nonferrous metals producers to take shares of Jiangxi Rare Earth and Rare Metals Tungsten Group Co. Ltd. Involvement of a much larger company with multinational reach will likely provide greater environmental and social scrutiny of the ion-adsorbed clays sector of rare earths as well.

The Mount Weld mine in Western Australia, which is the source of the ore for the LAMP facility in Malaysia is clearly lower impact than either Bayan Obo, Mountain Pass and indeed adsorbed clay deposits, given the small footprint of the mine itself, the remoteness of the location and the kind of ore being mined (rare earth oxides). Communicating the ecological differences between the various types of mine sites is essential to ensuring the social perception of the respective mines is not conflated. However, the connection between mining and the processing steps and the generation of various kinds of residues, including mildly radioactive thorium needs to be addressed.

3.0 PROCESSING

The processing of rare earths elements is a complex process and often involves multiple facilities. As with other metals, a combination of solvent extraction and flotation processes, coupled with some electrolytic processes may be used. Minimal research has been done on the environmental accounting of rare earth processing in terms of recovery. Hardly any empirical data is available on energy usage of the processing. Figure 1 provides one empirical analysis conducted by a postgraduate student at University College London of a mine in China (Bourakima, 2011).

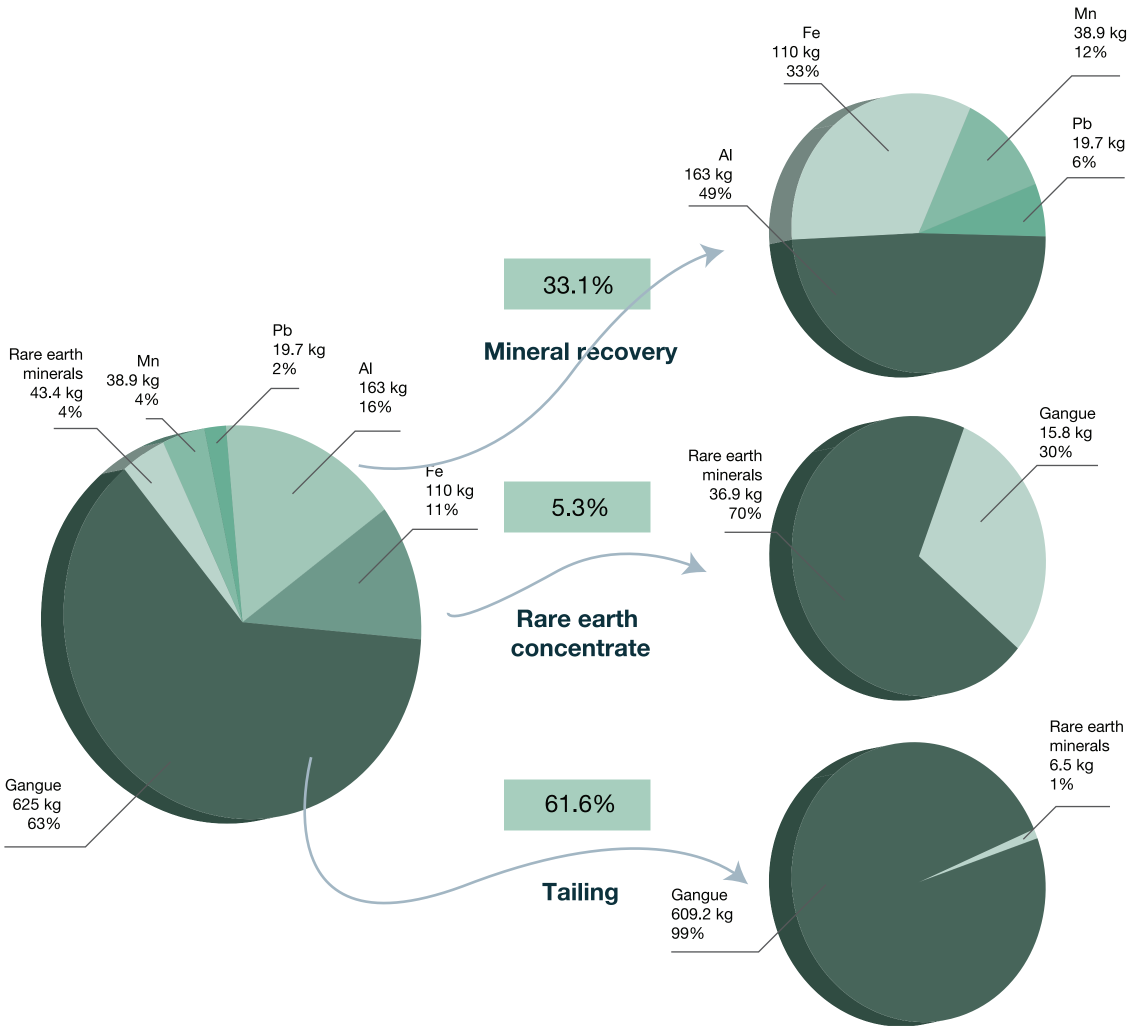

Figure 1: Environmental Accounting Analysis of the Maoniuping Mine China conducted by Bourakima, 2011.

It is worth noting that the amount of gangue produced and much of the concern around pollution concerns emanates from public perception of this wastes material. There is contention on the classification of this material as "wastes" since it has been argued by industry that given the thorium content, the material could be used at a later date for extracting usable products. The categorization of this material as non-residues has regulatory compliance implications since residues management requires an immediate disposal plan whereas potentially useful material can be stored with more flexible compliance mechanisms.

Each ore has a slightly different residues profile and the processing technologies and materials are proprietary at a detailed level. However, for compliance purposes the basic residues produced are generally known. Thus in the case of the LAMP facility in Malaysia, the process will produce some waste water and spent chemicals which will go through a waste water treatment facility before discharge; gypsum; magnesium-content gypsum and iron phosphor-gypsum (with thorium content).

The final product to be shipped to further refiners would be rare earth oxides which would need further processing before being available for manufacturing.

4.0 MANUFACTURING

After initial processing to extract rare earths, there is a specialized chemical refiners sector that produces specific metals which can be used by fabricators for products such as magnets and phosphors. Much of the processing techniques are similar but with a higher levels of extraction precision in smaller units. A Life-Cycle of a typical rare earths operation is provided in Figure 2 which highlights the particular environmental nodes which could be socially consequential.

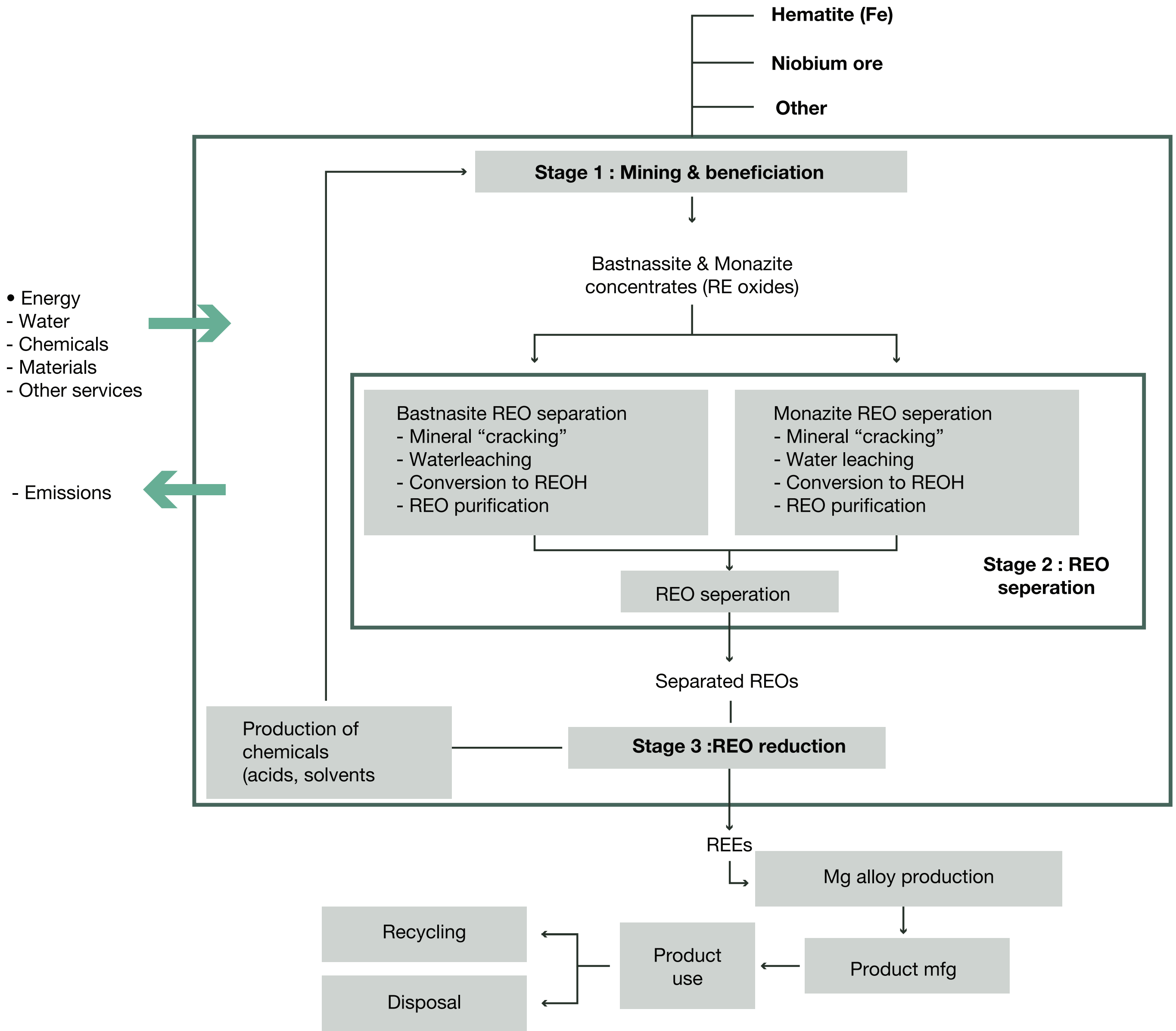

Figure 2: Life Cycle Analysis boundary for the production of rare earth element products (Diagram prepared by A. Tharmarajah and P. Koltun, CSIRO, Australia, 2012). REO=Rare Earth Oxides; REOH= Rare Earth Hydroxide

5.0 RECYCLING

Recycling of rare earths is still quite limited and was calculated in 2011 to be around 1% of supply. Binnemans et al (2013) have done an exhaustive review of the various recycling pathways for Rare Earths and their potentials. There is little doubt that recycled rare earths could reduce the ecological footprint of mining but the cost of extraction from products in which rare earths get embedded makes recovery less competitive. Figure 3 presents the closed loop prospect for rare earths products from which the extraction could be undertaken.

However, the potential for further developing this sector remains uncertain since there is also a competing strategy by some rare earths users to seek alternatives to the materials themselves and hence research and development has been divided between recycling proponents and substitute proponents.

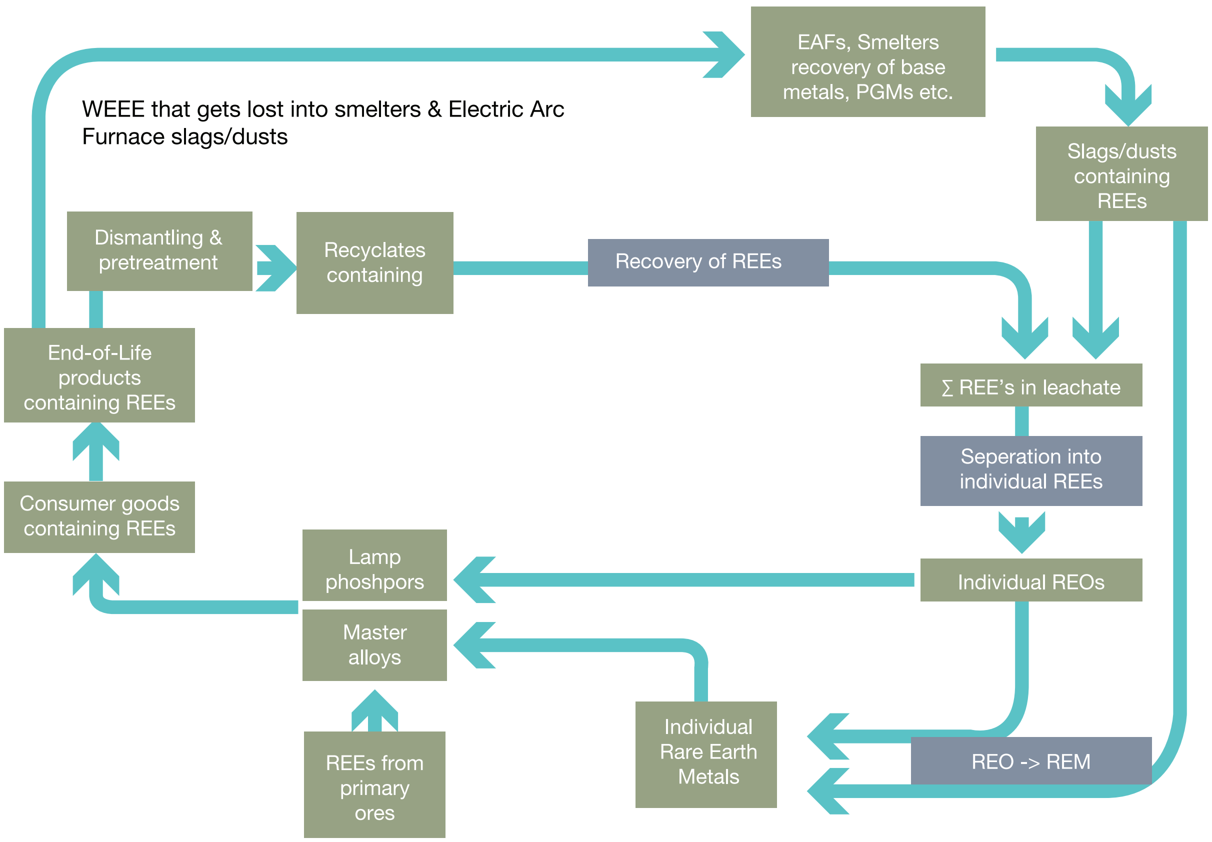

Figure 3: Recycling prospects for Rare Earths and Opportunities for Environmental Efficiency (Binnemans 2013). Acronyms: REE= Rare Earth Elements; EAF=Electric Arc Furnaces; REO=Rare Earth Oxides

6.0 MONITORING

Given the complexity of rare earths supply from mines to markets and the potential for a "cradle to cradle" circular economy approach, the sector requires a deliberate and detailed monitoring system which should be adaptive to technological changes. Monitoring protocols for complex industrial processes are often a key means of assuaging social concerns. In particular, the following 3 areas deserve prioritization for monitoring and enforcement:

6.1 Radiation

Rare earth elements themselves have some radioactive isotopes that need to be monitored based on the ore grade. With several decades of experience of monitoring pitchblende ore for uranium mines, there is potential for good lesson-drawing on radiation monitoring from the uranium mining sector. In particular, the high grade Athabascan uranium deposits in Saskatchewan, Canada deserve attention for comparative protocols on monitoring.

Often the major concern regarding radiation emanates from the processing of the ore which can lead to thorium production. Since the major decay process for thorium involves alpha particle emissions, it is important to have a particular monitoring plan around alpha-emitting sources. Alpha emissions don't travel far but can cause more cellular damage, particularly when inhaled. There is a vast amount of literature on monitoring alpha emissions from radon – a naturally occurring radioactive gas which has caused major public health concerns for indoor air pollution in the basements of North American homes

6.2 Environmental (Air, Water, Soil)

Environmental monitoring of rare earths facilities is similar to most large industrial operations. The use of complex organic and inorganic reagents in processing requires diligence in the waste water treatment system working and having secondary containment in case of failure (such containment is provided in the LAMP facility) and the same is true of the new Molycorp expansion at Mountain Pass, California. Given the history of pipe leakage at the site in the past, far more stringent environmental monitoring has been instated at the site.

Much of the monitoring for environmental harm is undertaken at the refinery level. As noted in a US Environmental Protection Agency report in 2011: "Extracting the ore from the Earth represents only a small portion of rare earth element production. Refining rare earth element bearing minerals into marketable products constitutes the major aspect of rare earth element production." (US EPA, 2011, p. 11)

Carbonate rare earth minerals provide a natural buffer against hyperacidity that may come from various acidic leaching processes in refinement. However, excessive carbonate presence can also lead to alkalinity and therefore pH monitoring of treated effluent is essential.

6.3 Safety

Monitoring of safety considerations at rare earths site follows protocols similar to other industrial establishment in which solvent extraction, electrolytic processes and infrastructure for piping of high intensity chemicals are used. Safety at sites is largely dependent on regulatory compliance and enforcement and rare earth processing sites can occur in close proximity to human habitation as long as there is stringent safety enforcement. French company Rhodia's rare earths processing site in La Rochelle France is a fine example of such a site which is located in a small, closely-knit town with a strong tourist economy and yet because of stringent safety standards there has been no palpable public opposition or any serious safety-related incident. The plant is subject to environmental surveillance by the *Installations Classées pour la Protection de l'Environnement* (ICPE) that has immense experience with monitoring of safety at sites with radiation concerns, given France's major dependence on nuclear power. Safety standards from this site in particular are worth considering as Blueprint for protocols at other rare earth refinement facilities.

6.4 Health

Much of the public health concerns around rare earths emanate from concerns around thorium-containing wastes as a source of radiation. The epidemiological evidence of the impact of rare earths mining is still somewhat limited since much of the processing in China has not been undertaken with publicly available monitoring. The only detailed study of rare earths heal-related toxicity was carried out in the early 1990s by Hirano and Suzuki (1996) and provides data similar to that of heavy metals toxicity concerns. The data on thorium health impacts is also very limited and any negative health impacts monitored are constrained by the fact that sample size in many cases has been too small to make any statistically significant causation (Najem and Voyce, 1990). On-going health monitoring must remain an important part of the overall community engagement plan for the LAMP site, particularly since so much of the environmental conflict has emanated from perceptions of what constitutes an "acceptable dose" of radiation. The public health data can render such arguments redundant if effectively demonstrated that there is no longitudinal health impact over a statistically significant sample size around the plant.

7.0 PUBLIC ENGAGEMENT

Because rare earth mining and processing has been predominant taking place in China for the past 2 decades, the public engagement experience on this sector is relatively limited. The Mountain Pass mine in California is located in a relatively isolated area and although Las Vegas is only 70 miles away and the pit is itself only a few miles from a major interstate highway, the physical location of the mine is hidden behind a mountain range. There has been very limited public interest on broad engagement beyond the environmental and social impact assessment on that project's reopening as well.

Given the lack of history of engagement, the Kuantan site for the LAMP facility had limited precedent to go by in designing an effective public engagement process. There was an underestimation of the level of resistance from residents and the awakening of fervent environmentalism. In any project where a foreign company is locating a complex industrial site remotely from the source of the mine, there can be some degree of suspicion that comes from what environmental scholars have traditionally called "The NIMBY Syndrome – 'Not in my Back Yard.'" This was clearly the case with the Kuantan site where the perception of the site being located in Malaysia far from the Australian mine raised suspicions among activists which were initially not adequately addressed. For example, there was spread of misinformation about the site not being permitted in Australia for environmental reasons.

However, a proactive policy of public engagement was initially not followed. Indeed, with rare earths sites, the importance of public engagement has now become more acute because the wider public has started to associate rare

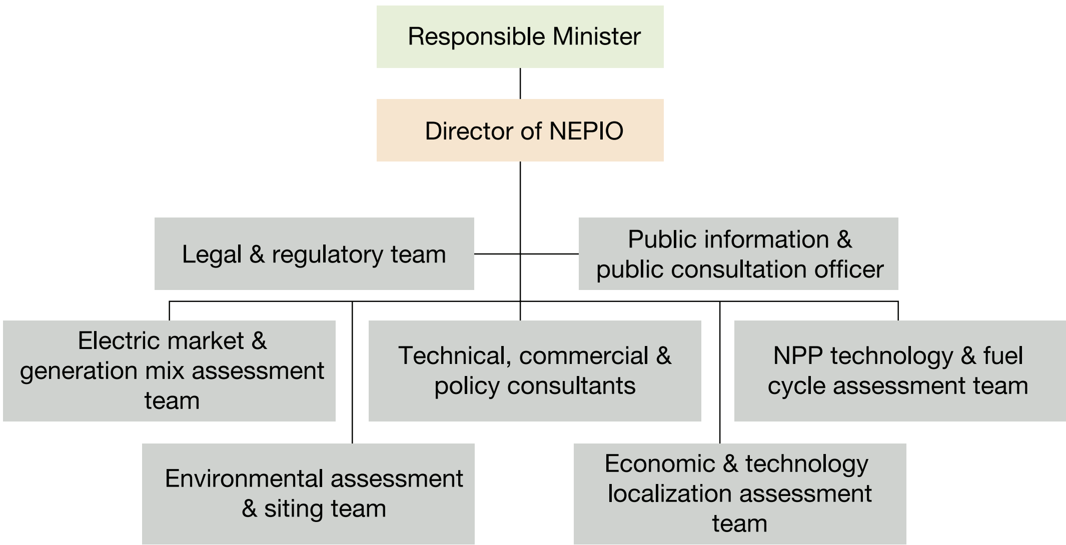

Figure 4: Structure of Korean Nuclear Energy Program Implementation organization (Choi et al, 2009)

earths with nuclear residues following greater Malaysian activism and their alliances with European and Japanese anti-nuclear groups. Some lessons of how to approach public engagement in this particularly polarized context can be learned from the Republic of Korea.

8.0 KOREA’S APPROACH TO NUCLEAR

An example of how public engagement around an environmentally charged development has been undertaken at a national level comes from the Republic of Korea’s experience with nuclear power development. Given the high degree of industrialization in Korea and the rapid rise of affluence, there has been concern about environmental fall-out and its impact on quality of life. While recognizing the need for stable energy sources, Koreans showed trepidation with the development of nuclear power. Valentine and Sovacool (2010) have documented how the social ethos around nuclear development of South Korea evolved with reference to their history of conflict and their familiarity with experiences in Japan.

The government’s approach to public engagement and the organizational issues which they covered in this approach have been studied in detail by Choi et al (2009). Figure 4 provides a schematic of the organizational structure of government communication in the country around 2007 which was suggested through International Atomic Energy Agency (IAEA) guidelines in response to growing environmental resistance to siting of nuclear residues sites in the country.

After the Japanese tsunami and the ensuing disaster at the Fukushima nuclear plant, Korean public sentiment towards the operating 23 nuclear power-plants has deteriorated. An investigation found nuclear plants were using components with faked safety certificates which led to the dismissal of Kim Kyun-seop, the head of state-run Korea Hydro & Nuclear Power Company.

President Park Geun-hye has said that it “would review the role of nuclear power to reflect “social acceptability” in its energy plan due by the end of 2013.” The Korean government had planned to build more reactors to cope with electricity demand it forecast to surge almost 60 per cent by the year 2027 but surveys show nuclear power is becoming increasingly unpopular. 63% of respondents to a March 2013 survey by pollster Hangil Research said they consider domestic reactors “unsafe,” compared with 54 % in a poll conducted a year earlier by the non-profit Korean Federation for Environmental Movement (South China Morning Post, August 10, 2013).

Given the previous sound record of the Korean government managing public engagement in this sector, it will be an important case to follow of how the current discontent on nuclear power and siting of power plants is managed by the government as a means of drawing lessons for countries like Malaysia.

9.0 CONCLUSION

The social component of sustainability can be defined as those components relating to the physical and psychological well-being of humans within society. In this case we include both the individual and social network elements which could be separated – for example under a “five capitals” approach. Recently socio-environmental issues of the health impacts of Rare Earth processing (from both radioactive and non-radioactive contamination) in areas of China has been raised as a major concern. The question of whether sites that have been contaminated by rare earths mineral processing can be adequately rehabilitated to allow for other uses post-mining from a social sustainability perspective is linked to perceptions of health risks and the technical ability to rehabilitate contaminated sites. The potential for such impacts has also been one of the key drivers behind protests at the Lynas Corporation plant in Malaysia, partially fueled by the negative experiences that a previous rare earths processing site on the peninsula.

Social resistance to rare earths mining also stems from arguments about environmental justice and how processing sites are often more difficult to get permitted in developed countries and hence lead to their location in developing countries. Indeed, environmental regulation was one key reason for the closure of RE operation in the USA. Much of the resistance to the Lynas plant in Malaysia questioned whether the choice of Lynas to situate the site in Malaysia was for purely economic factors or because social resistance in Australia would have been far too great. Assuaging such perceptions of differentiated standards and environmental justice concerns will be key in preventing escalation of socio-environmental conflict.

On the other hand, there can be a social argument made for rare earths development as a contribution towards developing a "green economy". The Malaysian industrial park in Kuantan has made this case in their branding of the initiative as part of national planning effort towards sustainability. Social perceptions of risk at the site level thus need to be balanced with broader national trajectory towards sustainable technology development in determining the social sustainability of the rare earths sector. Furthermore, recycling and service sector opportunities for this sector have much potential for development as technologies improve for micro-retrieval of the metals. There is likely to be less social resistance as efforts towards a circular economy for rare earths develops alongside their green economic uses in products.

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POTENT
IMPACT OF
INDUS

IAL ECONOMIC
RARE EARTHS
STRIES SECTOR

Ramli Bahroom
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POTENTIAL ECONOMIC IMPACT OF RARE EARTHS INDUSTRIES SECTOR

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1.0 SUMMARY

This chapter is to assess and evaluate the economic impact of establishing the total rare earths supply chain industry in the country to the Malaysian economy. As explained in Chapter 4 in this Blueprint, rare earths are used in many modern technologies and industries, such as magnets, lighting, glassmaking, disk drives and hybrid cars. The demand for rare earths has expanded dramatically over the last two decades with an exponential growth of hand-phones, computers and DVD markets. China is currently producing more than 90% of the world production of rare earths elements (REEs).

As had been pointed out in Chapter 4 of this Blueprint, the rare earth industry in Malaysia is not new having been established in 1976 with the establishment of the Malaysian Rare Earth Corporation (MAREC) which had started operation about 37 years ago. In 2011, the Malaysian Government had approved the construction and operation of a rare earth processing plant in Gebeng, Pahang, owned by the Australian Corporation Lynas, better known as Lynas Advanced Materials Plant (LAMP). The company started operations in 2013. At full capacity, the Lynas' Malaysian facilities could produce up to a fifth of annual global output—making the company potentially among the world's biggest light rare-earths suppliers (Hoyle, 2013). It has also been reported in Chapter 2 that potential reserves of rare earths-bearing minerals occur in parts of Peninsular Malaysia. These have led to a need to re-assess and review the expected contributions that mining, processing and rare earths-based industries would bring to Malaysia at both local and national levels. The International Council of Mining and Materials (2012) outlined in their report key factors determining the contribution of mining to the national economy such as availability of local supply capacity, infrastructure, local educational attainment, fiscal and revenue sharing policies and the strength of the financial domestic sector.

Therefore, there could be expected contributions of the rare earths-based industries to the Malaysian economy on the basis of foreign direct investment (FDI), national income (GDP), exports, expected employment and Government revenue. The expected minimal contributions of the rare earths (REs) industry to the national economy in terms of FDI, GDP and estimated employment are 2.4% (RM1.5 billion), 1% (RM 10.137 billion) and 0.04% (5000 jobs per annum) respectively by year 2020. Although tax incentives have been given to LAMP as a pioneer industry, in the short and long terms, the revenues accruing to the Government will be quite substantial. Even with the pioneer status accorded to LAMP for 12 years, LAMP's contribution to the national economy, in terms of paying for utilities, chemicals, wages, and so on, is substantial. It was reported in LAMP's 2013 Annual Report that LAMP's investment in Malaysia had amounted to some Ringgit Malaysia 2.94 billion while operational expenses amounted to some RM380 million.

With Malaysia's good infrastructure, reliable and cost-effective utilities and availability of expert labour as well as stable policies and a strong political base, the country is attractive for the revitalization of the mining industry and the establishment of a full of rare earths supply chain industry. Malaysia needs this new industry as a new source of economic growth to spur the nation move forward towards becoming a developed nation by 2020. The rare earths industries have the potential to contribute to the future economy and well-being of this country.

2.0 SUPPLY AND DEMAND FOR RARE EARTHS

As mentioned in Chapter 1 of this Blueprint, the demand for REEs has expanded dramatically over the last two decades with the exponential growth of hand-phone, computers, and DVD markets. Many rechargeable batteries, important in the production and use of cell phones and laptops, are manufactured with REEs. Moreover, with demand for REE's increasing in a myriad of high-tech markets, it is envisaged in future that green technology applications such as hybrid cars and next-generation wind turbines will drive double-digit market growth for REEs. As a result of a rapid growth of these new technologies, this has lead to a significantly increased demand for REEs.

In 2010, an estimated global demand totalled 136,100 tonnes, while global production totalled 133,600 tonnes annually (http://www.fas.org/sgp/crs/natsec/R41347.pdf). By the year 2015, it is estimated that the global demand of rare earth to reach anywhere from 185,000 tonnes to 210,000 tonnes of REEs per year. U.S.A's demand for REEs as it is for many industrialized nations are expected to increase in tandem with global demand. For example, demand for permanent magnets are predicted to grow by 10 to 16 percent over the next several years and demand for REEs needed in auto catalysts and petroleum refining will increase by 6 percent and 8 percent, respectively, during this time (Broken Mountain Rare Earth Mine Economic Impact Study, 2013).

Some examples of the commercial uses of Rare Earth Elements are given Chapter 3.

In August 2012, the first phase of the LAMP was completed to accommodate 30,000 tonnes of raw materials that are shipped from the Lynas Corporation Mount Weld mine site in Western Australia. It is envisaged in future that the processing of the raw materials will see the Lynas plant produce rare earth oxides at 11,000 tonnes per annum. The second phase of the LAMP project is still being constructed and when completed, the production of Lynas rare earth oxides will be doubled in terms of tonnes produced per annum.

The Academy of Sciences Malaysia and the National Professors' Council (2012) identified two important drivers for the rare earths industry in Malaysia:

1. The rare earths industry can contribute to and support the development of a green economy both domestically and globally,

2. As a nation, Malaysia will significantly benefit from the contribution of rare earths to the global market. This is an important factor to consider as the global supply of Rare Earth Elements (REEs) is dominated by China (approximately 97 per cent of global production).

With the growth in advanced technologies and a myriad of perceived benefits, the Rare Earths industry is seen as a promising new growth area under Malaysia's New Economic Model and the 10th Malaysia Economic Plan. The Rare Earth industry can be one of the drivers in transforming the country to be a developed nation by 2020.

3.0 RARE EARTHS INDUSTRY IN MALAYSIA

The rare earth industry in Malaysia has been the focus of intense political scrutiny, social activism and media interest during the past 2 years, in light of the Malaysian Government's approval of the construction and operation of an AUD$1 billion(RM3.3 billion) rare earths processing and refining plant at Kuantan in Pahang State (Reconciling Rare Earth in Malaysia, 2013). This facility is owned by Australian corporation Lynas and commonly referred to as the "Lynas Advanced Materials Plant" (LAMP).

4.0 ECONOMIC IMPACT

This section of the chapter will provide an in-depth assessment of the economic impact of the full supply chain rare earths industry in Malaysia.

4.1 Contributions of REE Industry-Overall

The expected contributions of the full supply chain rare earths industry in Peninsular Malaysia can be assessed at the national and local levels. The national levels are assessed by economic and social outcomes. A macroeconomic assessment will be made at national level. At local level, the rare earths industry is assessed by evaluating job creation opportunities in local communities through direct and indirect employment.

Table 1 below outlines the value of rare earths' contribution to the local economy and this depends on the overall value of production and the payments to production factors including financial capital, equipment, land and labour (ICMM, 2012).

The main areas of rare earths' (RE) contributions to the national economy are shown in Figure 1. The top line demonstrates that the greatest benefit RE affords to these national economies is not government revenue, but rather the contribution to foreign direct investment (estimated percentage of contribution of RE Industry to FDI is 1.53% and 2.40% in 2015 and 2020, respectively).

As in any typical mining operation, the top four segments of contribution (foreign direct investment, national income measured by GDP, employment and government revenue) accrue to national governments. Only the contribution from employment can be said to directly benefit local communities.

Table 1: Main Components of RE's Production Value

Main components of production value	Examples	Key factors determining contribution to the national economy
1. Operating expenditures	Consumables (fuel, power, tyres, reagents, water, transport); light engineering works	Availability of local supply capacity; infrastructure; enabling business environment; industrial policy
2. Salaries and wages	After-tax payment to labour providers; salary withholding taxes	Local educational attainment; availability of suitable skills; education policy
3. Capital expenditures (investment and depreciation)	Machines and equipment	Sophistication of host country industrial base
4. Taxes	Royalties; corporation tax; variable profits taxes	Fiscal regime and revenue sharing; strength and transparency of public sector financial management (expenditures)
5. Financing costs	Interest payments on short and long-term loans	Strength of domestic financial sector
6. Profit for shareholders	Dividends to shareholders (includes both private and government investors); share buy-backs; retained earnings	Degree of national ownership of mining sector (direct or through government shareholdings)

Source: ICMM, The role of mining in national economies: Mining's contribution to sustainable development, October 2012

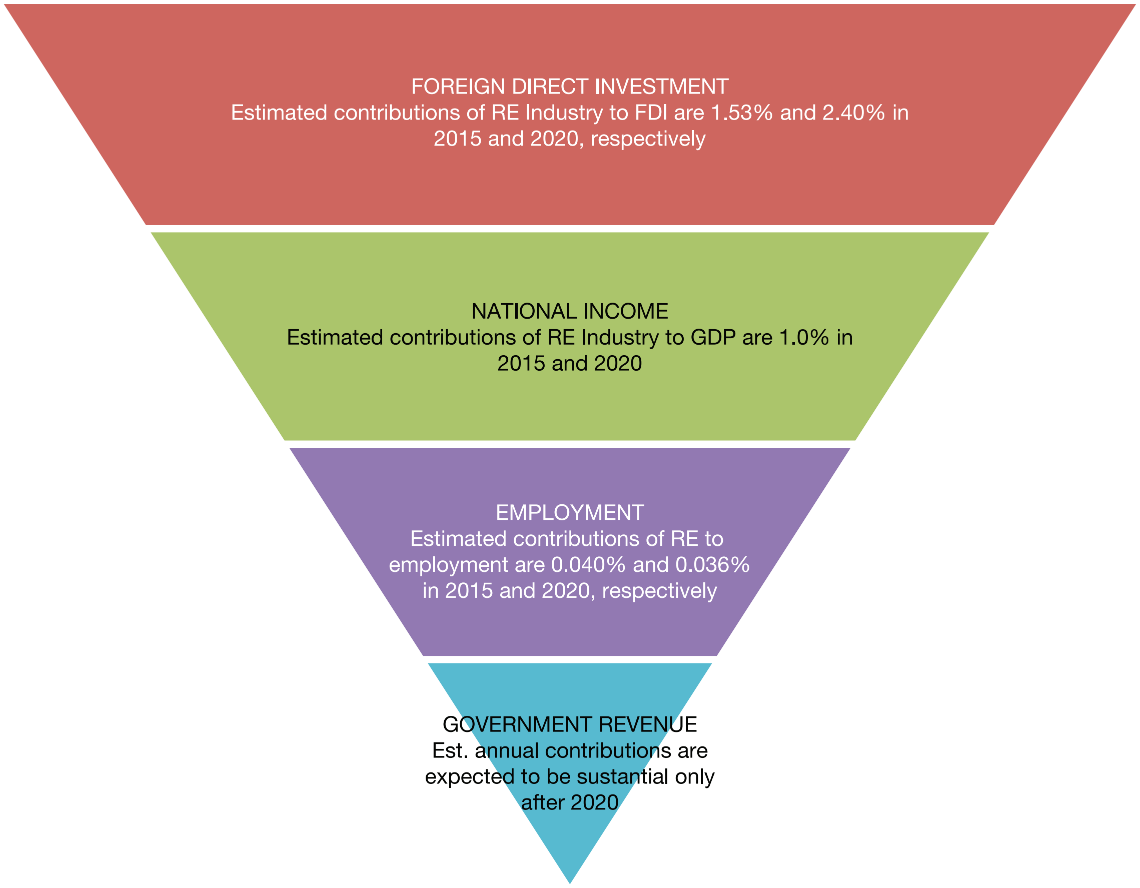

Figure 1: Macroeconomic Contributions of RE to the National Economy of Malaysia

4.2 Contributions Of the Rare Earths Industry At National Level

The contributions of the RE industry to Malaysian economy are elaborated as follows:

4.2.1 Foreign Direct Investment

Based from a World Bank Report, foreign direct investment (FDI) into Malaysia was RM38.312 billion in 2010 (World Bank, 2012). Based on this figure and an assumed growth rate of 5% per year, FDI inflows in to Malaysia is estimated to be RM48.897 billion and RM62.407 billion in 2015 and 2020, respectively.

Based on the experience of Lynas's setup costs of AUD514.5 million (RM1.5 billion over 2 years (2009-2010) (Economic analysis of LAMP: More precious than rare earths, 2013), it is estimated that the total investment required for just the processing and refining aspects of the rare earths industry in Malaysia would be RM10.0 billion to be spread over the next 10 years, or RM1.0 billion per year. This amount represents 1.53% and 2.4% of the average annual FDI inflows to the national economy for 2015 and 2020, respectively. The assumption is total investment are sourced 75% from outside the country.

4.2.2 National Income (GDP)

Malaysia would be an attractive country to invest, especially for developed countries like Australia. This is because salaries and wages in Australia are higher than it is in Malaysia. Many companies would be interested to invest in this industry because of the attraction of a skilled but reasonably priced labour force. Due to this, RE can be produced more cheaply in Malaysia and Malaysia can achieve a competitive advantage in the refining of RE. The selling of RE would not be a problem because many countries, for example, Japan would buy RE due to their downstream activities.

The contribution of mining and quarrying sector to GDP in Malaysia has been projected to decline to about 5% in 2020 (National Economic Advisory Council, 2010). Considering that RE industry is a new entrant to the mining sector, it is estimated that its contribution is 1.0% of GDP (or, RM10.137 billion) in 2020.

4.2.3 Exports

The income of the nation will improve through the increase in value added exports of rare earths minerals and downstream products. Malaysia exports of RE is predominantly in two minerals; monazite and xenotime. There has been an increase of these two minerals from year 2003 through year 2010 (ASM, 2013). Monazite and xenotime are found ubiquitously in Perak and Selangor, especially in the former Kinta and Kuala Lumpur tin fields, as a by-product of alluvial tin mining. However, as these two minerals contain much of the high-value and highly-sought heavy rare earth elements (HREEs), it is recommended that these two minerals not be exported but chemically processed locally and the HREEs extracted for use in local downstream industries. A word of caution is that monazite which has high (radioactive) thorium content thus, making it not an attractive resource. Monazite may be exported but xenotime should preferably not be exported but be utilized locally as xenotime contains much less radioactive elements compared with monazite.

Rare earths have become a commodity that is necessary in many products that is of strategic importance to many countries especially the industrially advanced countries. For example, rare earth magnets demand is expected to increase by 10% to 16% per year through 2012 (ASM, 2011). The strategy of the policy makers should therefore be realigned towards establishing mid-stream and down-stream RE industries in the country where value-adding can be enhanced.

In terms of pricing, one source reports that, since the first quarter of 2013, the “basket-price” or weighted average price of rare earths had declined by 13% from that of the previous three months to US$37.22/kilogram (Lynas Holds Back Rare Earth Production, 2013). Another source reports that the price is estimated to be US$41.00/kilogram (Topstocks, 2013) Based on these two recent sources, it is estimated that the average price of rare earth, in the near term, is US$40.00/kg and, using this price and a multiplier of 3.0 to reflect the upstream and downstream sectors of the industry, the total exports of rare earth elements (RRE) are estimated to be RM4.224 billion and RM8.448 billion in 2015 and 2020, respectively. This represents 0.52% contribution of rare earth to Malaysia’s in 2015 and 0.76% in 2020.

4.2.4 Government Revenue

In order to vitalize the industry, tax incentives such as fiscal incentives, investment tax allowance and pioneer status will be given by the Malaysian Industrial Development Authority (MIDA, 2010) as per Appendix II.

Given the above generous incentives by the Malaysian Government, revenues generated from rare earths-based industries will be exempted from corporate income taxes for at least 10 years, thus giving no revenue income to the Government in those years. The revenue from personal income taxes from salaries of employees of the industry will be minimal.

4.3 Contributions of REE Industry at Local Level

The contributions of REE industry at the local level are summarized as below;

4.3.1 Employment

Since large-scale mining is capital intensive, employment opportunities of 4,000-5,000 workers is estimated in this sector. Employment is created by indirect employment opportunities, such as in the logistics and transportation sectors where minerals need to be transported from the mines, for example.

Based on the above direct, indirect and induced employment creation, the RE industry is estimated to contribute about 0.040% and 0.036% (or, about 5,000 workers) of total employment in Malaysia in 2015 and 2020, respectively.

As mentioned in the earlier section, employment opportunities in the mining sector will be favourable. In whichever stage, Malaysia decides to enter into this industry whether upstream, mid-stream or downstream activities, this will give rise to development in human capital in terms of expertise/ know-how and the development and training of skills in mineralogy, mining or mining processing. In terms of research and development, the types of professions or skilled labour required are; geologists, geophysicists, mining engineers, mineral processing engineers or mineral technologists, geochemists and skilled labour in mining and mineral processing. There is also a need for supporting professionals in the field such as analytical chemists, mechanical and electrical engineers and environmental scientists. Hence, there is a need to develop and enhance the existing human capital availability by offering more university courses in mining engineering, for example. Presently, Universiti Malaya (UM), Universiti Kebangsaan Malaysia (UKM), Universiti Malaysia Kelantan (UMK), Universiti Malaysia Sabah (UMS) and Universiti Teknologi Petronas (UTP) all offer courses in Geology. Universiti Sains Malaysia (USM) offers majors in mineral resource engineering and produces mineral resource engineers with about 30-40 graduates per year. So far, USM has produced some 300-400 graduates (ASM, 2013). Skilled and able mining engineers are however in short supply not just in Malaysia but worldwide. Where the skilled workforce is concerned, there needs to be some restructuring and retraining of workers. Currently, the mining worker population in Malaysia represents an upside-down pyramid where there are many engineers and professionals like geologists etc at the top of the pyramid. Technical workers represent the middle part of the pyramid while the numbers of actual miners or skilled workers are minimal.

Malaysia should restructure this mining working population into a proper pyramid where engineers and geologists are only a minor portion at the top of the pyramid; technical workers remain at the middle of the pyramid while there should be an expansion of skilled workers at the bottom of the pyramid. Mines would need properly trained mining professionals who could be trained in local polytechnics or community colleges (preferably) or in colleges overseas, such as in Western Australia (Chapter 6) so that they are equipped with the proper knowledge in mining and would be able to carry out and adhere to proper mining, health and safety regulations. All these occupations are of the high-income types.

The recommended structure is shown in Figure 2.

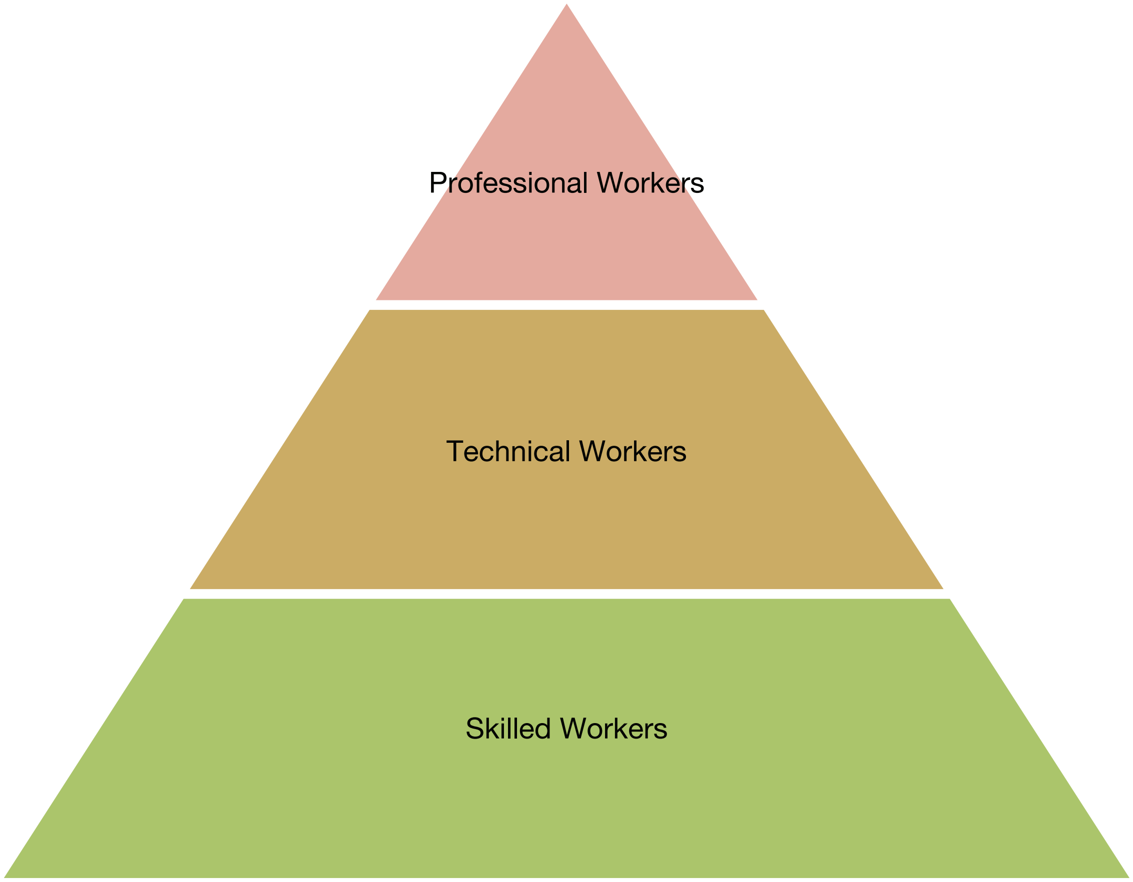

Figure 2: Recommended Structure of Employment in the Mining Industry

4.4 Procurement of Local Goods and Services

Formation of industries that are indirectly related to the RE industry, especially in the downstream activities of high-technology industries, are in information technology (IT); new advanced batteries, magnet and optoelectronics technology, miniaturization of electronic products, magnets, hard disks, metal alloys, computer memory chips, laser amplifiers and fibre optic communication cables, to name a few. This downstream sector also covers other technological sectors such as aerospace, aviation, electronic, energy, medical and health and so forth. For example, RE is used in cell phones, computers and DVDs and many rechargeable batteries use RE compounds. Such spin-off industries could lead to a spawning of SME's in this sector that could be capitalized by local entrepreneurs. It would provide a multitude of business and commercial opportunities for local entrepreneurs.

4.5 Entrepreneurship

The other indirect benefit is that this industry will stimulate local entrepreneurship in the country. Local entrepreneurs could capitalize on the RE industry in the form of exploration or mining activities or in midstream (processing) or downstream activities in terms of producing consumer products that are related to RE. As a result of this, there would be a spawning of small and medium scale enterprises and larger vendor companies in the industry.

4.6 Regional Vitalization

The revitalization of the rare earth industry will mean that there will be an increase in business activities related to the industry. The increase in mining activities will mean an increase in infrastructure development especially if the designated area is not very developed. Infrastructure development includes provision of transportation facilities such road systems, ports and utilities such as electricity and telecommunication lines. This can lead to the springing up of new townships in which there is a need for the development of housing, schools and hospitals for the local population. Regional areas would be re-vitalized spurring economic growth for the area and an influx of population increasing.

Production of consumer products related to RE will stimulate activities such as manufacturing, logistics, marketing and selling. These will result in an increase in human capital employed and also in increases in investments and profits – all of which will promote economic growth for the country.

4.6 Partnerships

As in any business activity, the revitalization of the rare earths industry will also promote possible collaborations amongst stakeholders. Venturing into downstream activities will mean collaborations amongst industries that are using RE components in Malaysia. Collaborations amongst regions, and countries, could also be forged as there are vast opportunities to produce RE products either in Malaysia or in other neighbouring countries.

4.7 Revitalization of Mining Industry

The Rare Earths Industry can be considered to be tied with the mining industry in Malaysia. For example, the Lynas Plant in Kuantan imports RE concentrates from Mt. Weld mines in Australia. Historically, the mining industry in Malaysia is entrenched in tin mining as evident by the many abandoned tin mines in the country, many of which have now been converted to resorts and nature reserves as well as retention ponds, all now serving an important economic function. The few remaining tin mines in Perak attest to the country's once-held supremacy in tin mining in the country. The Malaysian tin mines were either reduced or abandoned due to various reasons such as drastic reduction of world tin prices. With a regulated environment in mining and with a developed health and safety regulations in place (Chapter 8), mines could be re-opened again. Sophisticated technology, such as the use of robotics, has improved the efficacy and reduced costs of mining and changed the face of mining today. This would ultimately lead to the revitalisation of the mining industry in Malaysia

Historically, Sungai Lembing in Pahang had been the hub of tin mining (the deepest hard-rock tin mine in Malaysia) in the eastern part of the country but since the mine closed, the town of Sungai Lembing has become a sleepy off-the-beaten track small town with just a few sundry shops and food stalls. Lately, however, with the transformation of a mine being partially opened and the establishment of a Museum opened to the public as a tourist attraction, Sungai Lembing has been able to attract visitors. This is a good example of a government initiative that has resulted in a small boost in local tourism that has inadvertently led to an improvement in the local economy. Because of the many visitors especially in the weekends, new food stalls have opened in the centre of town with home stays set up by the local population seen cropping up in the vicinity. Therefore, Sungai Lembing is a testimony on how a declining or dormant industry can revive a township. As such, if there is a re-opening of the mine using the latest technology of mining, this could act as a catalyst for the tin mining in the area. Skilled workers would pour into the area causing, in turn, an increase in consumer spending and consumption in terms of housing, food and so forth. Due to spin-off industries being created, such as various SMEs in the downstream industries, this spill-over effect would positively affect areas like Panching, Gebeng and Pelabuhan making these areas even more attractive for development and investment. Malaysia has the necessary resources that are vital for mining; cheap electricity and water, a skilled workforce and good infrastructure.

5.0 GREEN ECONOMY

The RE industry has the potential to contribute to the green economy. There has been growing global interest in green technologies to mitigate the threat from climate change has given rise to a cluster of business opportunities together dubbed the “green economy”. The green economy has also expanded beyond just green products to also encompass green services. But the basic tenets of the green economy remain. It is about low carbon, less pollution, renewable and clean. The projection is that as more and more consumers embrace green purchasing, and as more governments practice green procurement, the demand for green products and services is set to witness exponential growth in the coming years. Practically speaking, a green economy is one whose growth in income and employment is driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services. These investments need to be catalyzed and supported by targeted public expenditure, policy reforms and regulation changes. This development path should maintain, enhance and, where necessary, rebuild natural capital as a critical economic asset and source of public benefits, especially for poor people whose livelihoods and security depend strongly on nature.

The use of rare earth elements in IT has increased dramatically over the past years. New advanced battery, magnet and optoelectronics technology is dependent on the use of these rare earth metals. Rare earth magnets are small, lightweight, and have high magnetic strength and so have become a key part of the miniaturization of electronic products. The key rare earth metals in magnets are neodymium, praseodymium and dysprosium. For example, neodymium is an important metal for hard disks. Another major use of rare earth oxides is in metal alloys. High-performance alloys involving rare earth metals have important uses in computer memory chips. Rare earth metals (particularly erbium) also act as laser amplifiers in increasingly important fibre optic communication cables.

It has been reported by Steven Chu, the United States Secretary of Energy and Nobel Laureate (ASM, 2010), that the green economy is vulnerable to rare earth minerals shortages. For example, many new and emerging clean energy technologies, such as the components of wind turbines and electric vehicles, depend on materials with unique properties, such as available in rare earth elements. The availability of a number of these materials is at risk due to their location, vulnerability to supply disruptions and lack of suitable substitutes. China supplies some 97% of global demand of REE.

In recent years, China has been consolidating its rare earth industry and reducing its production and export quotas in an attempt to retain more of these minerals for domestic use as well as to regulate the sector and clean up the industry, which creates air and water emissions and seepage from tailing ponds, and has social impacts on local villagers in rare earth mining areas. As an example, in 2011, the Chinese government had cut its export quotas for rare earth minerals by more than 11 per cent (China Daily 2010), which reduced the supply of REEs needed in other countries for high-tech products. To conclude, the use of rare earths in the full supply chain industries is another way forward to a green economy whereby revitalising the mining industry would mean paving the way to a richer Malaysia.

6.0 KEY SUCCESS FACTORS

The following key factors have been identified that determines the successful revitalization of the RE industry in Malaysia as below:

6.1 Government Support

One of the key determinants in the success of a particular industry is the role of the government. The government can establish an Institute of Critical Materials Technology Malaysia (ICMTM). ICMTM plays the roles pertaining to advanced and critical material and the relevant industry sector. Furthermore, ICMTM should be structured and organized in such a way that it is industry-driven and with at least half of its board consisting of members from the industry. The government should also provide incentives to revitalize the RE mineral industry by provision of the necessary funding to enable Minerals and Geoscience Department to undertake reconnaissance and follow-up exploration and related R&D programmes to identify potential RE resources (Chapter 2). Funding can be also in the form of provision for the support activities in human capital development. For example,- polytechnics, technical and community colleges can play a big role in developing skills, competencies and know-how for operational and technical staff for the mining and mineral sector. The government could encourage and promote more university courses in this field. Greater attention should also be given to RE-related subjects in the university curriculum. In addition, attention should be given by the government to upgrading the expertise in this sector by sponsorship of students, academics and government scientists for post-graduate studies in RE-related fields and establishment of bilateral and multilateral relationships with countries traditionally strong in the RE sector so that Malaysians can upgrade their knowledge and expertise through various training programmes.

Secondly, the government can give fiscal incentives to lower the cost of production in this sector. Additionally, incentives, fiscal or otherwise should be provided to local entrepreneurs and companies undertaking incentives towards investments in RE projects that will benefit the country. Thirdly, the government should organize (and sponsor) outward investment missions to seek opportunities in RE mineral development projects. Favourable government policies in terms of investment, taxation and incentives could be enacted to enable and to promote the mining and mineral sector to be a viable sector in Malaysia. Promoting the sector as a National Key Economic Area (NKEA) would result in much commercial interest in the industry as of strategic significance to the economy. Government policies needs to promote RE industry as a new economic growth area which help fuel the country's drive to achieve a high income status by 2020 as articulated in the New Economic Model (NEM) and the many supporting Economic Transformation Plans that the government has recently launched.

The government can use existing policies and regulations framework (Chapter 8) to enable the functioning of the rare earths business without compromising on the safety and health of the people and the environment. Furthermore, the government can undertake a coordinated, comprehensive and continual public awareness program and by pursuing regular engagement with the community on the risks and opportunities of the industry. Consequently, media interest and favourable publicity of the industry would be generated that will dispel or decrease the negative perceptions of the public towards the industry in the country.

6.2 Availability Of Expertise

As in any business venture, human capital in the form of expertise is integral to the success of the RE industry in Malaysia. There is now a global surplus of rare earth experienced exploration geologists and rare earth mining engineers. There are a number of local universities providing courses in Geology with USM offering courses in mineral processing engineering (Chapter 5). Canadian, American and Australian universities have also been educating students in these specialties for generations and seem eager to cooperate in exchange programs. In addition, rare earth process engineering studies outside of China have blossomed in the last 5 years in particular and trained specialists in this expertise are readily available in the marketplace.

7.0 CONCLUSION

In conclusion, Malaysia needs a new industry to move forward into the future. RE Industry does show potential in terms of global demand due to its increasing use in IT and other downstream sectors such as magnets, batteries, lighting and so forth. Malaysia does possess the key success factors for the successful development of RE industry and revitalisation of the mining sector, namely, infrastructure, availability of labour and cheap cost of utilities.   Malaysia also has reserves of RE deposits that are currently unexplored. At both national and local levels, RE industry is expected to contribute 2.40% of FDI, 1.00% of GDP and 0.04% of employment to the country in 2020. The contribution to revenue will only be significant after 2020. This shows that the country will derive some benefits from the RE industry. In addition, the industry will also contribute towards the green economy of the country.

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Appendix I: Estimated macroeconomic contributions of rare earth industry to the Malaysian economy.

	2010	2015	2020	Growth rate 2011-2015	Growth Rate 2016-2020
FDI (RM million)					
Total FDI	38,312	48,897	62,407	5.0%	5.0%
Estimated investment in Rare Earth industry (local & foreign)		1,000	2,000		14.9%
FDI from Rare earth (estimated at 75%)		750	1,500		14.9%
% of FDI from RE (1)		1.53%	2.40%		
GDP (RM million)					
Total GDP	538,069	727,510	1,013,691	6.1%	6.9%
Total Mining & Quarrying	41,887	44,309	46,615	1.1%	1.0%
% of M&Q	7.8%	6.1%	4.6%		
Anticipated contribution from RE to GDP		7,275	10,137		6.9%
% Contribution to GDP from RE (2)		1.00%	1.00%		
Employment (thousand)					
Employment Malaysia	12,029	12,357	13,981	2.4%	2.5%
Anticipated employment from RE		5	5		0.0%
% of employment from RE (3)		0.040%	0.036%		
Revenue (RM million)					
Total Revenue	165,800	216,700	276,570	6.1%	5.0%
Anticipated revenue from RE (e.g. Personal income taxes)		45.0	54.0		3.7%
% of Revenue form RE (4)		0.02%	0.02%		

Sources: EPU,World Bank and National Economic Advisory Council, New Economic Model: Part 1 (2010)

Notes:
(1) Percentage of FDI from RE is the ratio of the annual FDI from RE to total annual FDI into Malaysia for the period.
(2) Percentage of contribution to GDP from RE is the ratio of the annual contribution to GDP from RE to total GDP of the country for the period.
(3) Percentage of employment in RE is the ratio of the employees in RE to total employed workers of the country for the period.
(4) Percentage of revenue from RE is the ratio of the annual tax revenue from RE to total annual revenue of the country for the period.

Appendix II

Incentives Given by Malaysian Industrial Development Authority (MIDA), 2010

1. Fiscal incentives

Tax incentives should be given to lower the cost of production. More land should be made available for exploration and mining. Mining should be a promoted activity and, therefore, enjoy the appropriate incentives. The rare earths mining, and the related mid-stream and downstream industries, should be identified as a National Key Economic Area (NKEA) (ASM, 2013**)**.

It is recommended that, as the mining of rare earths elements is of national importance, such projects qualify for:

a. Pioneer Status with income tax exemption of 100% of the statutory income for a period of 10 years. Unabsorbed capital allowances and accumulated losses incurred during the pioneer period can be carried forward and deducted from the post pioneer income of the company ; or

b. Investment Tax Allowance of 100% on the qualifying capital expenditure incurred within five years from the date of the first qualifying capital expenditure is incurred. This allowance can be offset against 100% of the statutory income for each year of assessment. Any unutilized allowances can be carried forward to subsequent years until fully utilized (MIDA, 2010).

2. Mining of REE can qualify for incentives given for high-technology companies such as;

a. Pioneer Status with income tax exemption of 100% of the statutory income for a period of five years. Unabsorbed capital allowances and accumulated losses incurred during the pioneer period can be carried forward and deducted from the post pioneer income of the company; or

b. Investment Tax Allowance of 60% on the qualifying capital expenditure incurred within five years from the date the first qualifying capital expenditure is incurred. The allowance can be utilized to offset against the 100% of the statutory income for ear year of assessment. Any unutilized allowances can be carried forward to subsequent years until fully utilized. (MIDA, 2010)

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Sukiman Sarmani
Amran Abd. Majid

GOVERNANCE SECTOR

Sukiman Sarmani FASc, *Universiti Kebangsaan Malaysia (UKM), Bangi, Selangor*
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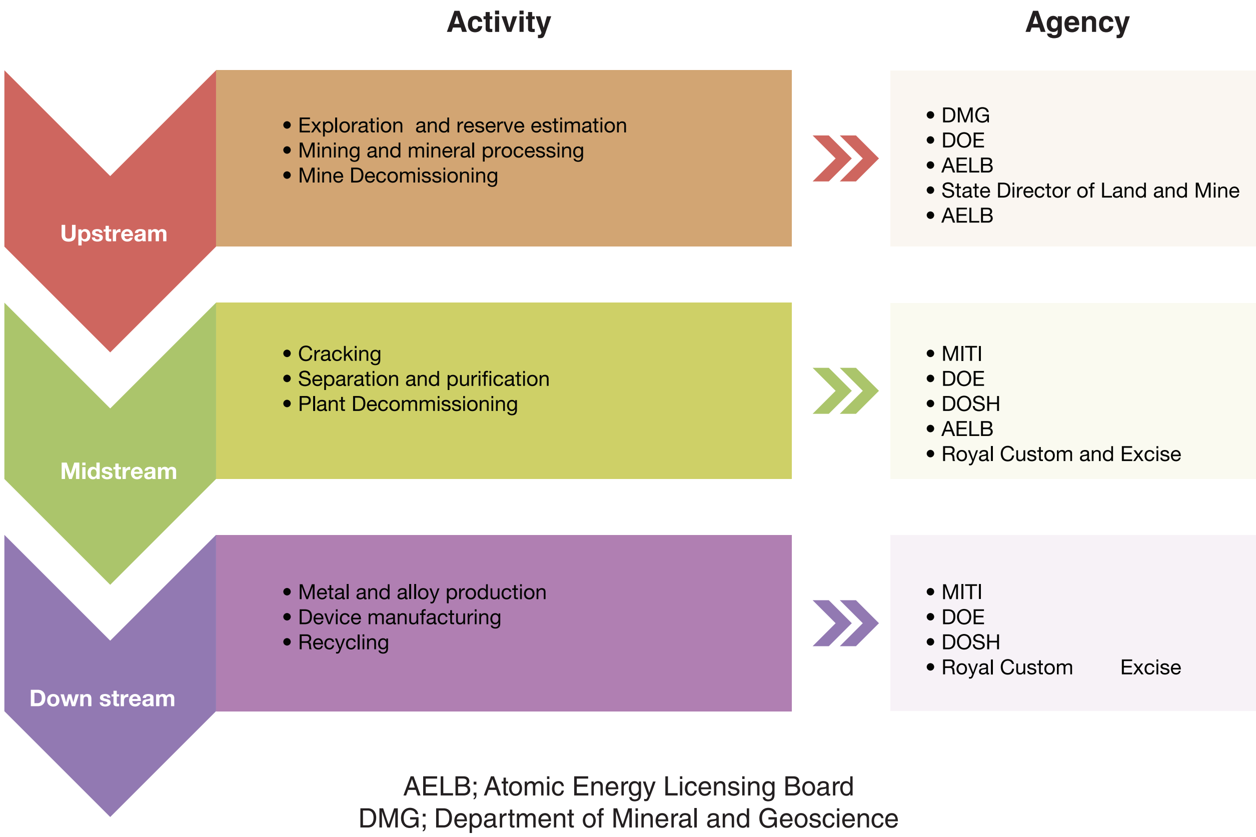
1.0 SUMMARY

Mining and mineral processing have been identified as important industries for Malaysia with potential worth over RM 4 billion. While there are sufficient laws and regulations to support such investments and industries for sustainable economic development, government agencies and departments are required facilitate the establishment of such industries by providing accurate information and regulatory obligations. The approval process is done in a transparent manner where investors can monitor application progress while the public are assured of benefits and safety of the proposed industry. Detailed information of certain regulations and procedures on starting a REE industry is spelled out in this chapter to help investors in connecting with government agencies regarding business licenses.

2.0 INTRODUCTION

This chapter deals with governance, regulations and procedures related to the rare earth industry covering the upstream to downstream activities. The rare earth industry cycle starts from prospecting, mining, mineral separation, rare earth elements separation and purification, manufacturing of devices using rare earth elements, recycling and closure or decommissioning of the mine and extraction plants. It should be noted that each step involves production of wastes in various physical and chemical forms. Therefore, waste handling and treatment are important aspects and should be included in each step of the cycle. Each stage of the rare earth industry is governed by specific rules and regulations enforced by certain agencies as shown in Figure 1.

As Malaysia is diversifying its economic base in the high-technology manufacturing industry to move to a high-income nation, the government is facilitating industrial development by setting up a policy and regulatory framework that strengthens public-private partnership to effect the economic transformation. The private sector is expected to play an important role in corporate social responsibility as well as driving the economy whereas the public sector must continue to play its role in advocacy for sustainable development, and ensuring safety for the environment, the workers and the public.



AELB; Atomic Energy Licensing Board
DMG; Department of Mineral and Geoscience
DOE; Department of Environment
MITI; Ministry of International Trade and Industry

Figure 1. Activities of RE Industry and related regulating agencies

3.0 EXPLORATION AND MINING

Mining is an important industry for our country in order to have adequate and dependable supplies of minerals and materials to meet our economic and security needs at acceptable environmental, energy, and economic costs. The importance of the sector is spelled out in the National Mineral Policy 2 which is to enhance the contribution of the mineral sector to the socio-economic development of the nation through the efficient, responsible and sustainable development as well as the optimum utilisation of mineral resources. The industry's potential as estimated by the Ministry of Natural Resources and the Environment was worth over RM4 billion in 2010. Modern mining is an industry that involves the exploration for and removal of minerals from the earth, economically and with minimum damage to the environment. The development of a mine consists of several principal activities: conducting a feasibility study, including a financial analysis to decide whether to abandon or develop the property; designing the mine; acquiring mining rights; filing an Environmental Impact Assessment (EIA); and preparing the site for production.

Prospecting, field mapping and exploration in Peninsular Malaysia to identify possible locations of rare earth mineral anomaly and deposits have been done quite extensively by the Department of Minerals and Geoscience (DMG). The department is empowered to carry out such activities in order to diversify our mineral resources. Further exploration for detail mapping of selected areas to locate and to estimate economic value of deposits is normally done by private sectors with authorisation from DMG and state authorities, as it involves larger investment. These activities are regulated by state as it is empowered to do so in the constitution but the safety of the public, workers and the environment are covered by appropriate Federal Laws. The primary legislations that govern mining are the Mineral Development Act 1994 and the various State Mineral Enactments. Prospecting and mining of minerals is not subjected under the Atomic Energy Licensing Act 1984 but as soon as the person responsible in the activities discover or come into possession of radioactive materials he shall immediately report to the Atomic Energy Licensing Board.

Under the Ninth Schedule of the Federal Constitution, land is a state matter as stated under the State List, while List II 2(c) authorises the state to issue permits and licences for prospecting for mines; mining leases and certificates. The mining of rare earth bearing minerals is therefore regulated by States Laws where the respective states have the power to approve mining applications in consultation with federal agencies. However, under the Ninth Schedule of the Federal Constitution, the federal government retains powers over certain provisions for forests and forestry, resource conservation and local government plans through its ministries and departments (Yong, 2000).

The State Mineral Enactment provides the State with powers and rights to issue mineral prospecting and exploration licenses and mining lease and other related matters, and the State Director of Land and Mines is responsible to administer these powers. The licenses may be granted to a natural person or legal entity as investor. The Mineral Development Act1994 delineates the powers of the Federal Government on matters related to the inspection and regulation of mineral exploration, mining and other related activities. The legislation is enforced by the Department of Minerals and Geoscience of Malaysia. The rules and regulations that apply to Malaysian mining industry are listed in Appendix 1.

Minerals are a non-renewable resource, and because of this, the life of mines is finite, and mining represents a temporary use of the land until the mine closure. The closure of a mine refers to cessation of mining at that site and it involves completing a reclamation plan as abandoned mines can cause a variety of health-related hazards and threats to the environment, such as the accumulation of toxic chemicals, and the use of these mines for residential or industrial and municipal wastes dumping, posing a danger from unsanitary conditions. Adherence to Environmental Impact Assessment (EIA) procedures as required by the Department of the Environment must be complied with to return the mined areas close to its original state. The Environmental Quality Act 1974 requires certain activities to have EIA or Detailed EIA (DEIA) done before relevant licenses are issued.

4.0 MINERAL CRACKING AND PURIFICATION OF REE

The mineral concentrates which contains 30-70% Rare Earth Elements from the mines will be processed further to extract and separate the rare earth elements as a group or individually. For the purpose of this report such activities are classified as the Middle Stream Activities. The industry generally practises sulphuric acid cracking followed by solvent extraction to obtain high-purity rare earth elements. The process involves relatively high technology with extensive capital investment. In setting up of such an industry or operation, the first step is to contact the Malaysian Investment Development Authority (MIDA) of the Ministry of International Trade and Industry (MITI) to gather information on investment regulations and licenses.

5.0 LICENSING PROCESS

Based on previous experience in approving industries which carried out mineral processing to extract rare earth elements, such as the Malaysian Rare Earths Corporation, Ipoh, Perak, the Asian Rare Earth Sdn. Bhd., Ipoh, Perak, and the Lynas Advanced Material Plant (LAMP), Gebeng, Pahang, or the extraction of titanium dioxide pigment by Huntsman Tioxide (M) Sdn. Bhd., Kemaman, Terengganu, the licensing process involved is summarised in Figure 2.

Some of the important issues at this stage are as follows:

- All agencies must facilitate investors to comply with the requirements for license approval.
- Independent and transparent license approval process must be maintained at all times and can easily be scrutinised by the public, if it is necessary to do so.

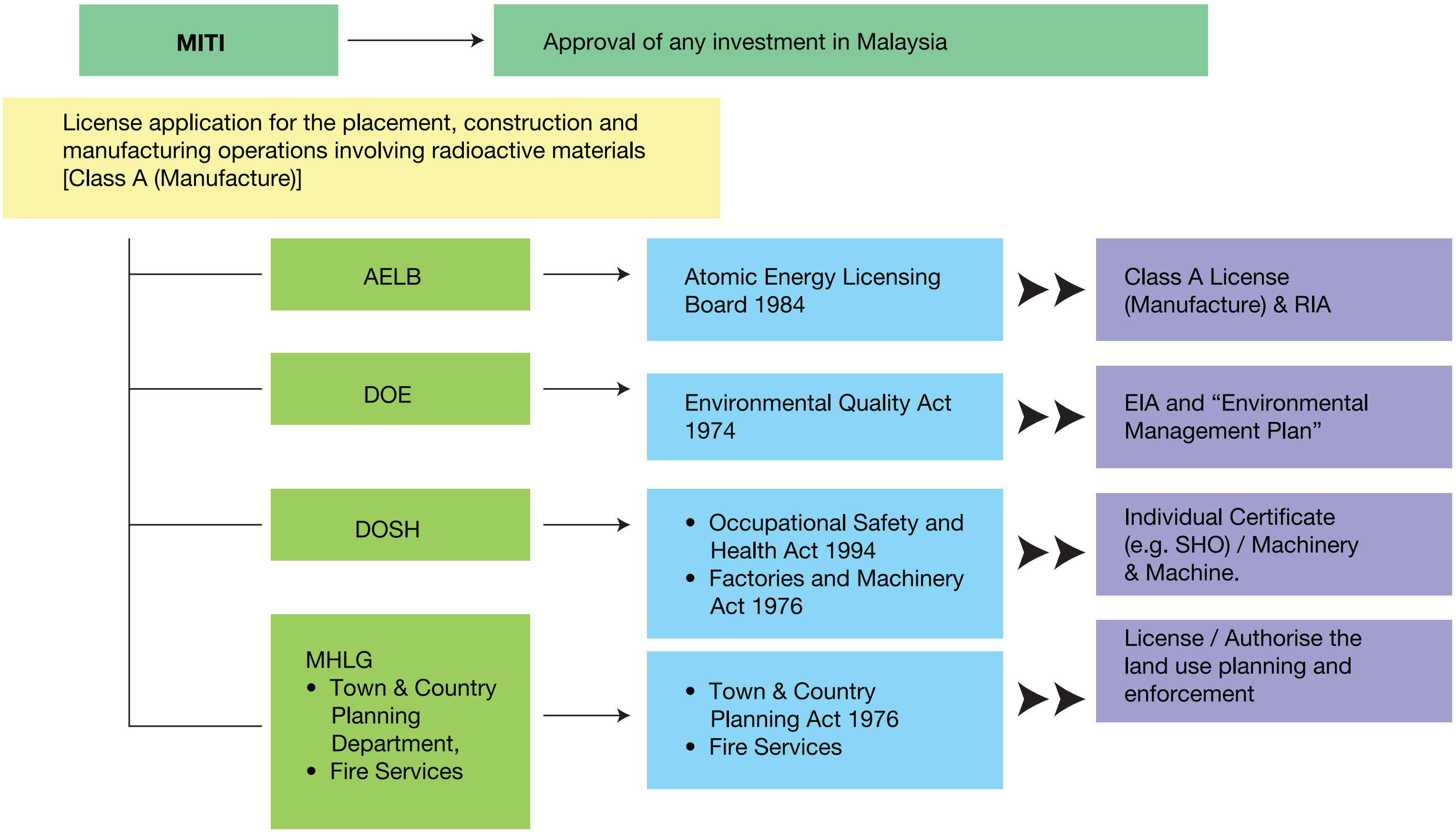


Figure 2. The agencies involved in license approval

- The special committee that assists the authority in evaluating license application should be appointed from among experts.

6.0 THE ROLES OF GOVERNMENT AGENCIES

It is important to note that there are several relevant authorities or government departments involved in the process of approving a license and the roles of these authorities are given in Table 1. The summary of the laws and regulation administered by the agencies are shown in Table 2 while the relevant legal documents are given as Appendix. The main roles of government agencies are:

- Facilitate investment in Malaysia
- Implement and enforce the relevant regulations fairly for the benefit of all.
- Establish excellent coordination between agencies.
- Keep track on the progress of the project.
- Communicate accurate information as required by the public efficiently.
- Train their enforcement officers on latest technology.
- Obtain legal commitment from investors on plant decommissioning.
- Encourage recycling of REE to conserve resource and environment
- Ensure sufficient funding for R&D in REE.

Table 1 Law and Regulations Enforced by Government Agency Related To Rare Earth Industry

Ministry	Science, Technology and Innovation (MOSTI)	Health (MOH)	Human Resources (HR)	Natural Resources and Environment (NRE)	Others (Education (MOE), Multimedia & Communication)
Functions	Matters related to radioactive materials and atomic energy	Medical aspects of workers and public	Occupational safety and health of workers	Natural resources management and environmental conservation.	Outreach program, public information, public awareness, etc.
Main Regulatory Authority	Atomic Energy Licensing Board (AELB)	Medical Device Authority (MDA)	Department Of Occupational Safety And Health (DOSH)	Department of Environment (DOE), Department of Mineral and Geoscience (DMG)	Department of Higher Education Multimedia Department (RTM)
Functions of the Regulatory	Licensing and compliance inspection	To protect the public health and safety, to provide a high quality medical services	Ensuring safety, health and welfare of workers and public	Environmental monitoring and impact assessment	Continuous education and public information & public awareness (PIPA) program
Law and Regulations Enforced	Atomic Energy Licensing Act 1984 and its regulations.	Atomic Energy Licensing Act 1984	Occupational Safety and Health Act 1994 and its regulations Factories and Machinery Act 1967 (Revised- 1974)	Environmental Quality Act 1974 -Mineral Development Act 1994	Supportive Government Policies -Liberal Equity Policy

The Malaysian Royal Customs and Excise currently charges very low rates or even duty free for minerals imported to Malaysia for processing and extraction of rare earths elements.

Table 2 Acts and Regulations Related to REE Industry

Ministry	Agency	Acts & Regulations	Relevant Section
Natural Resource and the Environment	Department of Minerals and Geosciences	Geological Survey Act 1974	Authority for geological survey. Power to enter land and notice to enter land. To regulate and control geological surveys, to establish geological archives
		Mineral Development Act 1994	Regulations on Exploration And Mining. Notices of intent to explore or carry out development work. Compliance with operational mining scheme. Accident And Inquiry Good and safe practices and environmental standards Record books on operations. Enforcement, Investigation, Evidence. Offences And Penalties. Enforcement by mines officer.
	Department of Environment	Environmental Quality Act 1974 (Revised 2009)	Clean Air Regulations 1978. Licensing Regulations 1977. Environmental Impact Assessment (EIA), to evaluate possible impact to environment and mitigation method require to deal with the residual risk or impact. Scheduled Wastes Regulations 2005. Scheduled wastes shall be disposed of at prescribed facility or premises only.

Ministry of International Trade and Industry	Malaysia Investment Development Authority	Licensing of New Product.	Strategic Domestic Investment Funds. MIDA assists companies which intend to invest in the manufacturing and services sectors, as well as facilitates the implementation of their projects, providing information on the investments opportunities and joint venture partners.
Ministry of Human Resource	Department of Occupational Safety and Health	Factories and Machineries Act 1967	Mineral Dust Regulations, 1989. To protect employee's respiratory tract from mineral dust at workplace. Safety Health and Welfare Regulations 1970. Fencing of Machinery and Safety Regulations 1970. To control factories operations with respect to safety, health and welfare of worker and other person at workplace. Registration and to control factories operations with respect to safety, health and welfare of persons. Registration and inspection of machinery.
		Occupational Safety and Health Act 1994	Safety and Health Committee Regulations 1996. Assist in the development of safety & health rules and safe systems of work;
Ministry of Urban Wellbeing, Housing and Local Government	Fire and Rescue Department	Fire Services Act 1988	Fire Certificate Regulation 2001. -Industrial Area Planning Guidelines Provisions for effective and efficient functioning of the Fire Services Department for the protection of persons and property from fire risks.
	Urban and Country Planning Department	Town and Country Planning Act (Act 172)	Development Plans (Structure and Local Plans) Rules 1984 Planning Control (General) Rules. Restriction of land used and application for planning permission of industrial development purposes. Development Charge Rules The determination by the local planning authority of the amount of the development charge

Ministry of Science, Technology and Innovation	Atomic Energy Licensing Board	Atomic Energy Licensing Act 1984.	Issuing operational license, regulate and control of the licensee activity as stipulated in terms of license.
		Radiation Protection (Licensing) Regulations 1986, Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations, 2010	To ensure that the licensees carry out activity in such a manner to protect health and safety of the workers and members of public and to minimize the hazard and risk to life, property and environment. Evaluation of the residue/ waste management and the decommission plan.
		Atomic Energy Licensing (Radioactive Waste Management) Regulations 2011	Disposal of Radioactive Waste must be managed in such a way as to avoid imposing an undue burden on future generations; the waste generator have to seek and apply safe, practicable and environmentally acceptable solutions for its long term management.
		LEM/TEK/38-Guidelines for Application Guide Dissolution of Radioactive Minerals Manufacturing Facility Installations.	Class G License. To restore the factory so that the level of radioactivity in the factory area is back to background levels. Safe Management of the residue/ waste.
		LEM/TEK/56-Guidelines for Decommissioning of Facilities Contaminated with Radioactive Materials.	Establishment of Decommissioning criteria and plan. To provide standard guidelines and procedures, to licensee when embarking on decommissioning operation on any facility contaminated with radioactive materials.
Ministry of Education, Ministry of Science, Technology and Innovation	Higher Education Division, R& D Division		To encourage and provide enough fund for R&D on REE. Public outreach and education.

7.0 REGULATORY SETTING

Rare earth minerals are normally associated with other minerals containing uranium and thorium and their progeny which are radioactive. If the minerals contain radioactive materials higher than 1 Bq/g limit than permission from the Atomic Energy Licensing Board is required because handling of these minerals has radiological implication and therefore it is governed by the Atomic Energy Licensing Act 1984 and its subsidiary legislations. The Board has issued guidelines, licensing requirements and conditions to ensure safe use, handling, storage, disposal and security of the radioactive materials in the country. Apart from the national regulations, international standards published by the International Atomic Energy Agency (IAEA) such as the Pre-disposal Management of Radioactive Waste Requirement and the Management of Radioactive Wastes from Mining and Milling of Ores have to be fulfilled as well. Examples of the guideline documents are:

- The guidelines on safe handling of materials containing NORM.
- Documents on radiation protection and safety of radiation sources (Basic Safety Radiation Protection) Regulations 2010.
- Document that addresses safe transport of radioactive materials (Radiation Protection (Transport) Regulations 1989).

A Radiological Impact Assessment (RIA) must be carried out to assess potential radiological impact caused by the operation of the plant to its workers and members of the public living in the surrounding areas of the plant and to confirm that such operation would not cause undue radiological risk beyond what was allowed by the AELB. The assessment is based on the AELB LEM/TEK/30 Sem. 2 guidelines, while for the non-radiological impact need to be addressed under the Environmental Impact Assessment – Environmental Quality Act 1974.

Decommissioning notification is another issue specifically relevant for plant that processes radioactive bearing minerals and the detail procedures are spelled out in the AELB guidelines LEM/TEK/38. The operator is required to deposit sufficient fund to the government for cleaning up purposes upon decommissioning of the plant.

8.0 RESEARCH AND DEVELOPMENT (R & D)

In order to make the rare earths industry in Malaysia sustainable, it is very important for the Government to encourage and provide enough funds for the Research and Development (R & D) activities, not just for technical areas, but also in areas of good governance. Research and Innovation in management procedures in government department related to license processing need to be looked into to meet industry's expectation for efficient services. Some regulations and orders made under certain laws must be revised based on facts relevant to local situations and international practices. Regulations of radioactive material handling in Malaysia are very stringent as compared to other countries in Asia or Europe and sometimes these regulations are restricting industrial growth. Research in improving the government's delivery system encompassing rules and regulations related to rare earths industry must be considered as a priority area.

Sufficient fund from both the government and private sectors is critical to ensure success in R & D activities. The existing mechanism of application and evaluation of R&D grant such as Fundamental Research Grant Scheme (FRGS), Exploratory Research Grant Scheme (ERGS), Techno-Fund and Science Fund can be adopted or used for specific areas of research.

9.0 CONCLUSION

Investments in high technology such as extraction of rare earth elements and manufacturing of devices based on rare earth elements are encouraged and welcome in Malaysia and investors are offered with very attractive incentives and tax relief. There are sufficient laws and regulations to support such investments and industries for sustainable economic development. Government agencies and departments will facilitate the establishment of such industries by providing accurate information and regulatory obligations. The approval process is done in a transparent manner where investors can monitor application progress while the public are assured of benefits and safety of the proposed industry. In the mineral processing industry which may involve in handling of radioactive materials the public anxiety and resistance can be overcome by continual public information and public awareness programme. This is the role to be played by both of the government agencies and the industry. In order to improve the efficiency of government delivery systems, research and innovation on good governance as well as rules and regulations pertinent to the industry must be funded and carried out.

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Akta Perlesenan Tenaga Atom 1984, Perintah Perlesenan Tenaga Atom (Pengecualian) (Bahan Radioaktif Keaktifan Rendah) 2002.

Akta Perlesenan Tenaga Atom 1984, Peraturan-Peraturan Perlesenan Tenaga Atom (Pengurusan Sisa radioaktif) 2011.

Appendix 1 The relevant Federal Laws and Regulations

List 1: Federal Laws and Agencies

1. Geological Survey Act 1974 enforced by Department of Minerals and Geoscience.
2. Mineral Development Act 1994 enforced by Department of Minerals and Geoscience.
3. Occupational Safety and Health Act 1994 enforced by Department of Occupational Safety and Health.
4. Factories and Machineries Act 1967 (Revised 1974) enforced by Department of Occupational Safety and Health.
5. Environmental Quality Act 1974 enforced by Department of Environment.
6. Atomic Energy Licensing Act 1984 enforced by Atomic Energy Licensing Board.

List 2: Regulatory Setting

1. Any activity to be carried out in Malaysia, which has radiological implication, is governed by the Atomic Energy Licensing Act (AELA) 1984 and its subsidiary legislations.
2. AELB also introduced various guides, licensing requirements and conditions to ensure safe use, handling, storage, disposal and security of the radioactive materials in country.
3. Apart from the national regulations, international standards such as the Pre-disposal Management of Radioactive Waste Requirement and the Management of Radioactive Wastes from Mining and Milling of Ores have to be fulfilled.
4. The guidelines that are addressing technical issues related to safe handling of materials containing NORM is referred in LEM/TEK/30 Sem.2.
5. Documents specifically addressed radiation protection aspects and safety of radiation sources are referred in AELB (Basic Safety radiation Protection) Regulations 2010
6. Document specifically addressed on safe transport of radioactive materials is referred in AELB Radiation Protection (Transport) Regulations 1989.

List 3: Radiological Impact Assessment (RIA)

- To assess potential radiological impact caused by operation of the plant to the workers and members of the public living in the surrounding areas of the plant and to confirm that such operation would not cause undue radiological risk beyond what was allowed by the regulatory authority (AELB).
- Based on the AELB LEM/TEK/30 Sem. 2 guidelines and it addressed the radiological impact of the plant's operation.
- The non-radiological impact was addressed under the Environmental Impact Assessment – EQA 1974.

List 4: AELB legal documents

1. Atomic Energy Licensing Act 1984 (Act 304)
2. Radiation Protection (Licensing) Regulations, 1986
3. Radiation Protection (Transport) Regulations, 1989
4. Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations, 2010
5. Atomic Energy Licensing (Radioactive Waste Management) Regulations, 2011

List 5. Ministry of Human resources

Department of Occupational Safety and Health

Regulations under Factories and Machinery Act 1967

1. Factories and Machinery (Mineral Dust) Regulations, 1989

2. Factories and Machinery (Noise Exposure) Regulations, 1989

3. Factories and Machinery (Building Operations and Works of Engineering Construction) (Safety) Regulations, 1986

4. Factories and Machinery (Asbestos) Regulations, 1986

5. Factories and Machinery (Leads) Regulations, 1984

6. Factories and Machinery (Compoundable Offences) Regulations, 1978

7. Factories and Machinery (Compounding of Offences) Rules, 1978

8. Factories and Machinery (Notification of Fitness and Inspections) Regulations

9. Factories and Machinery (Certificates of Competency Examinations) Regulations, 1970

10. Factories and Machinery (Administration) Regulations, 1970

11. Factories and Machinery (Safety, Health and Welfare) Regulations, 1970

12. Factories and Machinery (Person in Charge) Regulations, 1970

13. Factories and Machinery (Fencing of Machinery and Safety) Regulations, 1970

14. Factories and Machinery (Electric Passenger and Goods Lift) Regulations, 1970

15. Factories and Machinery (Steam Boiler and Unfired Pressure Vessel) Regulations, 1970

List 6: Regulations Under Occupational Safety and Health Act 1994

1. Occupational Safety and Health (Notification of Accident, Dangerous Occurrence, Occupational Poisoning and Occupational Disease) Regulations 2004

2. Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) Regulations 2000

3. Occupational Safety and Health (Safety and Health Officer) Regulations 1997

4. Occupational Safety and Health (Classification, Packaging and Labelling of Hazardous' Chemicals) Regulations 1997

5. Occupational Safety and Health (Safety and Health Committee) Regulations 1996

6. Occupational Safety and Health (Control of Industrial Major Accident Hazards) Regulations 1996

7. Occupational Safety and Health (Employers' Safety and Health General Policy Statements) (Exception) Regulations 1995

List 7: DOSH Guidelines

1. Guidelines for the Protection of Employees Against the Effects of Haze at Workplaces

2. Guidelines for Media Professionals

3. Guidelines on Occupational Safety and Health Management Systems (OSHMS)

4. Guidelines on Occupational Safety and Health Act 1994 (Act 514), 2006

5. Guidelines on Occupational Safety and Health (Notification of Accident, Dangerous Occurrence, Occupational Poisoning & Occupational Disease) Regulations 2004 (NADOPOD), 2005

6. Guidelines on Occupational Safety and Health in the Service Sector, 2004

7. Guidelines on Gender Issues in Occupational Safety & Health, 2003

8. Guidelines on Occupational Safety and Health in the Office, 1996

List 8. Ministry of Natural Resources and Environment Department of environment

1. Environmental Quality Act 1974

2. Environmental Quality (Appeal Board) Regulations 2003 - P.U.(A) 115-2003

3. Environmental Quality (Clean Air) (Amendment) Regulations 2000 - P.U.(A) 309-2000

4. Environmental Quality (Clean Air) Regulations 1978 - P.U.(A) 280-78

5. Environmental Quality (Control of Pollution From Solid Waste Transfer Station And Landfill) Regulations 2009 - P.U.(A) 433-2009

6. Environmental Quality (Industrial Effluent) Regulations 2009 - P.U.(A) 434-2009

7. Environmental Quality (Licensing) Regulations 1977 - P.U.(A) 198-77

List 9: Ministry of Natural Resources and EnvironmentDepartment of Mineral Geoscience

1. State Mineral Enactment

2. Mineral Development Act

3. National Mineral Policy

4. Geological Survey Act

5. Quarry Rules

List 10. Ministry of Urban Wellbeing, Housing and Local Government Department of Town and Country Planning

1. Town and Country Planning Act (Act 172)

2. Fire Services Act 1988 (Act 341)

3. Fire Services (Compounding of Offences) Regulations 2000

4. Fire Services (Fee Pusat Latihan Bomba) Regulations 1996

5. Fire Services (Fire Services Department Welfare Fund) Regulations 1997

6. Fire Services (Designated Premises) Order 1998

7. Fire Services (Fire Certificate) Regulations 2001

8. Fire Services (Conduct of Fire Officer) Regulations 2003

List 11: Malaysia Investment Development Authority

- Manufacturing Sector

- Services Sector

- Post Licensing and Post Incentive Applications

- Strategic Domestic Investment Funds

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Jack Lifton

OPPORTUNITIES FOR MALAYSIA FOR A DOMESTIC TOTAL RARE EARTHS' SUPPLY CHAIN IN THE 21ST CENTURY

Jack Lifton, *Founding Principal, Technology Metals Research LLC, USA*

1.0 INTRODUCTION

The spread of mass-produced consumer technologies, enabled by what has been earlier referred to in Chapter 1 as the "rare technology" metals, is well under way as the world enters the twenty-first century. But I think it is a mistake to perceive this expansion of access as just a natural and inevitable feature of the current globalization movement in manufacturing and trade. Those who have access to rare technology-metals enabled consumer goods have that access as a result of their domestic level of, and the rate of growth of, their national GDPs, in other words, because they are accessible economically. But to ensure such access can continue it is necessary that nations have both politically secure sources of rare technology metals and a domestic educational system that provides and ensures a domestic capability to manufacture end-use rare technology-metals enabled consumer devices.

A nation, such as Malaysia, has secure access to the technology metals necessary for, and critical to**, a self-sustaining domestic consumer technology industry.**

The **miniaturization** of devices that transform electricity into mechanical motion and create electricity from mechanical motion as well as the displays that create non-incandescent light by the flow of electricity **is critically dependent** on just a few alloys and compounds of those rare technology metals known as the rare earth metals. Neither the rare earth metals nor their alloys, nor their compounds, is found in those forms in nature. The total supply chain for the production of these metals, alloys, and compounds is a man-made artifice. Malaysia is a lucky nation in that it is blessed with a high and sustained rate of GDP growth, a domestic system of educating manufacturing engineers and scientists, and domestic resources of the rare earth minerals in sufficient quantity and grade to anchor a total rare earth industrial products supply chain.

Malaysia's economy; the rate of growth of its GDP; and its standard of living today already generate sufficient domestic demand for rare earth enabled electrical and electronic consumer devices to support a total rare earths industries' supply chain. There is also sufficient regional demand for rare earth enabled consumer technology in south Asia so that Malaysia can look forward to becoming a regional supplier of end-use consumer products using rare earth enabled technologies by creating a total rare earth industries' supply chain to support a strong export sector.

2.0 HISTORY OF MINIATURIZATION OF DEVICES

Up until the development of rare earth-enabled miniaturization of devices that convert electricity into motion, sound, and light such conversion was mostly wasteful of energy and expensive. The first wave of consumer labor, and materials, saving technology devices, electric motors, generators, and incandescent lamps in the early twentieth century were extremely inefficient. Thus most electricity generated by or used by the first generations of consumer devices literally threw away most of the electricity used or generated (as waste heat), and in addition required large amounts of first generation (relatively) common key technology enabling metals such as copper, iron, and tungsten.

In the last generation before the end of the twentieth century in particular miniaturization has come to allow us to produce and use electricity just exactly where we want it to be used to produce just enough electricity, motion, sound, and light to do the specified job. This has been the first step in the greening of our energy economy; the dramatic reduction in the use of energy per device that has allowed the benefits of technologies to be spread widely in consumer use. There would be no point to reducing the carbon footprint of today's energy production if it were not for the fact that the use of rare technology metals such as the rare earths has reduced the demand for electricity and raw materials per capita to the point where much less energy can support so many more consumer devices. This reduction in use is what gives the most hope for alternate energy sources to ultimately replace the carbon fueled electrical energy generation of today.

It is noted here that even though the goal is to use solar, wind, and safe nuclear sources of electricity so as to eliminate the carbon fueled generation of electricity some nations, such as Malaysia, have not yet exhausted their potential to generate massive quantities of electricity by the energy of falling water (hydroelectric dams). This gives them the unique advantage of being able to generate large amounts of green electricity in order to construct an economy that can permanently run on a minimum of carbon-fueled electricity generation.

The first age of metals-based technology as a driver for the wealth of a nation occurred in Great Britain in the eighteenth century when the use of both (animal and human) muscle power and of the mechanical energy from falling water began to be supplanted by steam power. The concomitant increased demand for iron and steel to contain steam generation and to transform that generation into motive power caused a rapid increase of both the quantity and of the (metallurgical) quality of the iron and steel making capacities of Great Britain and France in the first metal-based technological revolution.

At the same time European natural philosophers discovered that "metal" was not just a quality of an admixture of the "four elemental forms" theorized by the ancient Greeks, but a category in nature, and they saw that there were metals that were each themselves elemental in nature. For the previous two thousand years they had seen the differences among metals to be qualities brought about by mixtures of the Greek elemental forms with gold the most purifiable and therefore most "noble (unchangeable by further separation processes)" of them and a metal such as lead as something lesser or "base" (changeable by processes that did not affect metallic gold).The "base metals" were in fact thought to be admixtures of the elements as defined by the ancient Greeks. These terms, "noble" and "base," are still used but not in their original sense. The discovery of the fundamental reasons for the differentiation of the metals (their atomic "structure,") had to wait another century and a half, but the empirical elucidation of their repeatable preparation, blending (alloying), and "chemistry" was much more rapid. It was the first, and, in many ways the finest achievement in history of the "scientific method" of experiment, hypothesis, and validation of the experimental result by the operations suggested by the hypothesis.

None of this knowledge produced by experimental philosophy (modern 'science") required a reductionist core philosophy as an "explanation" of why metals were able to be separated from the "earths" that contained them, or that once separated they could be purified to a point where no further purification was possible, so that a true element of nature had been produced. The production of this pure element in a metallic form was considered the last step in the process of proving the elementary nature of the material. This type of thinking was called positivist, empirical, and operational philosophy.

It was at that point with the production of the pure metals that a reverse set of procedures were undertaken to further prove the uniqueness of these newly baptized "chemical" elements. The metals were formed into compounds and alloys with other chemical "elements" and the properties of those compounds and alloys measured. It was considered critical for the proof of an element's existence that its compounds and alloys no matter where produced have the same properties such as melting points, the colors of the compounds, and the mechanical properties of the alloys.

One group of uncommon metals produced from what were thought in the empirical period to be rare earths (natural oxides) came to be known as the rare earth metals. These rare earths just did not fit into the early empirical "periodic tables," because periodic then meant that the chemical properties repeated periodically, but for the rare earths the chemical properties seemed to all be the same. Even more perplexing to the early chemists was that both the first ranking of the periodic table, by atomic masses, and even the next few ranking algorithms did not give a clue as to how many of the rare earth elements there might be. It was only after the discovery that the periodic properties of the chemical elements were due to the atomic number-the structure of their nuclei-that it was realized that the chemical properties of the rare earth elements were extremely similar to one another so that their chemical separation being based on tiny differences in their chemical properties was very labor intensive and reagent intensive, so that without a commercial demand driver such separation was never going to be done at a commercial level.

Such a commercial demand arose in the 1960s, more than 150 years after the first rare earths were discovered, and, in fact, only a few years after the last naturally occurring rare earth, dysprosium, had been first prepared in significant quantity in a laboratory. In early 1964 it was discovered that a cathodoluminescent phosphor allowing the reproduction of red colorations in Cathode Ray Tube, CRT, based "color" television could be made using the rare earth element europium and the non-rare earth, but chemically similar, rare element, yttrium.

A process pioneered in France in the 1920s for the separation of the rare earth neodymium from its fellow rare earths was chosen to be scaled up so that the production of europium and yttrium could be achieved in ton lots rather than the grams and kilograms then being produced by the slow and laborious technique of ion exchange. The American company Molycorp undertook to separate and purify just europium from the small quantity (0.1% of the total of the rare earths) of that element present in its bastnaesite deposit at Mountain Pass, California. In France, Rhone Poulenc decided to use the same technology, solvent extraction, to separate and purify not only yttrium but all of the rare earth elements at LaRochelle, France.

Rhone Poulenc thus became the world's first supplier of all of the rare earths. This led to both theoretical and practical chemical and metallurgical studies of the rare earth elements. And this led in the late 1970s to the commercialization of the most powerful magnets ever put into commercial development, the rare earth permanent magnets. This, in turn led to the miniaturization of consumer electronics and in combination with the signal processing capabilities of "silicon" based data processing gave us the modern world of mass produced consumer technologies that we take for granted.

It is still mistakenly presumed by many that it is the existence of or access to high grade large deposits of the rare earths that determines whether or not rare earth industrial products can be produced at any given location. This is not correct. It is a total rare earth supply chain culminating in the production of rare earth permanent magnets that is necessary. Further the entire supply chain must be located in a politically reliable nation or region where the only competition will be economic.

Today, the total rare earth supply chain exists only in China. This came about with the transfer of the American supply chain to China beginning in the 1980s when the world's only total rare earth supply chain was in the United States. The demand driver for this supply chain transfer was the economics of the 1980s in America. Today Chinese politics have given rise to a demand for the creation of regional or at least non-Chinese total supply chain creation. Malaysia presents an ideal location and situation for the creation of a total rare earth industries supply chain.

3.0 MALAYSIA'S OPPORTUNITIES

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 and the technologies necessary to develop a domestic total rare earth supply chain, so that the rare earth containing minerals mined within or imported to Malaysia can 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 motors, generators, and sensors used on an automobile, and used in alternate 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.

Malaysia has enough existing domestic demand for rare earth permanent magnets from its automotive and electronic manufacturing industries 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 total rare earth industrial supply chain consists of the following industries:

1. Rare earth minerals (ores) mining (including the recovery of rare earth minerals from by-product streams and ore-tailings (residues) such as cassiterite (tin) processing) and mechanical concentration;

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) 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.

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

4.0 RECOMMENDATIONS

It is believed that a commercial and domestic Malaysian total rare earth industry supply chain can be constructed in Malaysia. It is also believed that to achieve this it is necessary to immediately:

1. Survey Malaysia geologically to determine the location and (potential or existing) output of rare earth minerals (as recommended in Chapter 2);

2. Survey the global rare earth separation and purification knowledge base to determine the sequence in which such technology can be acquired and to determine the amount of time it will take to implement such technologies commercially within Malaysia;

3. Survey the world's rare earth metals and alloys technologies to determine if such should be acquired rather than developed internally;

4. Survey the world markets for rare earth end-use technologies to determine the regional markets for Malaysian-produced consumer devices; and

5. Develop a business model to determine the costs and benefits of such a Malaysian green technology base and to determine where government seed capital is required and where private capital can have sufficient return and speed of return to invest directly.

Malaysia can profitably go green by developing a rare earths-based industry total supply chain that delivers globally. The timing and the developed world's economy are right for such a development. The Global1000 private corporations and those of the Global SOEs, (State- Owned Enterprises) that are in the developed world are eager to distribute their risk of the security of supply of the rare earths and their downstream products from today's total dependence on the People's Republic of China to a tomorrow with multiple alternate sources that are competent and competitive. This is the right time for Malaysia to enter the competition.

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TH INDUSTRIES ROAD-MAP FOR MALAYSIA

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RARE EARTH INDUSTRIES ROAD-MAP FOR MALAYSIA

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1.0 INTRODUCTION

The use of road maps is an excellent way to provide the directions towards specified goals and to remain focused on the targets to be achieved.

The road maps below serve to outline how this rare earths Blueprint is to be implemented and collectively, is intended to be a detailed guide on what needs to be done and by when, towards the development of the rare earths industry in Malaysia into a major industry contributing significantly to the Malaysian economy.

The rare earths industry comprises three main sectors, namely upstream, midstream and downstream. In Malaysia, these sectors are in various stages of development and as such the road maps within each sector are necessarily different from those in the other sectors.

To facilitate target achievement, for each sector there would be short term road maps and long term road maps, the former being more specific in nature with more defined timelines.

2.0 UPSTREAM SECTOR

2.1 Introduction

The Blueprint for the development of the upstream sector of the rare earths industry in Malaysia revolves mainly around the exploration for, and mining of, rare earths in the potential resource areas. Based on the potentials identified in Chapter 2, the Blueprint could be implemented through five road maps focusing on four types of resources and the R & D work to complement the development of the identified potential resources. The foci of 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

Priority should be given to Road Maps No. 1 and 2, and projects in Road Map No. 5 which have more achievable targets and are relatively easier to implement.

Subcommittee for the implementation of the Blueprint for the upstream sector

The implementation of the Blueprint for the upstream sector should start off with the establishment of a subcommittee for the implementation of the road maps. As most of the work involves exploration and mining, the Minerals and Geoscience Department (JMG), under the Ministry of Natural Resources and Environment (NRE), should be the anchor organization and secretariat for this subcommittee. The subcommittee should be headed by appropriate senior officials from NRE and JMG. For the subcommittee to be effective, both the public sector (including the academia) and the industry should be represented. Representatives should preferably have a background in geology, mining or related sciences or possess extensive experience in the mineral resource industry.

2.2 Road Map No. 1: On-Shore Alluvial Xenotime And Monazite

Malaysia's production of rare earths minerals namely, xenotime and monazite, has all along been largely dependent on the availability of *amang,* the production of which is, in turn, dependent on alluvial tin mining activities. The methodology to explore for on-shore alluvial xenotime and monazite deposits is no different from the exploration for alluvial tin deposits or, for that matter, any heavy mineral deposits. Thus, this exercise to evaluate the potential of on-shore alluvial xenotime and monazite should incorporate the evaluation of alluvial tin resources as well as the other economic heavy minerals such as zircon, ilmenite and struverite.

Lead agency and time frame

Since most of the mineral prospecting records and information required are lodged at JMG and its personnel are familiar with the origin of these records and information, JMG would be the most appropriate agency to undertake this evaluation exercise. The evaluation which involves data capture and compilation, processing and interpretation is expected to stretch over at least twelve months.

The process for implementation of Road Map No. 1 is summarized in Table 1.

Identification of project leader and establishment of study group

The project should start off with the identification of the project leader, who should be a senior geologist experienced in field mapping and mineral exploration. Two geologists, preferably with background in mineralogy and petrology as well as competent in Information Technology should be appointed to assist the project leader. Since the exercise would involve tedious data retrieval, compilation and handling, four assistants (Geological Assistants) would be needed.

Identification of focus areas and assignment of responsibilities

Xenotime and monazite occur throughout Peninsular Malaysia, commonly associated with cassiterite (a tin mineral). The initial focus should be on the western and eastern tin belts. One geologist could be assigned to cover the western tin belt and the other the eastern tin belt. The areas in each belt could be subdivided according to map sheets and prioritized according to their perceived potential for RE minerals and cassiterite resources based on existing knowledge.

Compilation of existing data

This will form the most time consuming part of the exercise.

The economic field records at JMG are the most comprehensive data available on the occurrences of xenotime, monazite and cassiterite. These records contain Quantitative Mineral Estimation (QME) results of stream concentrates collected by geologists undertaking field mapping in the past. Other records include mineral clearance survey reports, and published and unpublished map bulletins and memoirs.

A standard format for data compilation and input into the computer should be devised to facilitate data processing, analysis and interpretation.

The exercise should start with those map sheets in the western and eastern tin belts where encouraging tenor values are available and locations are recorded in Geographical Information System (GIS) compatible formats.

Data processing and interpretation

The data compilation and processing should be done on a topographic map (produced by the Peninsular Malaysian Survey Department, or JUPEM) sheet by map sheet basis and, if necessary, to make adjustments and improvements along the way so that data in the subsequent map sheets can be handled in a more effective and efficient manner.

Review and evaluation of results and report preparation

The results of the study should be reviewed and evaluated in total and presented in the final report. An opinion based on the findings should be expressed as to the potential of discovering commercially mineable quantities of RE minerals and cassiterite. Alternatively, further work may be recommended to fill in any gaps that may still exist.

The main objective of the exercise is to identify the potential of RE mineral resources particularly those in areas where the potential alluvial tin deposits exist. Hence, the output should include anomaly maps, and wherever possible their land status, as well as their worthiness for follow up investigation. Should the need arise to step up the preliminary evaluation; part of the work can be outsourced.

One of the roles of the government in promoting mining is to ensure that there is sufficient information on mineral resource to entice the private sector into investing in detailed exploration and, subsequently, mining. Hence, there must be sufficient and reliable information available for this purpose.

Follow-up field investigation

Any follow-up field investigation would depend very much on the results and recommendations of the above review and evaluation of existing data. Availability of funding would be another issue.

Follow-up field investigation would include collection of additional samples to fill in the gaps and subsequently drilling to assess the potential in more detail.

Table 1: Evaluation of On-Shore Alluvial Xenotime and Monazite Resources in Peninsular Malaysia

	ACTIVITY	MONTH											
		1	2	3	4	5	6	7	8	9	10	11	12
1.	Identification of project leader and establishment of study group	■											
2.	Identification of focus areas and assignment of responsibilities		■										
3.	Data compilation and entry			■	■	■	■	■	■	■			
4.	Data processing and interpretation				■	■	■	■	■	■	■		
5.	Evaluation of results and report preparation										■	■	■

Follow-up field investigation would depend on the outcome of the above activities.

2.3 Road Map No. 2: REE-Hosted Ion Adsorption Clays

Prior to 2013, no work has ever been done to search for REE-hosted ion adsorption clay deposits in Malaysia. The proposal to have such an investigation done is because Peninsular Malaysia has similar climatic conditions and geology as places where such deposits have been found, such as in south China, Laos, Vietnam and Thailand. Additionally, REE-hosted ion adsorption clay deposits are the best sources of HREE and also do not have the issue of radioactive elements in them.

The process for implementation of Road Map No. 2 is summarized in Table 2.

Lead agency and time frame

The evaluation of the potential existence of ion adsorption type RE clay deposits in Peninsular Malaysia is very much geological in nature and, as such, the best agency to undertake this exercise is JMG which has the necessary personnel and most of the facilities to do so. Twelve activities have been identified with the first nine spread out over a 12-month period. If the search for such deposits proved promising, only then will it be followed up with the next three activities relating to extraction.

Identification of project leader and establishment of study group

The project should start off with the identification of a project leader who should be an experienced senior exploration geologist with a strong background in chemistry or geochemistry. The study group should include both geologists and chemists.

A suitable set up would be one project leader, two geologists, one analytical chemist, four geological assistants (GAs) and one geochemical laboratory assistant. A mining engineer/chemical engineer/mineral processing engineer and a research chemist would be needed for activities 10 and 11.

The involvement of researchers from institutions of higher learning should be encouraged as strong academic knowledge of REE behavior is necessary. Collaborative efforts with foreign researchers in this field are also strongly recommended.

Literature research on REE hosted clays

Thus far, the commercial mining of ion adsorption clays for REEs has been carried out only in China and most of the mining is carried out on a small scale in remote places. Very little is known about ion adsorption clays containing REEs and there is a lack of literature on this subject especially in English. In this context, it would be advantageous to have a group member who is able to read and understand technical Chinese. A literature research on RE clay would be very useful in exploration planning and understanding the nature of this type of deposit. Literature research is a continuous process and should be done throughout the project period.

Table 2: Evaluation of Potential of Ree-Hosted Ion Adsorption Type Clay in Peninsular Malaysia

	ACTIVITY	MONTH											
		1	2	3	4	5	6	7	8	9	10	11	12
1.	Identification of project leader and establishment of study group												
2.	Literature research on RE clays												
3.	Identification of parameters, analytical methods and facilities												
4.	Identification of initial areas for study												
5.	Planning of field mapping and sampling programme												
6.	Field work including geological and soil mapping, and sampling												
7.	Sample analyses												
8.	Data processing and interpretation												
9.	Evaluation of results and report preparation												
10.	Research and development on extraction of REEs from the clay												
11.	Identification of suitable methods of extraction												
12.	Invitation for private sector to undertake follow up work												

To be undertaken only if activities 1-9 are successful and results show further investigation is warranted.

Identification of parameters, analytical methods and facilities

Before the field work starts, it is necessary to identify the parameters which are important in the study. These could include clay type, grain size and distribution, content of REEs, pathfinder elements, color of soil, ionic exchange properties, etc. Some ideas can be obtained through literature research especially from information on previous studies carried out elsewhere.

Apart from knowing the parameters, a decision has to be made on how these parameters are to be analysed. Are there analytical methods available? Which ones are most suitable for the present purpose and can these analyses be undertaken in-house? If not, are there facilities elsewhere which can be made available for use? As a start it may be useful to compile a list of facilities available locally for the analysis of REEs.

Identification of initial areas for study

Some of the areas identified for detailed work have been indicated earlier in this report (see Chapter 2). The study group need only identify the most suitable area/s to start off the detailed investigation.

Planning of field mapping and sampling programme

Field mapping is to include the study of rock and soil types and their distribution. This should include augering to determine the thickness of soil and distribution of the various soil horizons. The plan should include recommended auger-hole spacings, where to sample and sample size so that there is enough for the analysis of the various parameters. Establishing a standard operating procedure (SOP) from the very beginning would be useful. This could include any rapid field testing methods.

Field work including geological and soil mapping, and sampling

Since this is a new field of study it may be wise to split the field investigation into two parts. The first part should be planned based on the existing knowledge of ion adsorption clay as gathered from literature research and personal experience. The second part should be planned and undertaken based on the results of the first field work. Auger hole spacing may be redefined, the amount of sample collected may be changed and more attention could be focused on a different soil horizon.

Sample analyses

Samples could be analyzed in-house or out-sourced or through the use of facilities elsewhere.

Data processing and interpretation

Data interpretation should include the use of Geographical Information System (GIS) to highlight anomalous areas and horizons and their significance in the search for REE resources. Relationships between types of host rock, clay type, grain size, soil horizon and mineralization should be highlighted. This is an area where the project team can exercise their ingenuity, creativity and lateral thinking skills towards the search for REE deposits and therefore should be given most attention.

Evaluation of results and report preparation

The results of the study should be evaluated in total and presented in the final report. An opinion based on the findings should be expressed, especially on the potential of discovering commercially mineable quantities of REEs in the clays. Alternatively, further work may be recommended to fill in gaps that may still exist.

Research and development on extraction of REEs from the clay

Should the initial exploration show encouraging results, the follow-up initiative should be to research on the extraction of REEs from the clay. The initial step is to study the present methods being used by the miners in south China and determine if it can be applied to the Malaysian situation. Attention should be paid to the environmental aspect as this has been the main shortcoming of the RE clay mining in south China. Visits to view and study the Chinese mining operations could be helpful.

Identification of suitable methods of extraction

The suitability of an extraction method may differ according to clay type. What may be suitable in south China may not be suitable in Malaysia. Alternatively, there may be other methods which are more effective and efficient in extracting the REEs especially in terms of impact on the environment.

Invitation for private sector to undertake follow-up work

Once sufficient information is available, efforts should be made to attract investors to undertake follow-up and detailed work in the areas where there are potentials.

2.4 Road Map No. 3: RE Potential In Off-Shore Marine Sediments

Road Map No. 3 consists essentially of two parts, one pertaining to near-shore marine sediments and the other pertaining to deep-ocean marine sediments.

Identification of project leader and establishment of study group

The project should start off with the identification of a project leader who should be an experienced marine geologist, and the appointment of personnel who will be involved in the study. The study group should include geologists and environmental scientists who are familiar with the marine environment.

The exploration and mining initiatives should be divided into two parts, namely near-shore marine sediments and deep-ocean marine sediments.

RE minerals in near shore marine sediments

The road map for exploration and mining of near-shore marine sediment is summarized in Table 3.

Review and evaluation of existing information

Several agencies including JMG and universities have undertaken near-shore marine surveys within Malaysia's territorial waters. These surveys may not necessarily be related to exploration for xenotime and monazite per se but the reports from many of these surveys do contain information pertaining to the presence of xenotime and monazite in the marine sediments. A review and evaluation of these documents would be a good start.

Identification of potential areas

It is possible, from the evaluation of information contained in the above reports to identify areas which are suitable for further investigation. The areas of potential could also be identified through the study of the drainage system in coastal areas and the geology of the areas which the rivers flow through. Some potential areas have been identified in Chapter 2.

Detailed evaluation of potential areas

The data collected from the potential areas could be re-evaluated and the sediment samples re-examined for any justification for additional field investigation.

Decision to proceed with further investigation

Marine surveys are generally much more expensive and tedious than land surveys. As far as is known there is no commercial production of xenotime or monazite per se from off-shore (near-shore) mining. However, xenotime and monazite may have been produced as by-products from *amang* derived from off-shore tin mining activities.

REEs in deep-ocean marine sediments

It is well known now that substantial quantities of REEs are present in certain types of deep-ocean marine sediments. Although no mining has yet been carried, the technology to mine these deposits commercially may be available in the not too distant future.

The decision to get Malaysia involved in the exploration for, and mining of, REEs in deep-ocean marine sediments is very much dependent on the federal government. The decision involves amongst many aspects, national policy, strategy and availability of funding.

The road map for participation in mining of REEs in deep-ocean marine sediments is summarized in Table 4.

Table 3: Evaluation of Potential of Re Minerals in Near-Shore Marine Sediments

	ACTIVITY	MONTH											
		1	2	3	4	5	6	7	8	9	10	11	12
1.	Identification of project leader and establishment of study group												
2.	Review and evaluation of existing information												
3.	Identification of potential areas												
4.	Detailed evaluation of potential areas												
5.	Decision to proceed with further investigation												
6.	Preparation of proposal to undertake further investigation												
7.	Planning and sourcing of funding												
8.	Implementation of project												

Table 4: Participation in Exploration for and Mining of Rees in Deep-Ocean Marine Sediments

	ACTIVITY	MONTH											
		1	2	3	4	5	6	7	8	9	10	11	12
1.	Identification of project leader and establishment of study group												
2.	Aspect study												
3.	Identification of possible areas												
4.	Report preparation including recommendations												
5.	Decision-making process												
6.	Detailed planning (after decision made)												
7.	Funding sources (after detailed planning)												
8.	Implementation of project (after funds obtained)												

To be undertaken only if activities 1-5 are successful

Study group

Representatives from the following agencies could form the preliminary study group:

- Ministry of Natural Resources and Environment
- Minerals and Geoscience Department Malaysia (JMG)
- Maritime Institute of Malaysia (MIMA) including Centre for Ocean Law and Policy
- Ministry of Foreign Affairs
- PETRONAS
- EPU
- Relevant Institutions of Higher Learning

An appropriate person from the above agencies could be nominated to lead the study group.

Aspects to study

The objectives of the group are to study, amongst various aspects:

- The justification for Malaysia to be involved in exploration for, and mining of, REEs in deep-ocean marine sediments or mining of deep-ocean marine sediments in general,
- The legal framework governing the exploration for, and mining of, deep-ocean marine sediments,
- The technology involved in these activities and their impact on the marine environment, and
- The financial requirements and possible funding options available.

The results of the study shall be forwarded to the appropriate government authority for decision-making.

2.5 Road Map No. 4: RE Minerals In Primary (Hard Rock) Deposits

In Chapter 2, the potential for the discovery of hard rock RE deposits was trimmed down to two types of sources, namely accessory rare earths minerals in tin mineralized granitic rocks and possible discovery of RE-hosted alkaline igneous rocks and carbonatites.

Exploration for the latter is to be undertaken as part of the field mapping exercise particularly in Sabah and Sarawak. Road Map 4 is essentially focused on evaluating the possibility of extracting xenotime and monazite tin mineralized granitic rocks and its viability to do so commercially. As mentioned in Chapter 2, the most appropriate starting point is to study the quarry dust in the quarries working on the tin mineralized granites.

The process for evaluation of the potential of extracting RE minerals from quarry dust is summarized in Table 5:

Table 5: Evaluation of Potential of Extracting Re Minerals from Quarry Dust

	ACTIVITY	MONTH											
		1	2	3	4	5	6	7	8	9	10	11	12
1.	Identification of project leader and establishment of study group												
2.	Identification of quarries for study												
3.	Collection of samples												
4.	Mineralogical study of the granites and quarry dust												
5.	Separation trials using various mineral processing techniques												
6.	Review of results and cost estimation												
7.	Evaluation of results and report preparation												

Identification of project leader and establishment of study group

The project should start off with the identification of a project leader who should be well versed in granite mineralogy and petrology as well as mineral processing techniques. The study group should include both geologists and mineral processing engineers. This exercise should be carried out more as an R & D project (as opposed to exploration) and can be undertaken at JMG's Mineral Research Centre (PPM) or USM.

Identification of quarries for study

Since most of the tin mineralized granites are known to host xenotime and monazite as accessory minerals, quarries working on these rocks are the best areas for study.

Collection of samples

Samples of both the host rock as well as the quarry dust should be collected.

Mineralogical study of the granites and quarry dust

The mineralogy and petrology of the samples should be studied including content of xenotime and monazite, grain size and shape and their relationship with the other minerals. This information will be useful during the testing of the effectiveness of the various mineral processing techniques.

Separation trials using various mineral processing techniques

Various mineral processing techniques should be tried out to test their effectiveness in separating out the xenotime and monazite from the rest of the minerals in the granite dust.

Review of results and cost estimation

Upon completion of the mineral processing trials, the results should be reviewed. There should be cost estimation for each process for comparison.

Evaluation results and report preparation

Finally, the results should be evaluated especially on the commercial viability and a report prepared for reference.

2.6 Road Map No. 5: R & D In The Upstream RE Sector

Research and development (R & D) plays a very important role in the development of any industrial sector. Road Maps No. 1 – 4 each have their own R & D components but for the purpose of this report all the R & D projects have been grouped together into one road map. The R & D projects can just as well be undertaken as part of the individual road maps.

Special subcommittee for R & D

The secretariat for R & D work pertaining to the upstream RE industry should be based in PPM. A special coordinating committee (SCC) should be established to implement, monitor and evaluate the progress of the R & D work. All the participating agencies (some of which are listed below) should be represented in the SCC.

- Ministry of Natural Resources and Environment (NRE)
- Ministry of Science, Technology and Innovations (MOSTI)
- JMG including PPM
- Academy of Sciences Malaysia (ASM)
- Agensi Nuclear Malaysia
- SIRIM
- Relevant institutions of higher learning

The individual projects need not necessarily be undertaken (or even led) by the personnel in PPM themselves. One suggestion is to have the participating research institutions taking up projects which are most suited to their in-house expertise, including the availability of equipment, human capital and knowledge. For example, Nuclear Malaysia could take up projects relating to radiological aspects and PPM and USM could take up projects relating to mineral processing. Some of the projects could be taken up by post graduate students in the various institutions of higher learning as their M. Sc. or Ph. D projects.

The SCC should hold regular meetings to decide on issues which could include:

- R & D projects and institution/person responsible
- Source of funding
- Sharing of equipment
- Review and evaluation of progress of projects

List of R & D projects

The preliminary list of R & D projects suggested in Chapter 2 include:

- Detection of low concentrations of xenotime and monazite in rocks and sediments
- Mineral processing methods to produce higher purity xenotime and monazite
- Geochemical behavior of REEs during the weathering of granitic rocks
- Pathfinders in the exploration for REE-hosted ion adsorption clays
- Improved methods for analyzing for REEs in ion adsorption clays
- Improved methods for the mining and extraction of REEs in ion adsorption clays
- Mining and extraction of REEs in marine sediments
- Extraction of REEs from granitic quarry dust

Sharing of equipment

Sharing of equipment is encouraged. In many of the above projects, special equipment may be required. Many of the equipment are expensive and logically should not be duplicated if avoidable. The special committee could arrange for the sharing of such equipment.

Funding

Sources of funding could include:

- Normal research grants offered by the Ministry of Science, Technology and Innovations (MOSTI)
- University research grants for post graduate research
- Development allocations provided by the government to various ministries
- Funding from donor countries (e.g. Japan, South Korea) or International agencies for collaborative research
- Funding from industry organizations

International collaborations

International collaboration is important as it would benefit Malaysia in terms of exchange of knowledge, funding and even availability of special analytical equipment. Countries which could be useful in this respect include China, Japan, South Korea and Australia.

The process of implementing Road Map No. 5 on R & D is summarized in Table 6.

Long-term upstream road map

It can take from two to 10 years for an RE exploration and mining project to come to fruition i.e. from exploration to production. Many factors are involved including funding, technology, bureaucratic efficiency and government policy. Nevertheless some milestones and targets would be useful for guidance in long term planning.

The recommended milestones and targets to revitalize the upstream sector of the Malaysian RE industry is outlined below.

MILESTONE	TARGET
2015	All road maps to be initiated with the sufficient funding and personnel
2020	Areas of potential identified and follow-up exploration initiated
2025	Potential economic deposits identified. Private sector participation in detailed exploration including pre-feasibility and feasibility study
2030	New mines developed producing RE or REO.

Table 6: Implementation Of R & D Projects

	ACTIVITY	MONTH											
		1	2	3	4	5	6	7	8	9	10	11	12
1.	Establishment of special co-ordinating committee (SCC) for R & D												
2.	Review and prioritization of R & D projects												
3.	Identification of participating institutions and personnel for projects												
4.	Sourcing of funds and allocations												
5.	Implementation of projects with available funding												
6.	Quarterly meetings of SCC to review progress of projects												

	ACTIVITY	MONTH											
		13	14	15	16	17	18	19	20	21	22	23	24
7.	Implementation of projects with available funding												
8.	Quarterly meetings of SCC to review progress of projects												
8.	Review and evaluation of completed projects												
9.	Submission of successful projects to appropriate authorities												

3.0 MIDSTREAM SECTOR

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 (Chapter 3).

In the 1980s, Malaysia had a midstream rare earths industry in the form of MAREC which produced 60% yttrium concentrate from the processing of xenotime and ARE which produced light REE chloride and medium to heavy REE carbonate from monazite. However, the two operations were shut down in January 1994 (due to various reasons) and for many years there was no midstream RE industry in Malaysia.

After a hiatus of almost two decades, the midstream sector in the RE industry was re-established in Malaysia with the commissioning of the Lynas Plant in Gebeng in November 2012 with the arrival of the first Rare Earths concentrates from Western Australia. The Lynas Plant produces a range of REE concentrates and compounds from the monazite ore imported from Lynas' Mt. Weld Mine in Western Australia.

With the technology and investment for the midstream already in place the gap appears to be building of the necessary human capital to support this sector of the industry. In this respect, the road maps for the midstream should focus on research and education.

3.1 Gaps in the midstream processing

In establishing the midstream processing road map, there is a need to look at two important areas, namely, research and education (both in the technical and tertiary levels). In a review of the current situation in Malaysia in these areas, it was found that there is a distinct lack of researchers carrying out work relevant to rare earths midstream processing. In the mid 1980s, the only known work was in the separation and midstream processing. These were undertaken by researchers in UTM, UKM and PUSPATI where they worked on the extraction of thorium and uranium oxides from the ARE processing plant. Although it was not exactly the separation of rare earths oxides, the nature of the separation i.e. extraction processes was quite similar.

To overcome this problem, the work done at GRIREM, China, and Curtin University, Perth, can be emulated and many examples of the work done in these institutes can be adopted by Malaysian academics and researchers.

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 such as:

- X-Ray Diffraction (XRD) - a tool used for determining the atomic and molecular structure of a crystal
- X-Ray Fluorescence (XRF) - is widely used for elemental analysis and chemical analysis
- Inductively Coupled Plasma Mass Spectrometer (ICP MS) – an analytical technique for determining chemical elements in samples, particularly for rare earths elements
- Radioactivity detection sensors

3.1.1 Detailed recommendations

Initiatives to be undertaken as part of the roadmap for further development of the midstream sector of the rare earths industry are:

- Introduction of elective subjects such as rare earths metallurgy/extraction processes in undergraduate teaching, especially in the engineering and chemistry programmes;

- Use of rare earths as case studies in plant design or offer students to carry out final year projects related to rare earths;

- Introduction of engineering chemistry / molecular level in the curriculum.

- Collection and collation of more detailed data and information on the list of equipment and instruments available in Malaysia (problem: involvement of radioactive elements need extra safety measures in the laboratories, e.g. drainage)

- Increasing the pool of expertise involved in rare earths research and development by increasing the number of postgraduate students in the related areas including collaboration with more established institutions such as Peking University, Curtin University and University of Western Australia and Sustainable Minerals Institute, University of Queensland.

- Encouraging researchers who are involved the field of separations in other applications (for example, ion-exchange chromatography in the area of biotechnology) to add or focus on rare earths-related processes.

- Strengthening the cooperation between academic institutions, training institutions with rare earths industries in the area of midstream processing such as establishing research centres, chair of midstream processing etc.

3.2 Midstream Sector Long-Term Road Map

The long-term road map for the midstream sector of the Malaysian RE industry is outlined below:

PERIOD	INITIATIVE AND TARGET
2014 – 2015	a. Setting up of Rare Earths Research Centre (RERC) including a midstream processing pilot plant – RM22 million committed by Malaysian Government b. Establishing Rare Earths Chair at UMP – 1 Professor c. Postgraduate Training (Masters level) – 20 candidates d. Researchers to be sent for training in USA, China, Australia – 6 researchers
2016 – 2020	a. Postgraduate Training (Masters & PhD levels) – 30 candidates & 10 candidates, respectively b. Midstream processing pilot plant testing at RERC c. Patents filing (locally-developed technology)
2021 – 2025	a. Establishing midstream testing facility for global companies b. Design and construction of the first full scale commercial Malaysian rare earths midstream production plant c. Postgraduates training (Masters and PhD levels) – 40 candidates & 20 candidates, respectively
2026 – 2030	a. Exporting of rare earths products overseas and supplying to local downstream industries b. Postgraduate training (Masters & PhD levels) – 50 candidates & 30 candidates, respectively

4.0 DOWNSTREAM SECTOR

4.1 Introduction

Based on the overview and analyses of the downstream sector of the RE industry (in Chapter 4) 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.

4.2 Strategy

In order to set up these industries the following issues need to be addressed:

1. Technology – the know-how to manufacture the products,

2. Funding – the financial resources to establish the facilities and operations

3. 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.

1. 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,

2. Build up the human capital (skilled workforce) relevant to the industry, and

3. 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

4.3 Road map for attracting FDI

The Malaysian Investment Development Authority (MIDA) should put more effort into attracting foreign companies to invest in rare earths-related downstream industry taking the advantage of availability of local rare earths supply (from Lynas), existence of related and supporting industries, etc. Foreign direct investment is the most effective way to fast track the initiation of new industry sectors but this must be followed by other initiatives mentioned above to move up the value chain in the sector.

4.4 Road map for rare earths-related outward investment

Another strategy is for Malaysian GLCs or companies to invest in global companies which are already involved in such downstream manufacturing activities elsewhere (outward investment). Once they are in control efforts can be made to set up similar operations in Malaysia and effecting technology transfer to locals. MIDA (and MATRADE) would be an appropriate authority to collaborate on this initiative e.g. to do the ground work for outward investment such as searching out such suitable companies. In addition, consideration should be given to investing in RE mineral prospects overseas especially for HREE for security of supply for downstream manufacturing.

4.5 Human Resource Development and R & D

In most of the countries that have developed rare earths-related downstream industries R&D is the core of value creation for the industry. R&D activities in these countries (Japan, China, South Korea, etc.) are led by their respective governments through national research institutions for example, Material Science (NIMS) of Japan, Korea Institute for Rare Metals (KIRAM) of South Korea, General Research Institute for Nonferrous Metals of China, etc. Such national institutes play vital roles in the enhancing R&D and, accordingly, growth of the industry sectors.

Some of the roles played by these national institutions include:

1. Design of direction, strategy and national master plan for the relevant industry sectors especially in technology, manpower, infrastructure development.

2. Sourcing and management of funding and other resources and infrastructure for R&D in areas related to the industry sectors.

3. Bridging and coordination between industry and universities in R&D and human resource development relevant to the industry sectors.

4. Spearheading major R&D research programmes related to the industry sectors in collaboration with various industry players and universities.

5. Setting up and managing major research facilities and equipment which are open for access by industry and universities.

It is thus proposed that Malaysia sets up a similar national institute that focuses on advanced materials (non-ferrous). This idea has been mooted in the 1980s and brought to the attention of the then Prime Minister. In fact, such an institution was set up in the Kulim Hi-Tech Park but its focus may have shifted somewhat over time.

4.6 Institute of Critical Materials Technology Malaysia (ICMTM)

The proposed ICMTM should play the roles mentioned above pertaining to advanced and critical materials and 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 and with at least half of its board consisting of members from the industry.

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 which includes projection of future needs should be formulated and reviewed by ICMTM continuously.

4.7 Road map for the setting up of ICMTM

At this juncture it can only be proposed that ICMTM be set up based on the following timeline.

Activities	Year 1				Year 2			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Steering committee formation								
Formulation of ICMTM's vision, mission, objectives, organization structure, financial framework, etc.								
Approval process by Government								
Initial setup of ICMTM								

A detailed road map of Malaysia's rare earths-related or more general material-based industry should be formulated by the organization after its formation.

APPENDIX

INVESTMENT CLIMATE AND OPPORTUNITIES IN MALAYSIA (Malaysian Industrial Development Authority, MIDA)

1. Incentives For Investment

In Malaysia, tax incentives, both direct and indirect, are provided for in the Promotion of Investments Act 1986, Income Tax Act 1967, Customs Act 1967, Sales Tax Act 1972, Excise Act 1976 and Free Zones Act 1990. These Acts cover investments in the manufacturing, agriculture, tourism (including hotel) and approved services sectors as well as R&D, training and environmental protection activities.

The direct tax incentives grant partial or total relief from income tax payment for a specified period, while indirect tax incentives are in the form of exemptions from import duty, sales tax and excise duty.

2. Incentives For The Manufacturing Sector

2.1 Main Incentives for Manufacturing Companies

The major tax incentives for companies investing in the manufacturing sector are the Pioneer Status and the Investment Tax Allowance.

Eligibility for Pioneer Status and Investment Tax Allowance is based on certain priorities, including the level of value-added, technology used and industrial linkages. Eligible activities and products are termed as “promoted activities” or “promoted products”. (See http://www.mida.gov.my/env3/index.php?page=incentives-for-investment)

(i) Pioneer Status

A company granted Pioneer Status enjoys a five year partial exemption from the payment of income tax. It pays tax on 30% of its statutory income*, with the exemption period commencing from its Production Day (defined as the day its production level reaches 30% of its capacity).

Unabsorbed capital allowances as well as accumulated losses incurred during the pioneer period can be carried forward and deducted from the post pioneer income of the company.

Applications for Pioneer Status should be submitted to the Malaysian Investment Development Authority (MIDA).

* *Statutory Income is derived after deducting revenue expenditure and capital allowances from the gross income.*

(ii) Investment Tax Allowance

As an alternative to Pioneer Status, a company may apply for Investment Tax Allowance (ITA). A company granted ITA is entitled to an allowance of 60% on its qualifying capital expenditure (factory, plant, machinery or other equipment used for the approved project) incurred within five years from the date the first qualifying capital expenditure is incurred.

The company can offset this allowance against 70% of its statutory income for each year of assessment. Any unutilised allowance can be carried forward to subsequent years until fully utilised. The remaining 30% of its statutory income will be taxed at the prevailing company tax rate.

2.2 Incentives for High Technology Companies

A high technology company is a company engaged in promoted activities or in the production of promoted products in areas of new and emerging technologies (See http://www.mida.gov.my/env3/index.php?page=incentives-for-investment). A high technology company qualifies for:

i. Pioneer Status with income tax exemption of 100% of the statutory income for a period of five years. Unabsorbed capital allowances as well as accumulated losses incurred during the pioneer period can be carried forward and deducted from the post pioneer income of the company; or

ii. Investment Tax Allowance of 60% on the qualifying capital expenditure incurred within five years from the date the first qualifying capital expenditure is incurred.

The allowance can be utilised to offset against 100% of the statutory income for each year of assessment. Any unutilised allowances can be carried forward to subsequent years until fully utilised.

The high technology company must fulfill the following criteria:

i. The percentage of local R & D expenditure to gross sales should be at least 1% on an annual basis. The company has three years from its date of operation or commencement of business to comply with this requirement.

ii. Scientific and technical staff having degrees or diplomas with a minimum of 5 years experience in related fields should comprise at least 15% of the company's total workforce.

iii. Value-added must be at least 40%.

Applications should be submitted to MIDA.

2.3 Incentives for Strategic Projects

Strategic projects involve products or activities of national importance. They generally involve heavy capital investments with long gestation periods, have high levels of technology, are integrated, generate extensive linkages, and have significant impact on the economy. Such projects qualify for:

i. Pioneer Status with income tax exemption of 100% of the statutory income for a period of 10 years; Unabsorbed capital allowances as well as accumulated losses incurred during the pioneer period can be carried forward and deducted from the post pioneer income of the company; or

ii. Investment Tax Allowance of 100% on the qualifying capital expenditure incurred within five years from the date the first qualifying capital expenditure is incurred. This allowance can be offset against 100% of the statutory income for each year of assessment. Any unutilised allowances can be carried forward to subsequent years until fully utilised.

Applications should be submitted to MIDA.

2.4 Incentives for Small and Medium Enterprises

Small and Medium Enterprise (SMEs)

Effective from the Year Assessment 2009, for the purpose of imposition of income tax and tax incentives, the definition of SMEs is reviewed as a company resident in Malaysia with a paid up capital of ordinary shares of RM2.5 million or less at the beginning of the basis period of a year of assessment whereby such company cannot be controlled by another company with a paid up capital exceeding RM2.5 million.

SMEs are eligible for a reduced corporate tax of 20% on chargeable incomes of up to RM500,000. The tax rate on the remaining chargeable income is maintained at 25%.

Small-Scale Companies

Currently, small scale companies incorporated in Malaysia with shareholders' fund not exceeding RM500,000 and having at least 60% Malaysian equity are eligible for tax incentives for small scale companies under the Promotion of Investments Act (PIA), 1986. Effective from 3 July 2012, small scale companies are redefined as companies incorporated in Malaysia with shareholders' fund not exceeding RM2.5 million and having 60% to 100% Malaysian equity.

The small-scale company must fulfill the following criteria:-

(i) Incorporated under the Companies Act, 1965.

(ii) Shareholders' funds not exceeding RM2.5 million with the following Malaysian equity ownership:

- Companies with shareholders' fund of up to RM500,000 with at least 60% Malaysian equity
- Companies with shareholders' fund of above RM500,000 and not exceeding RM2.5 million with 100% Malaysian equity.

A small-scale company is eligible for the following incentives:

i. Pioneer Status with income tax exemption of 100% of the statutory income for a period of five years. Unabsorbed capital allowances as well as accumulated losses incurred during the pioneer period can be carried forward and deducted from the post pioneer income of the company; or

ii. Investment Tax Allowance of 60% on the qualifying capital expenditure incurred within five years. This allowance can be offset against 100% of the statutory income for each year of assessment. Any unutilised allowances can be carried forward to subsequent years until fully utilised.

A sole proprietorship or partnership is eligible to apply for this incentive provided a new private limited/limited company is formed to take over the existing production/activities.

A. For small scale companies with shareholders' fund of RM500,000 and less and engaged in promoted activities or producing promoted products in the small company promoted list (See Appendix III: Small Scale Companies) or in the General List (See http://www.mida.gov.my/env3/index.php?page=incentives-for-investment) must fulfill the following condition :-

- The company shall achieve at least **25% value added** in its activity or product;
- The company shall employ at least **20%** of their workers at the **managerial, technical and supervisory staff level**; and
- Not more than **20%** of the paid-up capital in respect of ordinary shares of **the company** is directly or indirectly owned by a **related company** having shareholders' funds of more than RM500,000.

B. For small scale companies with shareholders' fund of **above RM500,000 and not exceeding RM2.5 million** and engaged in promoted activities or producing promoted products in the small company promoted list (See http://www.mida.gov.my/env3/index.php?page=incentives-for-investment):

- The company shall achieve at least **25% value added** in its activity or product;
- The company shall employ at least **20%** of their workers at the **managerial, technical and supervisory staff** level; and
- Not more than **20%** of the paid-up capital in respect of ordinary shares of **the company** is directly or indirectly owned by a **related company** having shareholders' funds of more than RM2.5 million.

C. For small scale companies with shareholders' fund of **above RM500,000 and not exceeding RM2.5 million** and engaged in promoted activities or producing promoted products in the general promoted list:

- The **prevailing rates on Value Added index** under the general promoted list will be applicable;
- The **prevailing rates on Managerial, Technical and Supervisory Staff** index under the general promoted list will be applicable; and
- Not more than **20%** of the paid-up capital in respect of ordinary shares of **the company** is directly or indirectly owned by a **related company** having shareholders' funds of more than RM2.5 million.

Applications should be submitted to MIDA.

2.5 Incentives for the Machinery and Equipment Industry

2.5.1 Incentives for the Production of Selected Machinery and Equipment

Companies undertaking activities in the production of selected machinery and equipment are eligible for:

i. Pioneer Status with income tax exemption of 100% of the statutory income for a period of 10 years. Unabsorbed capital allowances as well as accumulated losses incurred during the pioneer period can be carried forward and deducted from the post pioneer income of the company; or

ii. Investment Tax Allowance of 100% on the qualifying capital expenditure incurred within five years from the date the first qualifying capital expenditure is incurred. This allowance can be offset against 100% of the statutory income for each year of assessment. Any unutilised allowances can be carried forward to subsequent years until fully utilised.

Applications should be submitted to MIDA. (See http://www.mida.gov.my/env3/index.php?page=incentives-for-investment)

2.6 Incentives for the Automotive Industry

2.6.1 Incentives for the Manufacture of Critical and High Value-added Parts and Components for the Automotive Industry

Companies undertaking the manufacture of selected critical and high value-added parts and components for the automotive industry are eligible for:

i. Pioneer Status with income tax exemption of 100% of the statutory income for a period of 10 years. Unabsorbed capital allowances as well as accumulated losses incurred during the pioneer period can be carried forward and deducted from the post pioneer income of the company; or

ii. Investment Tax Allowance of 100% on the qualifying capital expenditure incurred within five years from the date the first qualifying capital expenditure is incurred. This allowance can be offset against 100% of the statutory income for each year of assessment. Any unutilised allowances can be carried forward to subsequent years until they are fully utilised.

The qualifying critical and high value-added parts and components for the automotive industry are as follows:

- transmission systems;
- brake systems;
- airbag systems; and
- steering systems.

The qualifying critical parts and components supporting the manufacturing of hybrid and electric vehicles are:

- electric motors;
- electric batteries;
- battery management system ;inverters;
- electric air conditioning; and
- air compressors.

Applications received by 31 December 2014 are eligible for these incentives.

Applications should be submitted to MIDA.

2.6.2 Incentives for the Assembly or Manufacture of Hybrid and Electric Vehicles

Companies undertaking the assembly or manufacture of hybrid and electric vehicles are eligible for:

- Pioneer Status with income tax exemption of 100% of the statutory income for a period of 10 years. Unabsorbed capital allowances as well as accumulated losses incurred during the pioneer period can be carried forward and deducted from the post pioneer income of the company; or

- Investment Tax Allowance of 100% on the qualifying capital expenditure incurred within five years. This allowance can be offset against 100% of the statutory income for each year of assessment. Any unutilised allowances can be carried forward to subsequent years until fully utilised.

- 50% exemption on excise duty for locally assembled/manufactured vehicles or provision under the Industrial Adjustment Fund (IAF)

Applications should be submitted to MIDA

2.7 Additional Incentives for the Manufacturing Sector

(i) Reinvestment Allowance

Reinvestment Allowance (RA) is given to existing companies engaged in manufacturing and selected agricultural activities that reinvest for the purposes of expansion, automation, modernisation or diversification of its existing business into any related products within the same industry on condition that such companies have been in operation for at least 36 months effective from the Year of Assessment 2009.

The RA is given at the rate of 60% on the qualifying capital expenditure incurred by the company, and can be offset against 70% of its statutory income for the year of assessment. Any unutilised allowance can be carried forward to subsequent years until fully utilised.

- A company can offset the RA against 100% of its statutory income for the year of assessment if the company attains a productivity level exceeding the level determined by the Ministry of Finance. For further details on the prescribed productivity level for each sub-sector, please contact the Inland Revenue Board (see Useful Addresses – Relevant Organisations)

The RA will be given for a period of 15 consecutive years beginning from the year the first reinvestment is made.

Companies can only claim the RA upon the completion of the qualifying project, i.e. after the building is completed or when the plant/machinery is put to operational use. With effect from the Year of Assessment 2009, company purchasing an asset from a related company within the same group where RA has been claimed on that asset is not allowed to claim RA on the same asset.

Assets acquired for the reinvestment cannot be disposed off within a period of five years from the time of the reinvestment effective from the Year of Assessment 2009.

Companies that intend to reinvest before the expiry of its tax relief period, can surrender their Pioneer Status or Pioneer Certificate for the purpose of cancellation and be eligible for RA.

Applications for RA should be submitted to the Inland Revenue Board (IRB), while applications for the surrender of Pioneer Status or Pioneer Certificate for RA should be submitted to MIDA.

(ii) Accelerated Capital Allowance

After the 15-year period of eligibility for RA, companies that reinvest in the manufacture of promoted products are eligible to apply for Accelerated Capital Allowance (ACA). The ACA provides a special allowance, where the capital expenditure is written off within three years, i.e. an initial allowance of 40% and an annual allowance of 20%.

Applications should be submitted to the IRB accompanied by a letter from MIDA certifying that the companies are manufacturing promoted products.

SMEs are eligible for the following incentives:

- ACA on expenses incurred on plant and machinery acquired in the Year of Assessment 2009 and 2010. This allowance is to be claimed within one year that is in the year of assessment the asset is fully acquired. This incentive is effective for the Year of Assessment 2009 and 2010; and

- SMEs are not subject to the maximum limit of RM10,000 for capital allowance on small value assets effective from the Year of Assessment 2009.

Applications for ACA should be submitted to the IRB.

(iii) Accelerated Capital Allowance on Equipment to Maintain Quality of Power Supply

In order to reduce the costs of doing business, companies which incur capital expenditure on equipment to ensure the quality of power supply, are eligible for Accelerated Capital Allowance (ACA) for a period of two years which allows the companies to write off the capital expenditure within two years, i.e. an initial allowance of 20% and an annual allowance of 40%.

Only equipment determined by the Ministry of Finance is eligible for the ACA.

Applications should be submitted to the IRB.

(iv) Accelerated Capital Allowance on Security Control Equipment

Accelerated Capital Allowance (ACA) is given on security control equipment installed in the factory premises of companies licensed under the Industrial Coordination Act 1975. This allowance is eligible to be claimed within one year. Effective from the Year of Assessment 2009, this allowance is extended to all business premises. Security control equipment which is eligible for the allowance is:

- anti-theft alarm system;
- infra-red motion detection system;
- siren;
- access control system; closed circuit television;
- video surveillance system;
- security camera;
- wireless camera transmitter; and
- time-lapse recording and video motion detection equipment.

Applications submitted to the IRB from the Year of Assessment 2009 to 2012 are eligible for this allowance.

(v) Incentive for Industrial Building System

Industrial Building System (IBS) will enhance the quality of construction, create a safer and cleaner working environment as well as reduce the dependence on foreign workers. Companies which incur expenses on the purchase of moulds used in the production of IBS components are eligible for Accelerated Capital Allowances (ACA) for a period of three years.

Applications should be submitted to IRB.

(vi) Tax Exemption on the Value of Increased Exports

To promote exports, manufacturing companies in Malaysia qualify for:

- A tax exemption on statutory income equivalent to 10% of the value of increased exports, provided that the goods exported attain at least 30% value-added; or

- A tax exemption on statutory income equivalent to 15% of the value of increased exports, provided that the goods exported attain at least 50% value-added.

Under the National Automotive Policy (NAP), manufacturing in the automotive industry qualifies for:

- A tax exemption on statutory income equivalent to 30% of the value of increased exports, provided that the goods exported attain at least 30% value-added; or

- A tax exemption on statutory income equivalent to 50% of the value of increased exports provided that the goods exported attain at least 50% value-added.

This enhanced incentive is effective from the Year of Assessment 2010 until the Year of Assessment 2014.

To further encourage the export of Malaysian goods, a locally-owned manufacturing company with Malaysian equity of at least 60% is eligible for:

- A tax exemption on statutory income equivalent to 30% of the value of increased exports, provided the company achieves a significant increase in exports;

- A tax exemption on statutory income equivalent to 50% of the value of increased exports, provided that the company succeeds in penetrating new markets;

- A full tax exemption on the value of increased exports, provided that the company achieves the highest increase in export in its category.

Claims should be submitted to IRB.

(vii) Group Relief

Group relief is provided under the Income Tax Act 1967 to all locally incorporated resident companies. Effective from the Year of Assessment 2009, group relief is increased from 50% to 70% of the current year's unabsorbed losses to be offset against the income of another company within the same group (including new companies undertaking activities in approved food production, forest plantation, biotechnology, nanotechnology, optics and photonics) subject to the following conditions:

a) The claimant and the surrendering companies each has a paid-up capital of ordinary shares exceeding RM2.5 million;

b) Both the claimant and the surrendering companies must have the same accounting period;

c) The shareholding, whether direct or indirect, of the claimant and the surrendering companies in the group must not be less than 70%;

d) The 70% shareholding must be on a continuous basis during the preceding year and the relevant year;

e) Losses resulting from the acquisition of proprietary rights or a foreign-owned company should be disregarded for the purpose of group relief; and

f) Companies currently enjoying the following incentives are not eligible for group relief:

1. Pioneer Status
2. Investment Tax Allowance/Investment Allowance
3. Reinvestment Allowance
4. Exemption of Shipping Profits
5. Exemption of Income Tax under section 127 of the Income Tax Act 1967; and
6. Incentive Investment Company

With the introduction of the above incentive, the existing group relief incentive for approved food production, forest plantation, biotechnology, nanotechnology, optics and photonics will be discontinued. However, companies granted group relief incentive for the above activities shall continue to offset their income against 100% of the losses incurred by their subsidiaries.

Claims should be submitted to IRB.

Note: Please refer to http://www.mida.gov.my/env3/index.php?page=incentives-for-investment *Section 27 for other incentives related to the manufacturing sector.*

3. INCENTIVES FOR THE AEROSPACE INDUSTRY

Aerospace industry development was one of the strategic and high technology areas identified by the Government. It includes activities that directly and indirectly contribute to the design and development, construction, operation, maintenance and disposal of aerospace related products (spacecraft, aircraft, missile/rocket/launcher, and communication, navigation and navigation systems (CNS)).

Effective January 2010, the industry is eligible for a comprehensive tax incentive with the objective to make Malaysia a global centre for aerospace industry in Asia Pacific. The incentive package will be focusing on design, manufacturing and assembling, operator group, support and monitoring group.

i. Design, manufacturing and assembling group of activities consisting of research, design and development and system integration are eligible for:

   - Income tax exemption for a period of five to 15 years depending on the investment level, value-added, technology and other criteria.

To qualify for the incentive, company has to comply with the following criteria:

- Value added must be at least 40%; and

- Percentage of degree graduates in science and technical or diploma or Special/Specific Certificate from certification/licensing bodies recognized by the Government or related International Bodies must be at least 40%.

ii. Operator group consisting of general aviation such as helicopter operation, charter, business jet operation to air recreational (e.g. Flying School, Flying Club and Hornbill Skyway Helicopter) are eligible for:

- Investment Tax Allowance (ITA) of 100% on the qualifying capital expenditure within a period of 10 years subject to the investment in fixed assets exceeding RM150 million within five years.

iii. Support group consisting of maintenance, repair and overhaul activities (MRO) and training in aerospace such as airframe heavy maintenance, line maintenance, compartment maintenance, engine maintenance and modification or conversion of aircraft, missile, rocket and CNS are eligible for:

- Income tax exemption of 100% of statutory income for a period up to 10 years for companies which offer MRO and services related to MRO of aerospace end products such as aircraft, spacecraft, missile/rocket, communication and navigation system (CNS), simulator thereof and equipment, components, accessories or parts thereof;

- Income tax exemption of 100% of statutory income for a period up to 15 years for companies involved in conversion, upgrading and refurbishment or remanufacture of aerospace finished products; or

- ITA of 60% on the qualifying capital expenditure incurred within a period of five years for MRO companies operating in Malaysia which undertake expansion, modernisation or automation of current business or diversification of current business for related products in the same industry; and

- Double deduction on expenses incurred by employers providing pilot conversion and pilot instructor training.

iv. Pilot conversion and instructor pilot courses are eligible for double deduction on expenses incurred by the employers in training their employees.

v. Regulatory group consisting of companies undertaking aerospace related certification, standard development, testing and evaluation and licensing activities are eligible for:

- Pioneer Status with income tax exemption of 100% of statutory income for five years; or

- ITA of 60% on qualifying capital expenditure incurred within five years

These incentives are effective for applications received by MIDA from 1 January 2010 until 31 December 2014.

Note: Please refer to http://www.mida.gov.my/env3/index.php?page=incentives-for-investment *Section 27 for other incentives related to aerospace industry.*

4. INCENTIVES FOR ENVIRONMENTAL MANAGEMENT

4.1 Incentives for Residues Recycling Activities

Companies undertaking residues recycling activities that are high value-added and use high technology are eligible for Pioneer Status or ITA. These activities which include the recycling of agricultural residues or agricultural by-products, recycling of chemicals and the production of reconstituted wood-based panel boards or products are eligible for:

i. Pioneer Status, with income tax exemption of 70% of the statutory income for a period of five years. Unabsorbed capital allowances as well as accumulated losses incurred during the pioneer period can be carried forward and deducted from the post pioneer income of the company; or

ii. Investment Tax Allowance of 60% on the qualifying capital expenditure incurred within a period of five years. The allowance can be offset against 70% of the statutory income in each year of assessment. Any unutilised allowances can be carried forward to subsequent years until fully utilised.

Applications should be submitted to MIDA.

4.2 Incentives for Energy Conservation

(i) Companies Providing Energy Conservation Services

In order to reduce operation costs as well as to promote environmental preservation, companies providing energy conservation services are eligible for the following incentives:

a. Pioneer Status with income tax exemption of 100% of the statutory income for a period of 10 years. Unabsorbed capital allowances as well as accumulated losses incurred during the pioneer period can be carried forward and deducted from the post pioneer income of the company; or

b. Investment Tax Allowance (ITA) of 100% on the qualifying capital expenditure incurred within five years. The allowance can be offset against 100% of the statutory income for each year of assessment. Any unutilised allowances can be carried forward to subsequent years until fully utilised.

The companies must implement their projects within one year from the date of approval.

Applications received by 31 December 2015 are eligible for this incentive.

(ii) Companies Undertaking Conservation of Energy for Own Consumption

Companies which undertake conservation of energy for own consumption is eligible for ITA of 100% on the qualifying capital expenditure incurred within five years. The allowance can be offset against 100% of the statutory income for each year of assessment. Any unutilised allowances can be carried forward until fully utilised.

Applications received by 31 December 2015 are eligible for this incentive.

Applications should be submitted to MIDA.

4.3 Incentives for Energy Generation Activities Using Renewable Energy Resources

Companies undertaking generation of energy using biomass, hydropower (not exceeding 10 megawatts) and solar power that are renewable and environmentally friendly are eligible for the following incentives:

i. Pioneer Status with income tax exemption of 100% of statutory income for 10 years. Unabsorbed capital allowances as well as accumulated losses incurred during the pioneer period can be carried forward and deducted from the post pioneer income of the company; or

ii. Investment Tax Allowance of 100% on the qualifying capital expenditure incurred within a period of five years. This allowance can be offset against 100% of the statutory income for each year of assessment. Any unutilised allowances can be carried forward to subsequent years until fully utilised.

Companies must implement their projects within one year from the date of approval.

With effect from 8 September 2007, other companies in the same group are eligible for the same incentives as above even though one company in the same group has been granted the incentive. Applications received by 31 December 2015 are eligible for this incentive.

For the purpose of this incentive, ‘biomass sources’ refer to palm oil mill/estate residues, rice mill residues, sugar cane mill residues, timber/sawmill residues, paper recycling mill residues, municipal residues and biogas (from landfill, palm oil mill effluent (POME), animal residues and others), while energy forms refer to electricity, steam, chilled water, and heat.

Applications should be submitted to MIDA.

4.4 Incentives for Generation of Renewable Energy for Own Consumption

Companies which generate energy from renewable resources for its own consumption are eligible for the Investment Tax Allowance of 100% on qualifying capital expenditure incurred within a period of five years. This allowance can be offset against 100% of the statutory income for each year of assessment. Any unutilised allowances can be carried forward to subsequent years until fully utilised.

Applications received by 31 December 2015 are eligible for this incentive.

Applications should be submitted to MIDA.

4.5 Tax Incentives for Building Obtaining Green Building Index Certificate

In order to widen the usage of green technology, the Government has launched the green building index (GBI) on 21 May 2009. GBI is a green rating index on environment-friendly buildings. The index is based on certain criteria amongst which are:

- energy and water efficiency;
- indoor environmental quality;
- sustainable management and planning of building sites in respect of pollution control and facilities for workers;
- usage of recyclable and environment friendly materials and resources; and
- adoption of new technology.

As a measure to encourage the construction of buildings using green technology:

i. Owners of buildings awarded the GBI certificate, are eligible for tax exemption equivalent to 100% of the additional capital expenditure incurred to obtain the GBI certificate. The exemption is allowed to set-off against 100% of the statutory income for each year of assessment. The incentive is applicable for new buildings and upgrading of existing buildings.

The incentive is given only for the first GBI certificate issued in respect of the building.

This incentive is effective for buildings awarded with GBI certificates from 24 October 2009 until 31 December 2014.

Application for GBI certification should be submitted to Green Building Index.

ii. Buyers of buildings and residential properties awarded GBI certificate bought from real property developers are eligible for stamp duty exemption on instruments of transfer of ownership of such buildings. The amount of stamp duty exemption is on the additional cost incurred to obtain the GBI certificate. The incentive is given only once to the first owner of the building.

This incentive is effective for sales and purchase agreement executed from 24 October 2009 until 31 December 2014.

Application for incentive should be submitted to IRB.

4.6 Accelerated Capital Allowance for Environmental Management

Companies using environmental protection equipment are eligible for an initial allowance of 40% and an annual allowance of 20% on the qualifying capital expenditure. Thus, the full amount can be written off within three years.

These companies are:

- Residues generators and wish to establish facilities to store, treat and dispose of their residues, either on-site or off-site; and
- Undertake residues recycling activities.

Applications should be submitted to IRB.

In the case of companies that incur capital expenditure for conserving their own energy for consumption, the write-off period is accelerated by another one year.

Applications should be submitted to IRB with a letter from the Ministry of Energy, Green Technology and Water certifying that the related equipment is used exclusively for the purpose of energy conservation.

Note: Please see http://www.mida.gov.my/env3/index.php?page=incentives-for-investment

Section 27 for other incentives related to environmental management.

5. INCENTIVES FOR RESEARCH AND DEVELOPMENT

The Promotion of Investments Act 1986 defines research and development (R&D) as "any systematic or intensive study carried out in the field of science or technology with the objective of using the results of the study for the production or improvement of materials, devices, products, produce or processes" but does not include:

- quality control of products or routine testing of materials, devices, products or produce;
- research in the social sciences or humanities;
- routine data collection;
- efficiency surveys or management studies; and
- market research or sales promotion.

To further strengthen Malaysia's foundation for more integrated R&D, companies which carry out design, development and prototyping as independent activities are also eligible for incentives.

5.1 Main Incentives for Research and Development

(i) Contract R&D Company

A contract R&D company, i.e., a company that provides R&D services in Malaysia to a company other than its related company, is eligible for:

- Pioneer Status with income tax exemption of 100% of the statutory income for five years. Unabsorbed capital allowances as well as accumulated losses incurred during the pioneer period can be carried forward and deducted from the post pioneer income of the company; or
- Investment Tax Allowance (ITA) of 100% on the qualifying capital expenditure incurred within 10 years. The allowance can be offset against 70% of the statutory income for each year of assessment. Any unutilised capital allowances can be carried forward to subsequent years until fully utilised.

Applications should be submitted to MIDA.

(ii) R&D Company

A R&D company, i.e. a company that provides R&D services in Malaysia to its related company or to any other company, is eligible for an ITA of 100% on the qualifying capital expenditure incurred within 10 years. The allowance can be offset against 70% of the statutory income for each year of assessment. Any unutilised allowances can be carried forward to subsequent years until fully utilised.

Should the R&D company opt not to avail itself of the allowance, its related companies can enjoy double deduction for payments made to the R&D company for services rendered.

Applications should be submitted to MIDA.

Eligibility:

Contract R&D and R&D companies that fulfil the following criteria can apply for the various incentives:

a. Research undertaken should be in accordance with the needs of the country and bring benefit to the economy;

b. At least 70% of the income of the company should be derived from R&D activities;

c. For manufacturing-based R&D, at least 50% of the workforce of the company must be appropriately qualified personnel performing research and technical functions; and

d. For agriculture-based R&D, at least 5% of the workforce of the company must be appropriately qualified personnel performing research and technical functions.

(iii) In-house Research

A company that undertakes in-house R&D to further its business can apply for an ITA of 50% of the qualifying capital expenditure incurred within 10 years. The company can offset the allowance against 70% of its statutory income for each year of assessment. Any unutilised allowances can be carried forward to subsequent years until fully utilised.

Applications should be submitted to MIDA.

(iv) Incentives for Reinvestment in R&D Activities

R&D companies/activities mentioned in categories (i) - (iii) are eligible for a second round of Pioneer Status for another five years, or ITA for a further 10 years, where applicable.

See http://www.mida.gov.my/env3/index.php?page=incentives-for-investment *List of Promoted Activities and Products for Reinvestment*

Applications should be submitted to MIDA.

(v) Incentives for Commercialisation of Public Sector R&D

To encourage commercialisation of resource-based and non-resource-based R&D findings of public research institutes, the following incentives are given:

a. A company that invests in its subsidiary company engaged in the commercialisation of the R&D findings is eligible for a tax deduction equivalent to the amount of investment made in the subsidiary company; and

b. The subsidiary company that undertakes the commercialisation of the R&D findings is eligible for Pioneer Status with income tax exemption of 100% of statutory income for 10 years. The commercialisation of non-resource-based findings is subject to the list of promoted activities/products under the Promotion Investment Act, 1986.

The incentive for the commercialisation of non-resource-based findings is effective for applications received by MIDA from 29 September 2012 until 31 December 2017.

The incentive is provided on the following conditions:

a. At least 70% of the investing company (holding company) and the company undertaking the commercialisation projects are owned by Malaysians;

b. The company which invests should own at least 70% of the equity of the company that commercialises the R&D findings;

c. The commercialisation of the R&D findings should be implemented within one year from the date of approval of the incentive.

5.2 Additional Incentives for Research and Development

(i) Double Deduction for Research and Development

- A company can enjoy a double deduction on its revenue (non-capital) expenditure for research which is directly undertaken and approved by the Minister of Finance.
- Double deduction can also be claimed for cash contributions or donations to approved research institutes, and payments for the use of the services of approved research institutes, approved research companies, R&D companies or contract R&D companies.
- Approved R&D expenditure incurred during the tax relief period for companies granted Pioneer Status can be accumulated and deducted after the tax relief period.
- Expenditure on R&D activities undertaken overseas, including the training of Malaysian staff, will be considered for double deduction on a case-by-case basis.

Claims should be submitted to IRB.

(ii) Incentives for Researchers to Commercialise Research Findings

Researchers who undertake research focused on value creation will be given a 50% tax exemption for five years on the income that they receive from the commercialisation of their research findings. The undertaking has to be verified by the Ministry of Science, Technology and Innovation.

Claims should be submitted to IRB.

Note: Please see http://www.mida.gov.my/env3/index.php?page=incentives-for-investment *Section 27 for other incentives related to R&D.*

6. INCENTIVES FOR TRAINING

6.1 Main Incentives for Training

To encourage human resource development, the following incentives are available:

Investment Tax Allowance

New private higher institution (PHEIs) in the field of science and companies that establish technical or vocational training institution are eligible for an Investment Tax Allowance (ITA) of 100% for 10 years. This allowance can be offset against 70% of the statutory income for each year of assessment. Any unutilised allowances can be carried forward to subsequent years until fully utilised.

- The above incentive also applies to existing PHEIs in the field of science and existing companies providing technical or vocational training that undertake new investments to upgrade their training equipment or expand their training capacities.

The qualifying science courses for PHEIs are as follows:

i. **Biotechnology**

- Medical and health biotechnology
- Plant biotechnology
- Food biotechnology
- Industrial and environment biotechnology
- Pharmaceutical biotechnology
- Bioinformatics biotechnology

ii. **Medical and Health Sciences**

- Medical science in gerontology
- Medical science in clinical research
- Medical biosciences
- Biochemical genetics
- Environmental health
- Community health

iii. **Molecular Biology**

- Immunology
- Immunogenetics
- Immunobiology

iii. **Material sciences and technology**

iv. **Food science and technology**

Applications should be submitted to MIDA.

6.2 Additional Incentives for Training

(i) **Deduction for Cost of Recruitment of Workers**

Cost of recruitment of workers is allowed as a deduction for the purpose of tax computation. Cost includes expenses incurred in participation in job fairs, payment to employment agencies and head-hunters.

Claims should be submitted to IRB.

(ii) **Deduction for Pre-Employment Training**

Training expenses incurred before the commencement of business qualify for a single deduction. Nevertheless, companies must prove that they will employ the trainees.

Claims should be submitted to IRB.

(iii) **Deduction for Non-Employee Training**

Expenses incurred in providing practical training to residents who are not employees of the company can be considered for single deduction.

Claims should be submitted to IRB.

(iv) **Deduction for Cash Contributions**

Contributions in cash to technical or vocational training institutions that are not operating primarily for profit and those established and maintained by a statutory body qualify for single deduction.

Claims should be submitted to IRB.

(v) **Special Industrial Building Allowance**

Companies that incur expenditure on buildings used for approved industrial, technical or vocational training can claim a special annual Industrial Building Allowance (IBA) of 10% for 10 years on qualifying capital expenditure for the construction or purchase of a building.

Claims should be submitted to IRB.

(vi) **Tax Exemption on Educational Equipment**

Approved training institutes, in-house training projects and all private institutions of higher learning are eligible for import duty, sales tax and excise duty exemptions on all educational equipment including laboratory equipment for workshops, studios and language laboratories.

Applications should be submitted to MIDA.

(vii) **Tax Exemption on Royalty Payments**

Royalty payments made by educational institutions to non-residents (franchisors) for franchised education programmes that are approved by the Ministry of Education are eligible for tax exemption.

Claims should be submitted to IRB.

(viii) **Double Deduction for Approved Training**

Manufacturing and non-manufacturing companies that do not contribute to the Human Resource Development Fund (HRDF) qualify for double deduction on expenses incurred for approved training.

For the manufacturing sector, the training could be undertaken in-house or at approved training institutions. However, for the non-manufacturing sector, the training should be held only at approved training institutions. Approval is automatic when the training is at approved institutions.

For the hotel and tour operation business, training programmes, in-house or at approved training institutions, to upgrade the level of skills and professionalism in the tourism industry, should be approved by the Ministry of Tourism.

Effective from the year of assessment 2009 to year of assessment 2012, employers who incur expenses for training their employees in the following skills are eligible for double deduction:

- Post graduate courses in information and communication technology (ICT), electronics and life sciences;
- Post basic courses in nursing and allied health care; and
- Aircraft maintenance engineering courses.

Claims should be submitted to IRB.

(ix) **Human Resource Development Fund (HRDF)**

Please refer to Chapter 5 on Manpower for Industry.

Claims should be submitted to IRB.

Note: Please refer http://www.mida.gov.my/env3/index.php?page=incentives-for-investment *for other incentives related to the training.*

(x) **Tax Incentive for Structured Internship Programme**

Double deduction is given on expenses incurred by companies that implement the structured internship programme. The qualifying criteria for this programme among others are as follows:

a. The internship programme is for full time undergraduate students from the Public/Private Higher Educational Institutions; and

b. Internship programme is for a minimum period of 10 weeks with a monthly allowance of not less than RM 500.

Claims should be submitted to IRB.

The incentive applicable for Year of Assessment 2012 until 2016.

(xi) **Incentive For Awarding Scholarships**

Scholarships awarded by private companies to Malaysian students pursuing study at diploma and bachelor's degree in local institutions of higher learning registered with the Ministry of Higher Education will be given double deduction.

Scholarships awarded are for students that fulfil the following criteria:

a. Full time student;

b. Have no sources of income; and

c. Total monthly income of parents or guardian of the student does not exceed RM 5,000.

Claims should be submitted to IRB.

The incentive is applicable for year assessment 2012 until 2016.

7. DOMESTIC INVESTMENT STRATEGIC FUND

Domestic Investment Strategic Fund of RM1 billion was established to accelerate the shift of Malaysian-owned companies in targeted industries to high value-added, high technology, knowledge-intensive and innovation-based industries. The package of assistance is granted under the Customised Incentive Scheme, based on the request of the companies and the merits of each case. The Fund aims to harness and leverage on outsourcing opportunities created by MNCs operating in Malaysia; intensify technology acquisition by Malaysian-owned companies; and enable Malaysian-owned companies to obtain international standards/certifications in strategic industries. The Fund does not offer an outright grant and is contingent on the investments by the applicant.

7.1 Incentives

The Domestic Investment Strategic Fund will provide matching grants (1:1) as follows:

a. For training and R&D activities;

b. To undertake outsourcing activities;

c. To comply with international standards; and

d. For licensing/purchase of technology.

7.2 Eligibility Criteria

a. Incorporated under the Companies Act, 1965.

b. New companies in the manufacturing and services sectors with Malaysian equity ownership of at least 60%.

c. Existing companies in the manufacturing and services sectors with Malaysian equity ownership of at least 60% undertaking reinvestments (expansion / modernisation / diversification).

d. Companies producing promoted products/engaged in promoted activities in the following priority sectors:

- Aerospace;
- Medical Devices;
- Pharmaceuticals;
- Advanced Electronics;
- Machinery and Equipment;
- Renewable Energy;
- Services including design, R&D, testing, quality and standard certification, engineering services, technical and skills training and logistics service providers (3PL); and
- Other industries, on a case by case basis.

7.3 Scope of the Fund

The Fund will cater for expenditures incurred for the following activities:

a. Training of Malaysians;

b. R&D activities carried out in Malaysia;

c. Modernisation and upgrading of facilities and tools to undertake manufacturing or services activities for Multinational Corporations (MNCs) and Malaysian conglomerates (outsourcing activities[1]);

d. Obtaining international standards/certification; and

e. Licensing or purchase of new/high technology.

[1] *Outsourcing is a subcontracting process that involves manufacturing, manufacturing related services, business services and delegation of some/all operations to an external entity, usually specialised in that operation.*

Applications received by Malaysian Investment Development Authority (MIDA) from 3 July 2012 are eligible to be considered for this incentive.

8. GUIDELINES FOR INCENTIVES FOR ACQUIRING A FOREIGN COMPANY FOR HIGH TECHNOLOGY

8.1 Incentives

(i) A locally-owned company in the manufacturing or services sector that acquires a foreign-owned company abroad will be eligible for an incentive in the form of an annual deduction of 20% of the acquisition cost for 5 years for the following purpose:

- Establishment of a manufacturing facility/ company or services company within Malaysia; or
- Utilisation of the acquired technology in their existing operations within Malaysia.

(ii) The incentive is in the form of an annual deduction to ascertain the adjusted income of the locally-owned company, and any unutilised deduction can be carried forward until fully utilised.

8.2 Eligibility Criteria

(i) The acquirer must be a locally-owned company that is incorporated under the Companies Act, 1965 with at least 60% Malaysian equity ownership involved in manufacturing or services activities.

(ii) Malaysian equity ownership of at least 60% must be held for a period of 5 years from the date of application.

(iii) For a public listed company:

- At least 60% of its equity is directly owned by Malaysians on the first day of listing on the stock exchange; and
- At least 50% of its equity is directly owned by Malaysians.

(iv) An acquisition by a holding company having interests in manufacturing or services activities will be considered on a case by case basis.

(v) The acquiree must be a foreign company with 100% foreign equity ownership that is located abroad and uses the high technology in the activity of manufacturing or services.

(vi) The acquisition should be a direct acquisition of at least 51% of the equity of the foreign company abroad.

(vii) The acquisition must be in the form of a cash transaction. Acquisitions through share-swapping will not be eligible for this incentive.

(viii) The acquisition must be completed within three (3) years.

(ix) Acquisition costs eligible for the deduction comprise:

- Value of shares purchased by the Malaysian company (acquirer); and
- Incidental costs, including professional fees paid to bankers, valuers, auditors, accountants, tax agents, consultants, or legal advisers; cost of transfers including stamp duties; related travelling and accommodation expenses incurred for the purpose of the acquisition.
- The acquisition of the foreign technology company must result in increase of performance or enhancement of technology and processes of the company's operation in Malaysia.

(x) Definition of High Technology means new and emerging technologies acquired by a locally owned company in Malaysia with the object of using the high technology for:

- The production or improvement of material, devices, products, produce or processes; or

- The improvement of processes or quality of the selected services

(xi) Other Considerations

- Applications for the incentive can be made prior to, during the course of negotiations, or within six months after the completion of the acquisition.

- A company currently enjoying incentives under the Promotion of Investments Act (PIA), 1986 or Income Tax Act, 1967, is not eligible for this incentive.

- The acquisition must be held for at least five years. Where the acquired foreign-owned company is disposed of within five years from the date of the completion of the acquisition, any annual deduction granted will be withdrawn in the year of assessment such ordinary shares are disposed of.

- The annual deduction will be granted from the date of the completion of the acquisition and all the costs of acquisition are deemed to be incurred on that completion date.

- For an acquisition undertaken with the objective of acquiring high technology for production within the country, the applicant company is also eligible to be considered for incentives granted to high technology companies. However, they will be limited to the manufacture of new products using the acquired technology.

- For an acquisition undertaken with the objective of acquiring high technology to provide services within the country, the applicant company is also eligible to be considered for incentives granted to services activities. However, they will be limited to the new services using the acquired technology.

- Any subsequent application by the acquirer or its related companies will not be eligible for the incentive

Applications received by Malaysian Investment Development Authority (MIDA) from 3 July 2012 until 31 December 2016 are eligible to be considered for this incentive.

9. OTHER INCENTIVES

This section covers other incentives not mentioned elsewhere and may be applicable to the following sectors: manufacturing, agriculture, aerospace, tourism, environmental management, research and development, training, information and communication technology, Approved Service Projects and manufacturing related services.

9.1 Incentive for Acquiring Proprietary Rights

Capital expenditure incurred in acquiring patents, designs, models, plans, trademarks or brands and other similar rights from foreigners qualify as a deduction in the computation of income tax. This deduction is given in the form of an annual deduction of 20% over a period of five years.

Claims should be submitted to IRB.

9.2 Tax Incentives for Small and Medium Enterprises to Register Patents and Trademarks

In line with the Government's objective to promote innovation and intellectual property development among small and medium enterprises (SME), expenses incurred in the registration of patents and trademarks in the country will be allowed as a deduction for the purpose of income tax computation.

Such registration expenses include fees or payment made to patent and trademark agents registered under the Patents Act 1983 and the Trade Marks Act 1976.

The definitions for the purpose of this tax incentive are as follows:

i. Companies as defined under paragraph 2A and 2B, Schedule 1, Income Tax Act 1967

ii. Manufacturing industries, manufacturing related services industries and agro- based industries

- Enterprise with full-time employees not exceeding 150 persons; or with annual sales turnover not exceeding RM25 million

iii. Services industries, primary agriculture and Information & Communication Technology (ICT)

- Enterprise with full-time employees not exceeding 50 persons; or with annual sales turnover not exceeding RM5 million

This is effective from the year of assessment 2010 until the Year of Assessment 2014.

9.3 Tariff Related Incentives

(i) Exemption from Import Duty on Raw Materials/ Components

Full exemption from import duty can be considered for raw materials/ components, regardless of whether the finished products are meant for the export or domestic market.

Where the finished products are for the export market, full exemption from import duty on raw materials/ components is normally granted, provided the raw materials/components are not produced locally or, where they are produced locally, are not of acceptable quality and price.

Where the finished products are for the domestic market, full exemption from import duty on raw materials/components that are not produced locally can be considered. Full exemption can also be considered if the finished products made from dutiable raw materials/ components are not subject to any import duty.

Hotel and tourism projects qualify for full exemption of import duty and sales tax on identified imported materials.

Applications should be submitted to MIDA.

(ii) Exemption from Import Duty and Sales Tax on Machinery and Equipment

It is the policy of the government not to impose taxes on machinery and equipment used directly in the manufacturing process and not produced locally. Most categories of machinery and equipment are therefore, not subject to import duties. In cases where the imported machinery and equipment are taxable but are not available locally, full exemption is given on import duty and sales taxes. For locally purchased machinery and equipment, full exemption is given on sales tax.

Applications should be submitted to MIDA.

(iii) Exemption from Import Duty and Sales Tax on Spares and Consumables

Manufacturing companies qualify for import duty and sales tax exemptions on spares and consumables that are not produced locally and which are used directly in the manufacturing process.

Applications should be submitted to MIDA.

(iv) Exemption from Import Duty and Sales Tax for Outsourcing Manufacturing Activities

To reduce the cost of doing business and enhance competitiveness, owners of Malaysian brands with at least 60% Malaysian equity ownership who outsource manufacturing activities are eligible for:

a. Import duty and sales tax exemptions on raw materials and components used in the manufacturing of finished products by their contract manufacturers locally or abroad

b. Import duty and sales tax exemptions on semi-finished goods from their contract manufacturers abroad, to be used by their local contract manufacturers to manufacture the finished products.

Applications should be submitted to MIDA.

(v) **Exemption from Import Duty and Sales Tax for Maintenance, Repair and Overhaul (MRO) Activities**

Aerospace companies undertaking maintenance, repair and overhaul activities, qualify for import duty and sales tax exemption on raw materials, components, machinery and equipment, spares and consumables. These are subject to each importation to be accompanied by certificates of parts and components issued by one of the following original equipment manufacturers (OEM):

c. FAA Form 8130-3 from the United States of America

d. EASA Form 1 from the European UnionCertificate of Compliance Certificate of Conformance Certificate from vendors

e. Distributor certificate

Applications should be submitted to the Ministry of Finance.

(vi) **Exemption from Import Duty and Excise Duty on Hybrid and Electric Cars**

Generally, the importation of completely built-up (CBU) cars including hybrid and electric cars below 2000cc is subject to import duty, excise duty and sales tax that ranges from 10% to 80%.

However, to promote Malaysia as a regional hub for hybrid and electric cars and as an incentive for local car manufacturers and assemblers to prepare for assembly of such cars domestically, franchise holders of hybrid and electric cars are given 100% exemption on import duty and excise duty on new CBU hybrid and electric cars subject to the following criteria and conditions:

Hybrid Car:

a. Comply with the United Nations' definition as follows:

"A vehicle with at least two different energy convertors and two different energy storage systems (gasoline and electric) on-board the vehicle for the purpose of vehicle propulsion";

b. Limited to new CBU hybrid passenger cars with engine capacity below 2000cc;

c. Engine specification of at least Euro 3 Technology;

d. Certified by the Road Transport Department as hybrid car by obtaining Vehicle Type Approval and certified to have achieved not less than a 50% increase in the city-fuel economy or not less than a 25% increase in combined city-highway fuel economy relative to a comparable vehicle that is an internal combustion gasoline fuel; and

e. Emission of carbon monoxide of less than 2.3 gram per kilometre.

Electric Car:

a. Comply with the United Nations' definition follows:

"A vehicle with bodywork intended for road use, powered exclusively by an electric motor whose traction energy supplied exclusively by a traction battery installed in the vehicle.

b. Limited to new CBU electric car with electric motor power below 100kW;and

c. Certified by the Road Transport Department as electric car by obtaining of Vehicle Type Approval.

Applications submitted to the Ministry of Finance by 31 December 2013 are eligible for these incentives.

Sales Tax Exemption

Manufacturers licensed under the Sales Tax Act 1972 qualify for sales tax exemption on the inputs for their manufacturing operations. Manufacturers with an annual sales turnover of less than RM100,000 are exempted from licensing and are thus exempted from paying sales tax on their output. However, these manufacturers can opt to be licensed and obtain sales tax exemption on their inputs instead.

Certain categories of goods are exempted from sales tax at both the input and output stages. These include all goods (inclusive of packaging materials) used in the manufacture of controlled articles, pharmaceutical products, milk products, batik fabrics, perfumes, beauty or make-up preparations, photographic cameras, wrist- watches, pens, computers and computer peripherals, parts and accessories, carton boxes/cases, products in the printing industry, agricultural or horticultural sprayers, plywood, re-treaded tyres, uninterruptible power systems, machinery, and manufactured goods for export.

Applications can be made to the Royal Malaysian Customs Department

(vii) **Drawback on Import Duty, Sales Tax and Excise Duty**

Under Section 99 of the Customs Act 1967, Section 29 of the Sales Tax Act 1972 and Section 19 of the Excise Act 1976, a drawback on import duty, sales tax and excise duty that have been paid may be claimed by a manufacturer if the parts, raw materials or packaging materials are used in the manufacture of goods for export within a year based on conditions stipulated in the Acts.

Excise duties are imposed on a selected range of goods manufactured in Malaysia. Goods which are subject to excise duties include intoxicating liquor, cigarettes containing tobacco, motor vehicles, playing cards and mahjong tiles.

The movement of goods from the principal customs area or licensed premises (for goods subject to excise duty) for use in the manufacture of other products by a factory in a free industrial zone (FIZ) or licensed manufacturing warehouse (LMW) or the islands of Langkawi, Labuan and Tioman is considered as exports from Malaysia.

Applications should be made to the nearest Royal Malaysian Customs Department office where its factory is located.

9.4 Incentive for the Use of Environmental Protection Equipment

Companies using environmental protection equipment receive an initial allowance of 40% and an annual allowance of 20% on the capital expenditure incurred on such equipment. Thus, the full amount can be written off in three years.

Claims should be submitted to IRB.

ENVIRONMENTAL MANAGEMENT

To promote environmentally sound and sustainable development, the Malaysian government has established the legal and institutional framework for environmental protection. Investors are encouraged to consider the environmental factors during the early stages of their project planning. Aspects of pollution control include possible modifications in the process line to minimise residues generation, seeing pollution prevention as part of the production process, and focusing on recycling options.

1. **POLICY**

The National Policy on the Environment aims at continued economic, social, and cultural progress of Malaysia and enhancement of the quality of life of its people, through environmentally sound and sustainable development.

The Policy aims at achieving:

- A clean, safe, healthy and productive environment for present and future generations
- The conservation of the country's unique and diverse cultural and natural heritage with effective participation by all sectors of society
- A sustainable lifestyle and pattern of consumption and production

Malaysia's national environmental policy emphasises:

- Exercising respect and care for the environment in accordance with the highest moral and ethical standards
- Conserving the natural ecosystems to ensure the integrity of biodiversity and life support systems
- Ensuring continuous improvement in the productivity and quality of the environment while pursuing economic growth and human development objectives
- Managing natural resource utilisation to sustain the resource base and prevent degradation of the environment
- Integrating environmental dimensions in the planning and implementation of the policies, objectives and mandates of all sectors to protect the environment
- Strengthening the role of the private sector in environmental protection and management
- Ensuring the highest commitment to environmental protection and accountability by all decision-makers in the public and private sectors, resource users, non-governmental organisations and the general public in formulating, planning and implementing their activities
- Participating actively and effectively in regional and global efforts towards environmental conservation and enhancement

2. ENVIRONMENTAL REQUIREMENTS

The Environmental Quality Act 1974, and its accompanying regulations call for environmental impact assessment, project siting evaluation, pollution control assessment, monitoring and self-enforcement. Industrial activities are required to obtain the following approvals from the Director-General of Environmental Quality prior to project implementation:

i. Environmental impact assessment for Prescribed Activities

ii. Site suitability evaluation

iii. Written notification or permission to construct

iv. Written approval for installation of incinerator, fuel burning equipment and chimney

v. Licence to occupy and operate prescribed premises and prescribed conveyances.

2.1 Environmental Impact Assessment for Prescribed Activities

An investor should first of all check whether an environmental impact assessment (EIA) is required for his proposed industrial activities. The following are activities prescribed under the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 1987, which require an EIA before project approval:

(i) **Industry**

a. Chemicals Where production capacity of each product or of combined products is greater than 100 tonnes per day
b. Petrochemicals All sizes.
c. Non-ferrous Primary smelting:
Aluminium- all sizes
Copper- all sizes
Others - producing 50 tonnes per day and above of product
d. Non-metallic Cement - for clinker throughput of 30 tonnes per hour and above

Lime - 100 tonnes per day and above burnt lime rotary kiln or - 50 tonnes per day and above vertical kiln

e. Iron and Steel Require iron ore as raw materials for production greater than 100 tonnes per day; or sing scrap iron as raw materials for production greater than 200 tonnes per day

f. Shipyards Dead Weight Tonnage greater than 5,000 tonnes

g. Pulp and Paper Production capacity greater than 50 tonnes per Industry day

(ii) **Mining**

a. Mining of minerals in new areas where the mining lease covers a total area in excess of 250 hectares.

b. Ore processing, including concentrating for aluminum, copper, gold or tantalum.

c. Sand dredging involving an area of 50 hectares or more.

(iii) **Quarries**

Proposed quarrying of aggregate, limestone, silica, quartzite, sandstone, marble and decorative building stone within 3 kilometres of any existing residential, commercial or industrial areas, or any area for which a license, permit or approval has been granted for residential, commercial or industrial development.

(iv) **Residues Treatment and Disposal**

a. Toxic and Hazardous Residues

- Construction of incineration plant
- Construction of recovery plant (off-site)
- Construction of wastewater treatment plant (off-site)
- Construction of secure landfill facility
- Construction of storage facility (off-site)

2.2 Who Can Conduct EIA Study

An EIA study has to be conducted by competent individuals who are registered with the Department of Environment (DOE) under the EIA Consultant Registration Scheme. The list of registered EIA consultants and details on the registration scheme are available at the DOE website, www.doe.gov.my

2.3 Site Suitability Evaluation

One of the most important factors in obtaining environmental approval is the site suitability of the proposed project. Site suitability is evaluated based on the compatibility of the project with respect to the gazetted structure or local plans, surrounding land-use, provision of set-backs or buffer zones, the capacity of the area to receive additional pollution load, and residues disposal requirements.

Site suitability evaluation (SSE) has become the main process in ensuring site suitability for all development projects that are referred to DOE. As such, SSE has to be undertaken first for both prescribed and non-prescribed activities. For prescribed activities, SSE must be done before the EIA is conducted to ensure the site selected is suitable for the proposed activity and compatible with its surrounding land-use. This also helps the project proponent to save costs conducting EIA if the site is deemed unsuitable.

2.4 Written Notification or Permission to Construct

Any person intending to carry out activities as listed below must provide prior written notification to the Director-General of Environmental Quality:

i. Carry out any work on any premises or construct any building that may discharge or release industrial effluent or mixed effluent, or make or cause or permit a material change in the quantity or quality of discharge from an existing source, onto or into any soil, or into inland waters or Malaysian waters, other than premises as specified in the First Schedule under Environmental Quality (Industrial Effluent) Regulations, 2009;

ii. Discharge or release or permit the discharge of sewage onto or into any soil, or into any inland waters or Malaysian waters, other than any housing or commercial development or both having a population equivalent of less than one hundred and fifty (150) as specified under Environmental Quality (Sewage) Regulations, 2009;

iii. Carry out on any land any facility or building that may result in a new source of leachate discharge or release as specified under Environmental Quality (Control of Pollution from Solid Residues Transfer Station and Landfill) Regulations, 2009.

Any person intending to construct on any land or any building; or carrying out work that would cause the land or building to become prescribed premises (crude palm oil mills, raw natural rubber processing mills, and treatment and disposal facilities of scheduled residuess), as stipulated under Section 19 of the Environmental Quality Act, 1974 must obtain prior written permission from the Director-General of Environmental Quality.

Such application has to be accompanied by a prescribed fee.

2.5 Written Approval for Installation of Incinerator, Fuel Burning Equipment and Chimney

Applicants intending to carry out activities as listed below shall obtain prior written approval from the Director-General of Environmental Quality:

i. New installation near dwelling area as detailed out in Regulation 4 and First Schedule of the Environmental Quality (Clean Air) Regulations 1978.

ii. Any erection (including incinerators), installation, resiting or alteration of fuel burning equipment that is rated to consume pulverised fuel or solid fuel at 30 kg or more per hour, or liquid or gaseous fuel at 15 kg or more per hour as stipulated in Regulations 36 and 38 of the Environmental Quality (Clean Air) Regulations 1978.

iii. Any erection, installation, resiting, or alteration of any chimney from or through which air impurities may be emitted or discharged, respectively.

** No fee is imposed on the application for written approval.*

2.6 License to Occupy Prescribed Premises and Prescribed Conveyances

A license is required to occupy and operate prescribed premises, namely as below:

i. crude palm oil mills,

ii. raw natural rubber processing mills, and

iii. treatment and disposal facilities of scheduled wastes.

A license is required to use prescribed conveyances as stipulated in the Environmental Quality (Prescribed Conveyance) (Scheduled Wastes) Order 2005. Conveyance which is categorised as prescribed conveyance namely, any vehicle or ship of any description which is:

i. propelled by a mechanism contained within itself;

ii. constructed or adapted to be used on land or water; and

iii. used for the movement, transfer, placement or deposit of scheduled wastes.

Applications for the license shall be made after obtaining written permission and/or written approval (as mentioned in 2.3 and 2.4). Licensing fees apply for every licence issued for palm oil and raw natural rubber processing mills and facilities for the treatment and disposal of scheduled wastes, and prescribed conveyances.

2.7 Gaseous Emission and Effluent Standards

Industries are required to comply with air emission, industrial effluent, sewage and leachate discharge standards which are regarded as acceptable conditions allowed in Malaysia, as stipulated in the Environmental Quality (Clean

Air) Regulations 1978, Environmental Quality (Industrial Effluents) Regulations 2009, Environmental Quality (Sewage) Regulations 2009, and Environmental Quality (Control of Pollution from Solid Residues Transfer Station and Landfill) Regulations 2009.

2.8 Control-on Ozone Depleting Substances

Ozone depleting substances (ODS) are categorised as environmentally hazardous substances under the Environmental Quality (Refrigerant Management) Regulations 1999 and the Environmental Quality (Halon Management) Regulations 1999. New investments relating to the use of these substances are prohibited.

2.9 Scheduled Wastes Management

Malaysia has developed a comprehensive set of legal provisions related to the management of toxic and hazardous wastes. The regulation is based on the cradle to grave principle. A facility which generates, stores, transports, treats or disposes scheduled wastes is subject to the following main regulations:

i. Environmental Quality (Scheduled Wastes) Regulations 2005 (Amendment) 2007;

ii. Environmental Quality (Prescribed Conveyance) (Scheduled Wastes) Order 2005;

iii. Environmental Quality (Prescribed Premises) (Scheduled Wastes Treatment and Disposal Facilities) (Amendment) Order 2006;

iv. Environmental Quality (Prescribed Premises) (Scheduled Residues Treatment and Disposal Facilities) (Amendment) Regulations 2006;

v. Customs (Prohibition of Exports) Order 2008; and

vi. Customs (Prohibition of Imports) Order 2008.

2.9.1 A Summary of Environmental Requirements on Scheduled Wastes

Environmental Quality (Scheduled Wastes) Regulations 2005 replaced the Environmental Quality (Scheduled Wastes) Regulations 1989. Under these regulations, 77 types of scheduled wastes listed in the First Schedule are divided into 5 categories, namely:

(i) SW 1 Metal and metal-bearing wastes (10 types of scheduled wastes);

(ii) SW 2 Wastes containing principally inorganic constituents which may contain metals and organic materials (7 types of scheduled wastes);

(iii) SW 3 Wastes containing principally organic constituents which may contain metals and inorganic materials (27 types of scheduled wastes);

(iv) SW4 Wastes which may contain either inorganic or organic constituents (32 types of scheduled wastes)

(v) SW 5 Other wastes (1 type of scheduled residues)

Scheduled wastes can be stored, recovered or treated within the premises of the residues generators. Such activities do not require licensing by the Department of Environment. A residues generator may store scheduled wastes generated by him for 180 days or less after its generation provided that the quantity of scheduled wastes accumulated on site shall not exceed 20 metric tonnes. However, residues generators may apply to the Director General in writing to store more than 20 metric tonnes of scheduled wastes. The containers that are used to store scheduled wastes shall be clearly labeled with the date when the scheduled wastes are first generated as well as the name, address and telephone number of the residues generator.

Land farming, incineration, disposal and off-site facilities for recovery, storage and treatment can only be carried out at prescribed premises licensed by the Department of Environment. However, with the signing of the concession agreement between the Government of Malaysia and Kualiti Alam Sdn. Bhd on 18 December 1995 (15 years concession period), all off-site treatment and disposal (incineration, wastes water treatment, storage and secure landfill) of scheduled wastes is not allowed.

On-site incineration of scheduled wastes is not encouraged. If it is deemed necessary, application for the installation of such incinerator must strictly adhere to the Guidelines On the Installation of On-site Incinerator for the Disposal of Scheduled Wastes in Malaysia" (published by the Department of Environment), including carrying out a detailed environmental impact assessment and display of the EIA report for public comments.

Residues generators may apply for special management of scheduled wastes to have the scheduled wastes generated from their particular facility or process excluded from being treated, disposed of or recovered in premises or facilities other than at the prescribed premises or on-site treatment or recovery facilities, as stipulated under Regulation 7(1), Environmental Quality (Scheduled Wastes) Regulations 2005.

3. INCENTIVES FOR ENVIRONMENTAL MANAGEMENT

Further details on environmental management requirements can be obtained from the Department of Environment or visit www.doe.gov.my

ACRONYMS

AELB	Atomic Energy Licensing Board
AIST	National Institute of Advanced Industrial Science and Technology, Japan
ANSTO	Australian Nuclear Science and Technology Organisation
ARE	Asian Rare Earths
ASM	Academy Sciences of Malaysia
ADTEC	Advanced Technology Training Centre
BRIRE	Baotou Research Institute of Rare Earths
CSIRO	Commonwealth Scientific and Industrial Research Organization
DEHPA	Diethylhexyl Phosphoric Acid
DOE	Department of Environment
DOSH	Department of Occupational Safety and Health
EV	Electric vehicle
G2G	Government-to-Government
GIE	Gebeng Industrial Estate
GIS	Geographical Information System
GPS	Global Positioning System
HCD	Human Capital Development
HEV	Hybrid electric vehicle
HREEs	Heavy Rare Earth Elements
HS Code	Harmonized Commodity Description and Coding System
IAEA	International Atomic Energy Agency
IKBN	Institut Kemahiran Belia Negara (National Youth Skills Institute)
ILP	Industrial Training Institute

ISBA	International Sea-bed Authority
JMG	Jabatan Mineral dan Geosains (Minerals and Geoscience Department)
JORC	Joint Ore Reserves Committee
KIRAM	Korea Institute for Rare Metals
KITECH	Korean Institute Of Industrial Technology
LAMP	Lynas Advanced Materials Plant
LCD	Liquid Crystal Display
LCPN	Lanthanum-Cerium-Praseodymium-Neodymium
LTSF	Long-term Storage Facility
MAREC	Malaysian Rare Earths Corporation
MER	Materials and Electrochemical Research Corporation
MHLG	Ministry of Housing and Local Government
MIDA	Malaysian Investment Development Authority
MIMA	Maritime Institute of Malaysia
MITI	Ministry of International Trade and Industry
MNA	Malaysian Nuclear Agency
MTUN	Malaysian Technical University Network
NiMH	Nickel metal-hydride
NIMS	National Institute for Material Science, Japan
NORM	Naturally Occurring Radioactive Material
NRE	Ministry of Natural Resources and Environment
OECD	Organisation for Economic Cooperation and Development
OEM	Original Equipment Manufacturer
OJT	On-the-job training
QME	Quantitative Mineral Estimation
RE	Rare Earth
REE	Rare Earth Elements
REO	Rare Earth Oxides
RETA	Rare Earth Technology Alliance
RIKEN	Institute of Physical and Chemical Research, Japan (Rikagaku Kenkyusho)
SONAR	Sound Navigation and Ranging
SME	Small– and Medium–Enterprises

TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
ThO_2	Thorium Oxide
TNB ILSAS	Tenaga Nasional Berhad Integrated Learning Solutions
TVET	Technical Vocational and Education Training
UKM	Universiti Kebangsaan Malaysia
UMP	Universiti Malaysia Pahang
UTAR	Universiti Tunku Abdul Rahman
UTeM	Universiti Teknikal Malaysia Melaka
UTP	Universiti Teknologi Petronas
UNCLOS	United Nations Convention on the Law of the Sea
USGS	United States Geological Survey
WAMRI	Western Australia Mineral Research Institute
YPO_4	Yttrium phosphate

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