ESTABLISHMENT OF MALAYSIAN RARE EARTH INDUSTRY AS CONTRIBUTION TO THE GREEN TECHNOLOGY INITIATIVES

MUCET 2013

BADHRULHISHAM BIN ABDUL AZIZ
UNIVERSITI MALAYSIA PAHANG
4TH DEC 2013

WORLD SCENARIO

FOOD & WATER

GREEN TECHNOLOGY

SHORTAGE OF RESOURCES

CLIMATE CHANGE
MALAYSIAN SCENARIO

ROADMAP VISION 2020

The Goals

HIGH INCOME

Targets US$15,000-20,000 per capita by 2020

Enables all communities to fully benefit from the wealth of the Country

People quality of life

INCLUSIVENESS

Meets present needs without compromising future generations

SUSTAINABILITY

The Goals

CHARACTERISTICS IN 2020

- MARKET LED
- WELL-GOVERNED
- REGIONALLY INTEGRATED
- ENTREPRENURIAL
- INNOVATIVE

New Economy Model

Source: Academia-Industry Consultative Council 8th Dec 2011
ETP focuses on:
• 12 National Key Economy Areas (NKEAs)
• 131 entry point projects
• 3.3 millions new jobs by 2020
• 60% are middle & high income jobs

ETP 1 year progress:
• 66% or RM10 billion worth of projects have started
• 53% of 131 entry point projects have taken off
• Private investments increased 23.4% to RM512.2 billion from RM 41.5 billion

Source: Academia-Industry Consultative Council 8th Dec 2011

MALAYSIAN SCENARIO
HIGH INCOME
HIGH TECH & GREEN TECH
RARE EARTH
WHY RARE EARTH?

- Green Economy - Climate Change, Alternative and Conservative Energy
- Strategic - “Middle East has Oil, China has Rare Earth” (Deng Xiao Peng 1987)
- Human Capital Development - High Technology Experts

CHINA’S PROGRAM 863 (IN 1986)
- National High Technology Research and Development Program, namely Program 863
- The objective of the program is to “gain a foothold in the world arena; to strive to achieve breakthroughs in key technical fields that concern the national economic lifeline and national security; and to achieve ‘leap-frog’ development in key high-tech fields in which China enjoys relative advantages or should take strategic positions in order to provide high-tech support to fulfill strategic objectives in the implementation of the third step of China’s modernization process.”
mainly meant to narrow the gap in technology between the developed world and China, which still lags behind in technological innovation, although progress is being made.

- focuses on biotechnology, space, information, laser, automation, energy, and new materials.

- The use of rare earth elements can be found in each one of the areas in which Program 863 focuses.

Professor Xu Guangxian

in 2009, at the age of 89, won the 5 million yuan ($730,000) State Supreme Science and Technology Prize, China’s = Nobel Prize.
ABOUT RARE EARTH ......

ARE NOT REALLY RARE;

WIDELY SPREAD THROUGHOUT THE EARTH’S CRUST IN SMALL CONCENTRATIONS;

CANNOT BE MINED ECONOMICALLY.

Rare Earth Elements

Rare Earth Elements consist of a group of fifteen elements known as the Lanthanides. The lanthanides are located in block 5d of the periodic table from lanthanum to lutetium.
Rare Earths cannot be substituted in many applications

RARE EARTHS: LANTHANIDES PLUS YITTRIUM – UNIQUE PROPERTIES

- Chemical
  - Unique electron configuration
- Catalytic
  - Oxygen storage and release
- Magnetic
  - High magnetic anisotropy and large magnetic moment
- Optical
  - Fluorescence, high refractive index
- Electrical
  - High conductivity
- Metallurgical
  - Efficient hydrogen storage in rare earths alloys

Rare Earths underpin new materials technology required to sustain the needs of today’s society

<table>
<thead>
<tr>
<th>Energy efficiency through lower consumption</th>
<th>Environmental protection through lower emissions</th>
<th>Smaller yet more powerful digital technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Compact Fluorescent Lights</td>
<td>• Wind turbine</td>
<td>• Flat panel displays</td>
</tr>
<tr>
<td>• Hybrid vehicle</td>
<td>• Auto catalytic converter</td>
<td>• Disk drives</td>
</tr>
<tr>
<td>• Weight reduction in cars</td>
<td>• Diesel additives</td>
<td>• Digital cameras</td>
</tr>
</tbody>
</table>

22/10/2015
Rare Earth Advanced Materials

- Magnets
- Catalysts
- Lasers
- Phosphors
- Hydrogen Storage
- Magnetic Cooling
- Optical Fiber
- Laser Materials
- Supercurrent Materials
- Dielectric Materials
- Giant (colossal) magnetoresistance
- Magneto-optical storage
- Optical Glass & Polishing

Importance of REES to Modern Industry

- Aerospace industry
- Aviation industry
- Medical equipment
- Information Technology
- Electronics Industry
- Energy and Transport
Consumer Electronics

Green Technology
## LIGHT RARE EARTH AND USAGES

<table>
<thead>
<tr>
<th>Z</th>
<th>ELEMENT</th>
<th>SYMBOL</th>
<th>USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Scandium</td>
<td>Sc</td>
<td>Aerospace framework, high-intensity street lamps, high performance equipment</td>
</tr>
<tr>
<td>39</td>
<td>Yttrium</td>
<td>Y</td>
<td>TV sets, <a href="#">cancer treatment drugs</a>, enhances strength of alloys</td>
</tr>
<tr>
<td>57</td>
<td>Lanthanum</td>
<td>La</td>
<td>Camera lenses, battery-electrodes, hydrogen storage</td>
</tr>
<tr>
<td>58</td>
<td>Cerium</td>
<td>Ce</td>
<td>Catalytic converters, colored glass, steel production</td>
</tr>
<tr>
<td>59</td>
<td>Praseodymium</td>
<td>Pr</td>
<td>Super-strong magnets, welding goggles, lasers</td>
</tr>
<tr>
<td>60</td>
<td>Neodymium</td>
<td>Nd</td>
<td>Extremely strong permanent magnets, microphones, electric motors of <a href="#">hybrid automobiles</a>, laser</td>
</tr>
<tr>
<td>61</td>
<td>Promethium</td>
<td>Pm</td>
<td>Not usually found in Nature</td>
</tr>
<tr>
<td>62</td>
<td>Samarium</td>
<td>Sm</td>
<td>Cancer treatment, nuclear reactor control rods, X-ray lasers</td>
</tr>
</tbody>
</table>

*Ref: Namibia rare earths inc.*
<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europium</td>
<td>Eu</td>
<td>Color TV screens, fluorescent glass, genetic screening tests</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shielding in nuclear reactors, nuclear marine propulsion, increases durability of alloys</td>
</tr>
<tr>
<td>Gadolinium</td>
<td>Gd</td>
<td>TV sets, fuel cells, sonar systems</td>
</tr>
<tr>
<td>Terbium</td>
<td>Tb</td>
<td>Commercial lighting, hard disk devices, transducers</td>
</tr>
<tr>
<td>Dysprosium</td>
<td>Dy</td>
<td>Lasers, glass coloring, High-strength magnets</td>
</tr>
<tr>
<td>Holmium</td>
<td>Ho</td>
<td>Glass colorant, signal amplification for fiber optic cables, metallurgical uses</td>
</tr>
<tr>
<td>Erbium</td>
<td>Er</td>
<td>High efficiency lasers, portable x-ray machines, high temperature superconductor machines</td>
</tr>
<tr>
<td>Thulium</td>
<td>Tm</td>
<td>Improves stainless steel, lasers, ground monitoring devices</td>
</tr>
<tr>
<td>Ytterbium</td>
<td>Yb</td>
<td>Refining petroleum, LED light bulbs, integrated circuit manufacturing</td>
</tr>
<tr>
<td>Lutetium</td>
<td>Lu</td>
<td></td>
</tr>
</tbody>
</table>

**Market Demand: Sales of RE**

- **2010:** $3 BILLION
- **2015:** $9.2 BILLION

Global Demands:
- 2010: 180,000 metric tonnes
- 2015: 230,000 metric tonnes

*Commodity online, 13th Dec 2011*
Magnets will be the growth driver for Rare Earths demand to 2014. Polishing powder demand has dropped due to activities to improve productivity.

### Demand Forecast by Application

<table>
<thead>
<tr>
<th>2010 Demand by Application</th>
<th>2014 Demand Forecast by Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application</strong></td>
<td><strong>Demand (%)</strong></td>
</tr>
<tr>
<td>Magnets</td>
<td>25%</td>
</tr>
<tr>
<td>Battery Alloy</td>
<td>15%</td>
</tr>
<tr>
<td>Metallurgy ex batt</td>
<td>9%</td>
</tr>
<tr>
<td>Auto catalysts</td>
<td>7%</td>
</tr>
<tr>
<td>FCC</td>
<td>17%</td>
</tr>
<tr>
<td>Polishing Powder</td>
<td>11%</td>
</tr>
<tr>
<td>Glass Additives</td>
<td>6%</td>
</tr>
<tr>
<td>Phosphors</td>
<td>6%</td>
</tr>
<tr>
<td>Others</td>
<td>4%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
The world rare earth resource distribution (USGS 2010)

China, 36m tonne, 36.52%
US, 13.0m tonne, 13.19%
Malaysia, 0.03m tonne, 0.03%
Others, 22.0m tonne, 22.32%
Brazil, 0.048m tonne, 0.05%
India, 3.1m tonne, 3.14%
CIS, 19m tonne, 19.27%
## World Mine Production and Reserves (2012 Estimates)

<table>
<thead>
<tr>
<th>Country</th>
<th>Production (Metric Ton)</th>
<th>Reserves (Metric Ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>7,000</td>
<td>13,000,000</td>
</tr>
<tr>
<td>Australia</td>
<td>4,000</td>
<td>1,600,000</td>
</tr>
<tr>
<td>Brazil</td>
<td>300</td>
<td>36,000</td>
</tr>
<tr>
<td>China</td>
<td>95,000</td>
<td>55,000,000</td>
</tr>
<tr>
<td>India</td>
<td>2,800</td>
<td>3,100,000</td>
</tr>
<tr>
<td>Malaysia</td>
<td>350</td>
<td>30,000</td>
</tr>
<tr>
<td>Other countries</td>
<td>not available</td>
<td>41,000,000</td>
</tr>
<tr>
<td>World total (rounded)</td>
<td>110,000</td>
<td>110,000,000</td>
</tr>
</tbody>
</table>

*Ref: Hobart King, Geology.com*

---

The world rare earth supply in 2009 (USGS 2010)
Supply shortfall and increasing prices are a result of structural change as China addresses environmental and mining issues.

### SAMPLE OF RARE EARTH PRICES

<table>
<thead>
<tr>
<th>Oxide</th>
<th>January 2010 (US$/kg)</th>
<th>January 2011 (US$/kg)</th>
<th>July 2011 (US$/kg)</th>
<th>June 2013 (US$/kg)</th>
<th>% Change 20 mo (July ’11 - June ’13)</th>
<th>% Change 3 yr (Jan ’10 - June ’13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lanthanum</td>
<td>6</td>
<td>61</td>
<td>154</td>
<td>7</td>
<td>-95%</td>
<td>17%</td>
</tr>
<tr>
<td>Cerium</td>
<td>4</td>
<td>64</td>
<td>157</td>
<td>7</td>
<td>-96%</td>
<td>75%</td>
</tr>
<tr>
<td>Praseodymium</td>
<td>23</td>
<td>92</td>
<td>247</td>
<td>74</td>
<td>-70%</td>
<td>222%</td>
</tr>
<tr>
<td>Neodymium</td>
<td>24</td>
<td>93</td>
<td>328</td>
<td>57</td>
<td>-83%</td>
<td>138%</td>
</tr>
<tr>
<td>Samarium</td>
<td>5</td>
<td>49</td>
<td>127</td>
<td>11</td>
<td>-91%</td>
<td>120%</td>
</tr>
<tr>
<td>Europium</td>
<td>480</td>
<td>630</td>
<td>5560</td>
<td>883</td>
<td>-84%</td>
<td>84%</td>
</tr>
<tr>
<td>Terbium</td>
<td>350</td>
<td>618</td>
<td>4260</td>
<td>740</td>
<td>-83%</td>
<td>111%</td>
</tr>
<tr>
<td>Dysprosium</td>
<td>121</td>
<td>325</td>
<td>2911</td>
<td>475</td>
<td>-82%</td>
<td>293%</td>
</tr>
<tr>
<td>Yttrium</td>
<td>10</td>
<td>15</td>
<td>180</td>
<td>21</td>
<td>-88%</td>
<td>110%</td>
</tr>
</tbody>
</table>

Price Sources: Technology Metals Research derived from metalpages.com for 99% REO FOB China
RARE EARTH PROCESS & SUPPLY CHAIN

Ore
Ore is crushed into gravel size

Crusher

Mill
Gravel is milled into silt

Oxide
REE is first separated as an oxide

Separation Process
REE is separated from mineral

Alloy
Metals are combined to create alloys

Green energy
Hybrid electric vehicles
Water treatment
Defense
High tech

High tech applications
There are hundreds of high tech applications for REE.

Diagram 1

Mineral Processing

Exploration
Mining
Ore
Beneficiation
Concentrate
Impurity Removal
Leaching

Individual RE Oxides
Metal Making
Solvent Extraction
High-Purity RE Metal
Mixed RE Chloride

End-Use Alloy Making
Permanent Magnet Alloys

Legend
Production Phase
Intermediate (Non-Saleable)
Intermediate (Saleable)
DEVELOPING RARE EARTH PROJECT
[DUDLEY J. KINGSNORTH 2013]

Establish resource  Develop understanding of the mineralogy  Scoping study

Processing - beneficiation, extraction & separation  Environmental approach  Letters of intent

Definitive feasibility study & funding  Engineering, procurement & construction  Commissioning & startup

DATA BY TECHNOLOGY METAL RESEARCH [AS OF NOV 5, 2013]

51 advanced rare earth projects
57 rare-earth mineral resources
16 different countries
48 different companies
OPPORTUNITY FOR MALAYSIA

- High tech companies to Malaysia
- Min 30,000 tons of RE deposit

HUMAN TOUCH CASE STUDY: LYNAS

The Lynas Advanced Materials Plant (LAMP) is built to international environmental performance standards – gas, water and solids management.

Phase 1: 11,000t REO
Phase 2: 22,000t REO
Gebeng, Malaysia, has exceptional infrastructure required for a Rare Earths separation facility

**PROCESSING HUB WITH EXCEPTIONAL INFRASTRUCTURE**

**INDUSTRIAL INFRASTRUCTURE**
- Energy, chemicals, water, industrial land

**KNOWLEDGE INFRASTRUCTURE**
- Engineering, trade skills and services

**GOVERNMENT INFRASTRUCTURE**
- Including FDI incentives
  (12 years tax exemption for pioneer status)

---

**RIA’s Exposure Levels vs Actual Exposure Levels**

- **RIA** assumes the **WORST CASE SCENARIOS** in assessing exposure risk to all sensitive receptors.
- Actual occupational external dose exposures were **LESS** than the Constraint Limit of 6 mSv/y and **MUCH LESS** than the 20 mSv/y AELA’s Permissible Limit for radiation workers

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>RIA (mSv y(^{-1}))</th>
<th>ACTUAL (mSv y(^{-1}))</th>
<th>RELATIVE READINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck driver (Kuantan Port to LAMP: external radiation from Lanthane concentrate (LC): External radiation, 280 hr/y)</td>
<td>0.06</td>
<td>0.06</td>
<td>Equal (Background)</td>
</tr>
<tr>
<td>Workers handling LC stockpile in concentrate building: External radiation, 730 hr/y</td>
<td>2.19</td>
<td>0.77</td>
<td>2.8 x less</td>
</tr>
<tr>
<td>Truck driver handling WLP from filter press to RSF: external 576 hr/y</td>
<td>1.48</td>
<td>0.58</td>
<td>2.55 x less</td>
</tr>
<tr>
<td>Process Operator at WLP filter press: External radiation, 1332 hr</td>
<td>4.02</td>
<td>1.14</td>
<td>3.52 x less</td>
</tr>
<tr>
<td>PEL workers at WLP RSF :576 hr/y</td>
<td>2.96</td>
<td>1.45</td>
<td>2.04 x less</td>
</tr>
</tbody>
</table>
### Water Discharged (critical parameters only):
**ALL BELOW LIMITS and 100% COMPLIANCE with DoE Standard B**

**Levels (Mean) of Some Critical Parameters, May – July 2013**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>Std B</th>
<th>May</th>
<th>Jun</th>
<th>July</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>-</td>
<td>5.5 – 9.0</td>
<td>7.57</td>
<td>7.55</td>
<td>7.58</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/L</td>
<td>5</td>
<td>1.67</td>
<td>0.27</td>
<td>0.21</td>
</tr>
<tr>
<td>BOO₂ at 20°C</td>
<td>mg/L</td>
<td>50</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>COD</td>
<td>mg/L</td>
<td>200</td>
<td>36.7</td>
<td>37.7</td>
<td>33.6</td>
</tr>
<tr>
<td>Suspended Solid</td>
<td>mg/L</td>
<td>100</td>
<td>5.7</td>
<td>11.2</td>
<td>7.0</td>
</tr>
<tr>
<td>Cyanide</td>
<td>mg/L</td>
<td>0.10</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/L</td>
<td>1</td>
<td>0.07</td>
<td>0.19</td>
<td>0.14</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/L</td>
<td>2</td>
<td>0.10</td>
<td>0.08</td>
<td>0.04</td>
</tr>
<tr>
<td>Fluoride</td>
<td>mg/L</td>
<td>5</td>
<td>0.95</td>
<td>0.90</td>
<td>1.03</td>
</tr>
<tr>
<td>Barium</td>
<td>mg/L</td>
<td>4</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>

### AIR EMISSIONS

**Plant air emission – 100% compliance**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>CAR 1978* Emission Standards</th>
<th>Limits imposed by DOE’s for WGTS Stack</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>May</td>
<td>June</td>
</tr>
<tr>
<td>Total Suspended Particulates</td>
<td>mg/Nm³</td>
<td>400</td>
<td>100</td>
<td>42.4</td>
</tr>
<tr>
<td>Sulphuric Acid Mist or Sulphur Trioxide or Both</td>
<td>mg/Nm³</td>
<td>200</td>
<td>50</td>
<td>ND</td>
</tr>
<tr>
<td>Sulphur Dioxide</td>
<td>mg/Nm³</td>
<td>-</td>
<td>500</td>
<td>14.9</td>
</tr>
<tr>
<td>Hydrogen Fluoride</td>
<td>mg/Nm³</td>
<td>100</td>
<td>50</td>
<td>ND</td>
</tr>
</tbody>
</table>
PARAS SINARAN DI LUAR TAPAK (OFFSITE) LYNAS

<table>
<thead>
<tr>
<th>Radius</th>
<th>Purata Paras Sinaran (μSv/j)</th>
<th>Kesimpulan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 km</td>
<td>0.139±0.012</td>
<td>Tidak melebihi had yang ditetapkan oleh AELB</td>
</tr>
<tr>
<td>5 km</td>
<td>0.210±0.009</td>
<td></td>
</tr>
<tr>
<td>10 km</td>
<td>0.190±0.012</td>
<td></td>
</tr>
<tr>
<td>20 km</td>
<td>0.206±0.005</td>
<td></td>
</tr>
</tbody>
</table>

PERSPECTIVES FROM

AKADEMI SAINS MALAYSIA (ASM) & MAJLIS PROFESOR NEGARA (MPN)
RECOMMENDED STRATEGIES

Enhance the environment, safety and health aspects

Undertake a national exercise to map the potential rare earths deposits

Incentivise the upstream mining and extraction of rare earths

Incentivise investments in the downstream manufacturing of rare-earth based products

Build the key competence in human capital for the entire value chain of the rare earths business
### RECOMMENDED STRATEGIES

1. Strengthen the legal and regulatory framework to enable the effective functioning of the rare earths business.
2. Undertake coordinated, comprehensive and continual public awareness program & community engagement.

### IMPACT ON TECHNOLOGY DEVELOPMENT AND ADVANCEMENT

- Mining industry;
- Processing - *midstream (separation and refining)*;
- Downstream Application - *Catalyst, Magnet, Automotive*;
- Safety, Health and Environment.
R&D OPPORTUNITY

- Automotive industry
  - Hybrid and EV Vehicles
  - Catalytic Converter
  - NIH Battery
  - Fuel additives
- Superconducting Magnets
- Catalyst for Petroleum & Petrochemical
- Rare Earth Recycling
- Rare Earth Processing

MALAYSIAN RARE EARTH R&D GROUP

UNIVERSITIES
- UMP, UTEM, UTP, UKM

RESEARCH AREA
REFERENCES

1. Report Parliament Select Committee on Lynas Advanced Materials Plant (LAMP); Dewan Rakyat, Ke 12, Penggal ke 5, 2012.
5. LYNAS Investor Presentation; May 2011.
6. www.techmetalsresearch.com; 2013