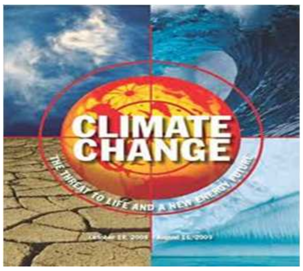
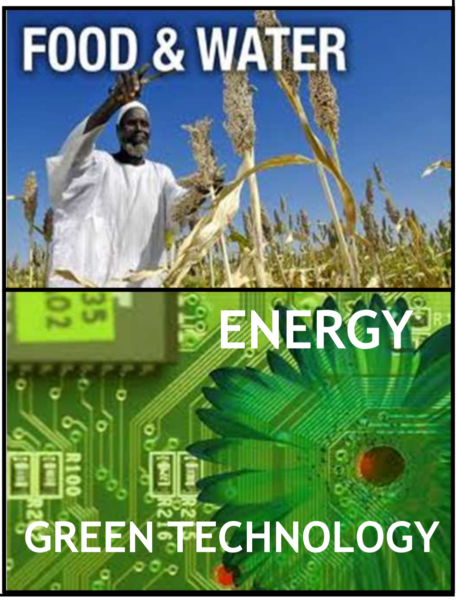
ESTABLISHMENT OF MALAYSIAN RARE EARTH INDUSTRY : CHALLENGES AND OPPORTUNITY IN ENERGY AND ENVIRONMENTAL ASPECTS

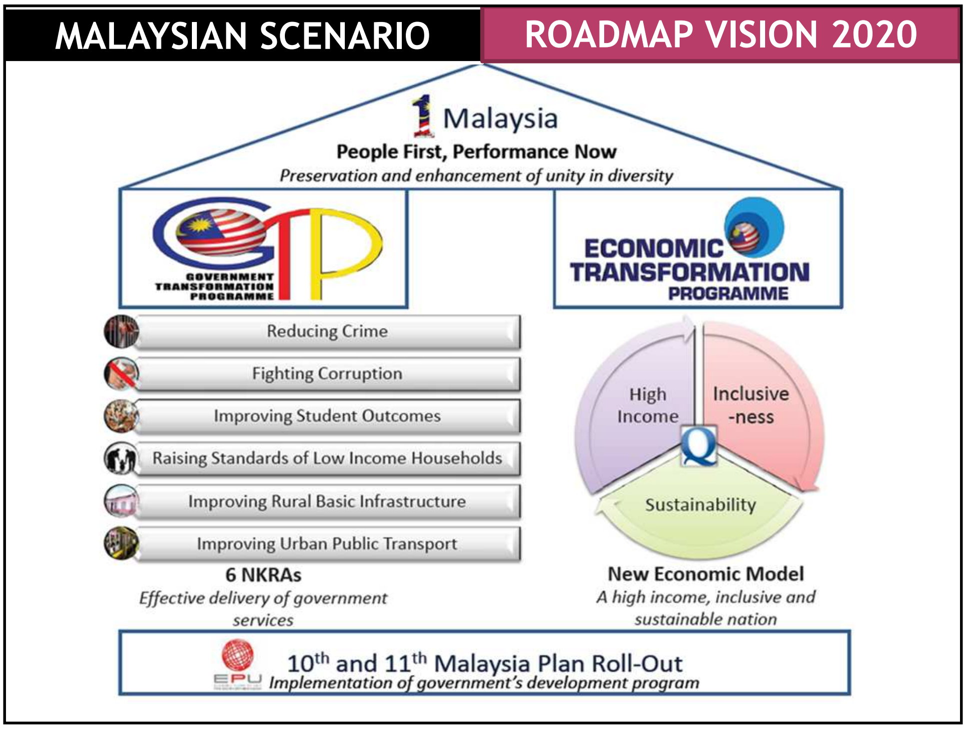
RACEE 2013

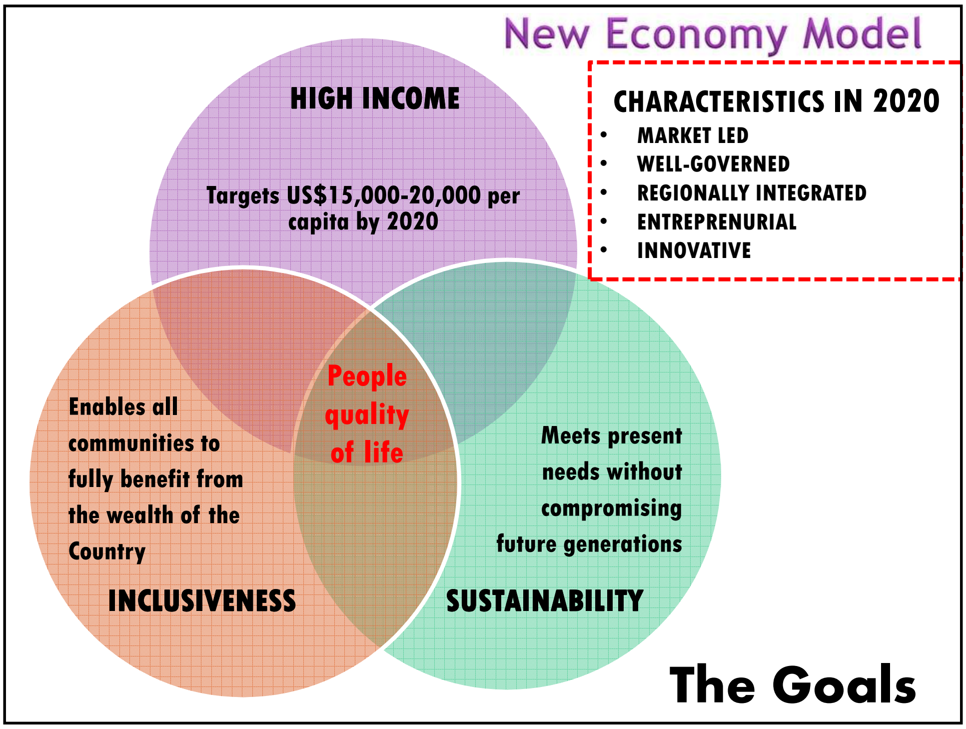
BADHRULHISHAM BIN ABDUL AZIZ
FACULTY OF CHEMICAL & NATURAL RESOURCES ENGINEERING,
UNIVERSITI MALAYSIA PAHANG
27TH FEB 2014

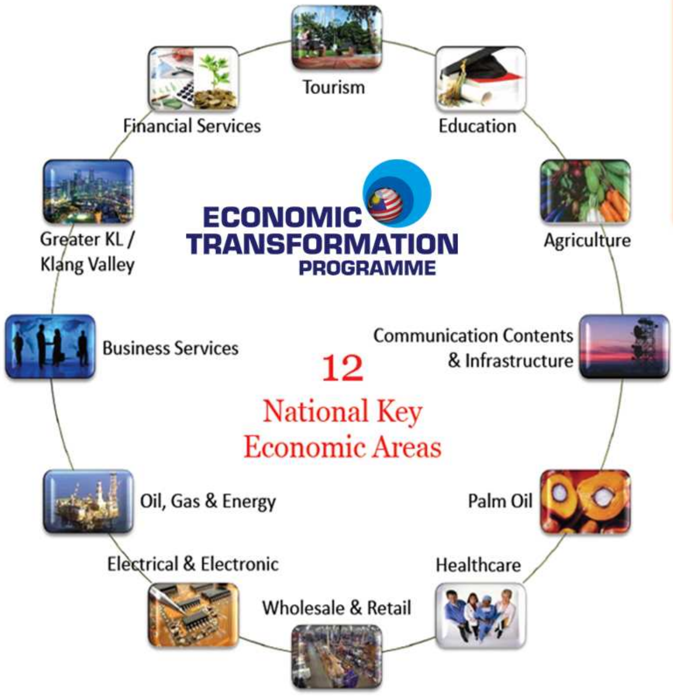
WORLD SCENARIO






MALAYSIAN SCENARIO
ROADMAP VISION 2020
1 Malaysia
People First, Performance Now
Preservation and enhancement of unity in diversity
GOVERNMENT TRANSFORMATION PROGRAMME
ECONOMIC TRANSFORMATION PROGRAMME
Reducing Crime
Fighting Corruption
Improving Student Outcomes
Raising Standards of Low Income Households
Improving Rural Basic Infrastructure
Improving Urban Public Transport
6 NKRAs
Effective delivery of government services
High Income
Inclusive -ness
Sustainability
New Economic Model
A high income, inclusive and sustainable nation
10th and 11th Malaysia Plan Roll-Out
Implementation of government's development program

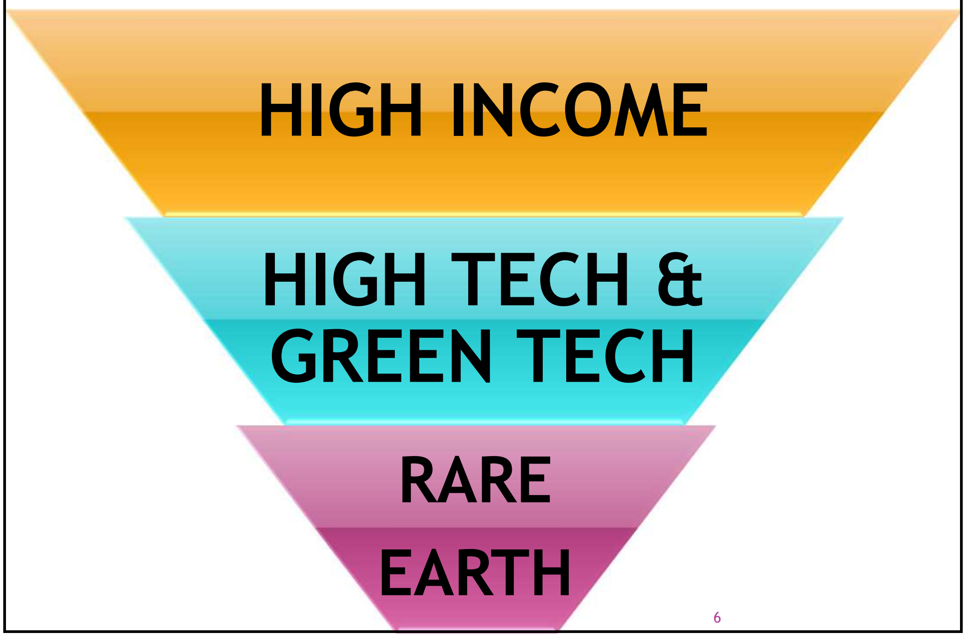

New Economy Model
HIGH INCOME
Targets US$15,000-20,000 per capita by 2020
CHARACTERISTICS IN 2020
• MARKET LED
• WELL-GOVERNED
• REGIONALLY INTEGRATED
• ENTREPRENURIAL
• INNOVATIVE
People quality of life
Enables all communities to fully benefit from the wealth of the Country
INCLUSIVENESS
Meets present needs without compromising future generations
SUSTAINABILITY
The Goals



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

MALAYSIAN SCENARIO



6

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

7

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."

8

RE IN PROGRAM 863

- 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.

9

FATHER OF CHINESE RARE EARTH CHEMISTRY

- **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.**

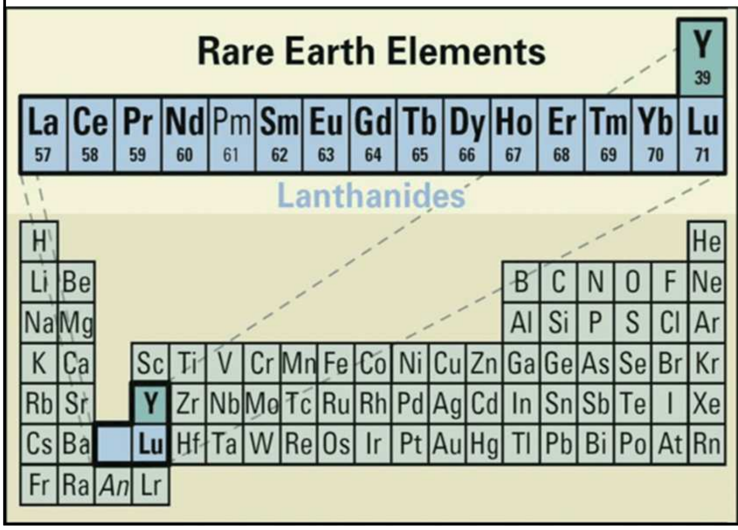
10

ABOUT RARE EARTH ......

- ARE NOT REALLY RARE ;
- WIDELY SPREAD THROUGH OUT THE EARTH'S CRUST IN SMALL CONCENTRATIONS;
- CANNOT BE MINED ECONOMICALLY.

Rare Earth Elements

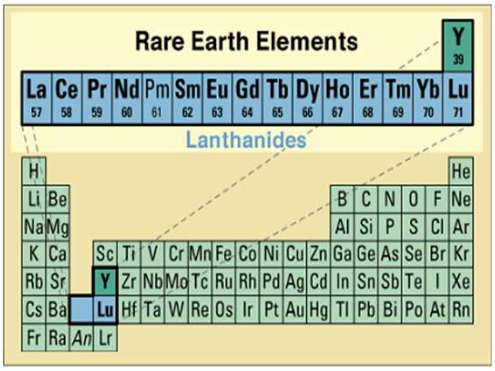
Rare Earth Elements consist of a group of fifteen elements known as the Lanthanides. The lanthanides are located in block 5d of the periodic table from lanthanum to lutetium



Lanthanum (La)
Cerium (Ce)
Praseodymium (Pr)
Neodymium (Nd)
Samarium (Sm)
Europium (Eu)
Gadolinium (Gd)
Terbium (Tb)
Dysprosium (Dy)
Holmium (Ho)
Erbium (Er)
Thulium (Th)
Ytterbium (Yb)
Lutetium (Lu)
Yttrium (Y)

Rare Earths cannot be substituted in many applications

RARE EARTHS: LANTHINIDES 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

Energy efficiency through lower consumption

- Compact Fluorescent Lights
- Hybrid vehicle
- Weight reduction in cars

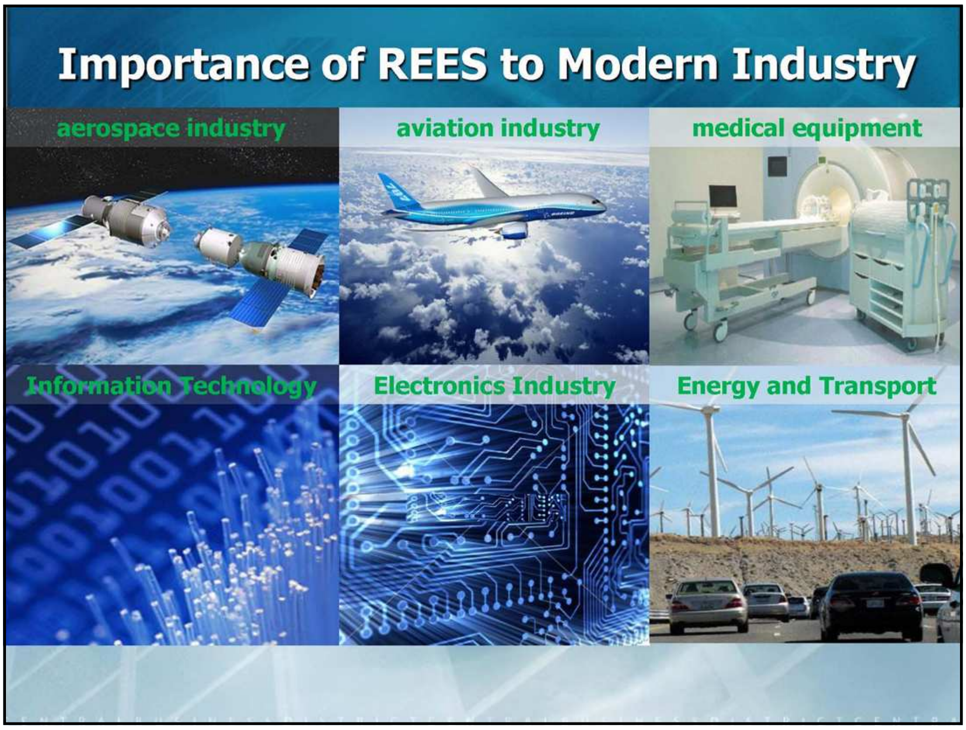
Environmental protection through lower emissions

- Wind turbine
- Auto catalytic converter
- Diesel additives

Smaller yet more powerful digital technology

- Flat panel displays
- Disk drives
- Digital cameras


Rare Earth Advanced Materials
Magnets
catalysts
Phosphor
Hydrogen Storage
Magnetic Cooling
Optical Fiber
Laser Materials
Superconductor 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
EV
FCEV
Powered By Hydrogen

LIGHT RARE EARTH AND USAGES

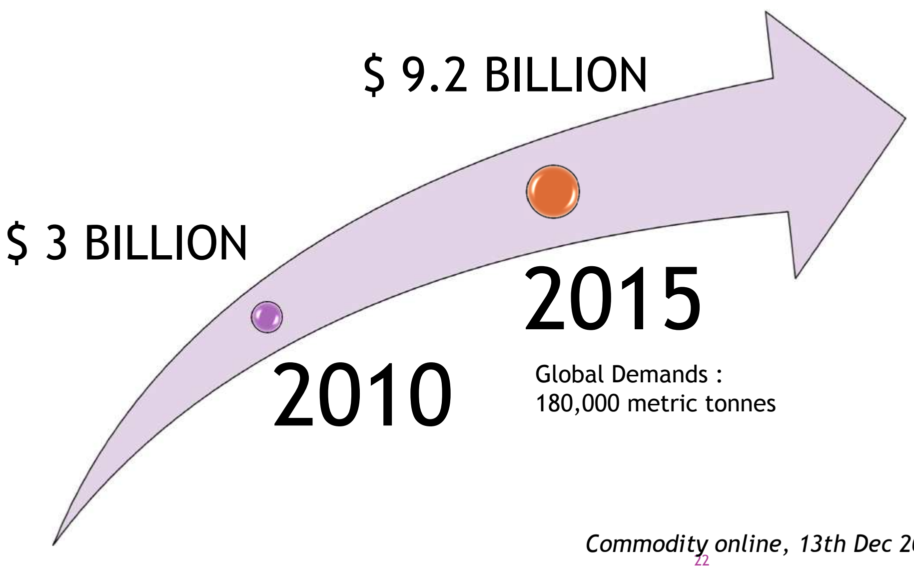
Z	ELEMENT	SYMBOL	USE
21	Scandium	Sc	Aerospace framework, high-intensity street lamps, high performance equipment
39	Yttrium	Y	TV sets, cancer treatment drugs, enhances strength of alloys
57	Lanthanum	La	Camera lenses, battery-electrodes, hydrogen storage
58	Cerium	Ce	Catalytic converters, colored glass,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

Ref :Namibia rare earths inc.

HEAVY RARE EARTH AND USAGES

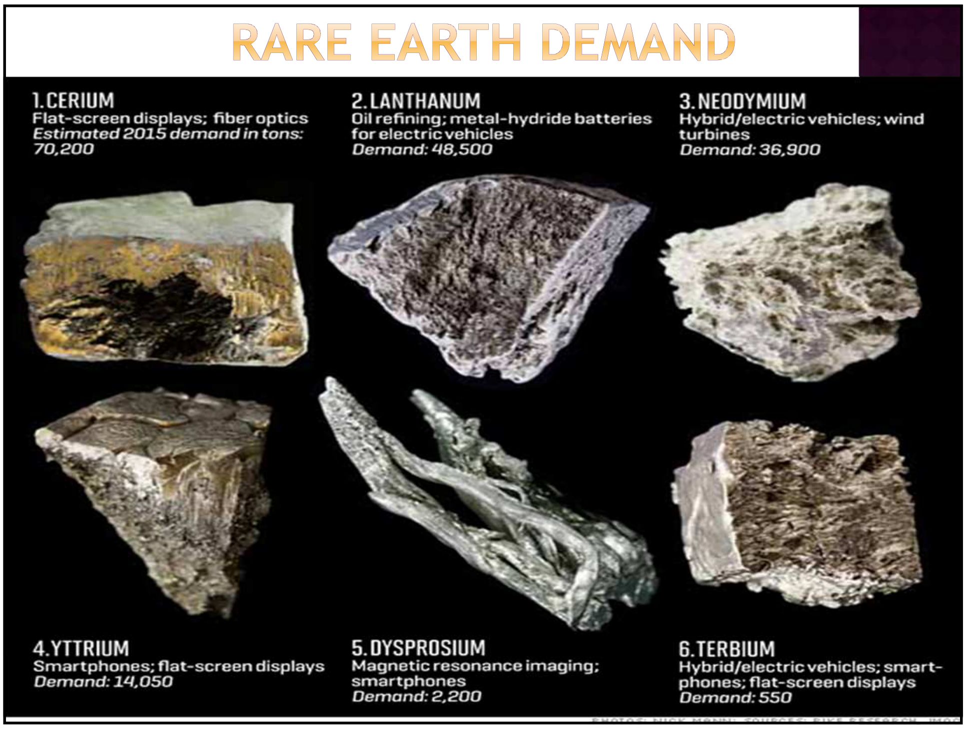
63	Europium	Eu	Color TV screens, fluorescent glass, genetic screening tests
64	Gadolinium	Gd	Shielding in nuclear reactors, nuclear marine propulsion, increases durability of alloys
65	Terbium	Tb	TV sets, fuel cells, sonar systems
66	Dysprosium	Dy	Commercial lighting, hard disk devices, transducers
67	Holmium	Ho	Lasers, glass coloring, High-strength magnets
68	Erbium	Er	Glass colorant, signal amplification for fiber optic cables, metallurgical uses
69	Thulium	Tm	High efficiency lasers, portable x-ray machines, high temperature superconductor
70	Ytterbium	Yb	Improves stainless steel, lasers, ground monitoring devices
71	Lutetium	Lu	Refining petroleum, LED light bulbs, integrated circuit manufacturing

MARKET DEMAND : SALES OF RE



Commodity online, 13th Dec 2011

22

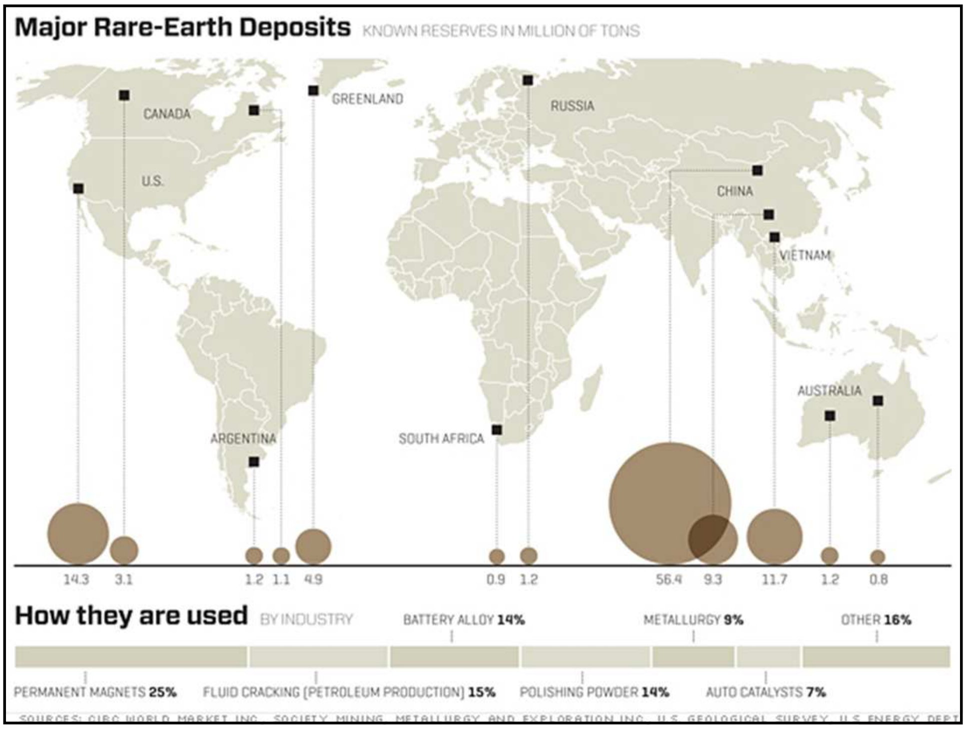


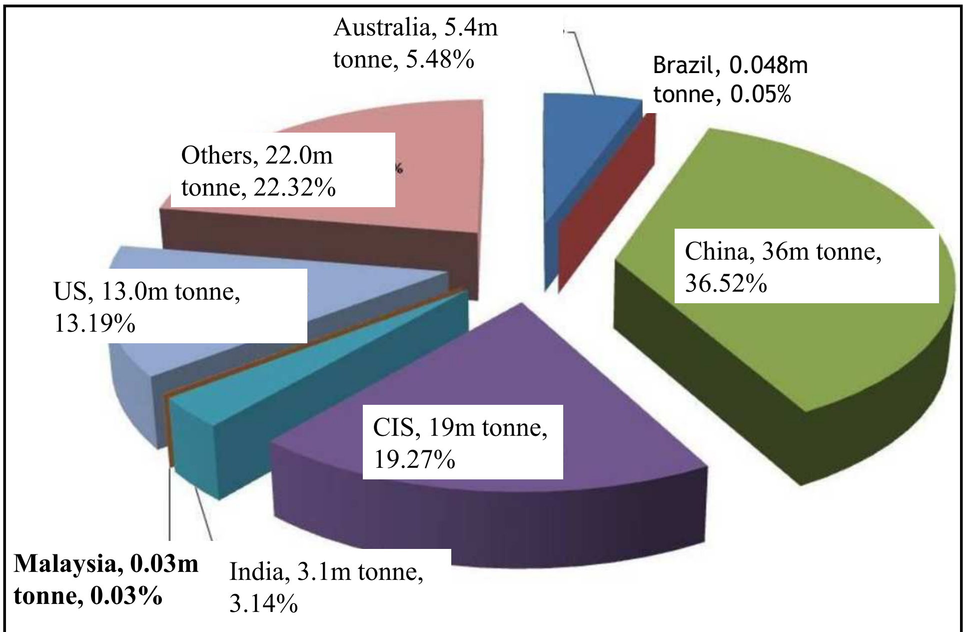
Magnets will be the growth driver for Rare Earths demand to 2014. Polishing powder demand has dropped due to activities to improve productivity

DEMAND FORECAST BY APPLICATION

2010 Demand by Application		
Application	Demand (%)	Demand (t)
• Magnets	25%	31,500
• Battery Alloy	15%	18,600
• Metallurgy ex batt	9%	11,700
• Auto catalysts	7%	9,000
• FCC	17%	21,300
• Polishing Powder	11%	14,000
• Glass Additives	6%	7,800
• Phosphors	6%	7.900
• Others	4%	5,700
Total	**100%**	**127,500**

2014 Demand Forecast by Application		
Application	Growth (%)	Demand (t)
• Magnets	12%	49,600
• Battery Alloy	15%	32,500
• Metallurgy ex batt	2%	12,700
• Auto catalysts	8%	12,200
• FCC	4%	24,900
• Polishing Powder	10%	20,600
• Glass Additives	0%	7,800
• Phosphors	8%	10.800
• Others	8%	6,100
Total	**8%**	**177,200**



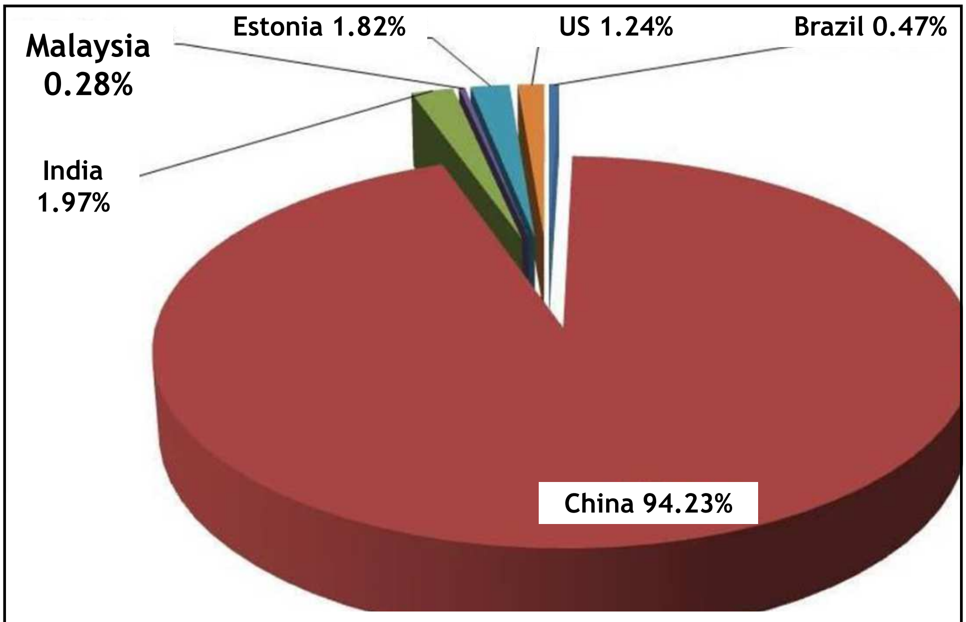


The world rare earth resource distribution (USGS 2010)

26

World Mine Production and Reserves (2012 Estimates)		
Country	Production (Metric Ton)	Reserves (Metric Ton)
United States	7,000	13,000,000
Australia	4,000	1,600,000
Brazil	300	36,000
China	95,000	55,000,000
India	2,800	3,100,000
Malaysia	350	30,000
Other countries	not available	41,000,000
World total (rounded)	110,000	110,000,000

Ref :Hobart King, Geology.com

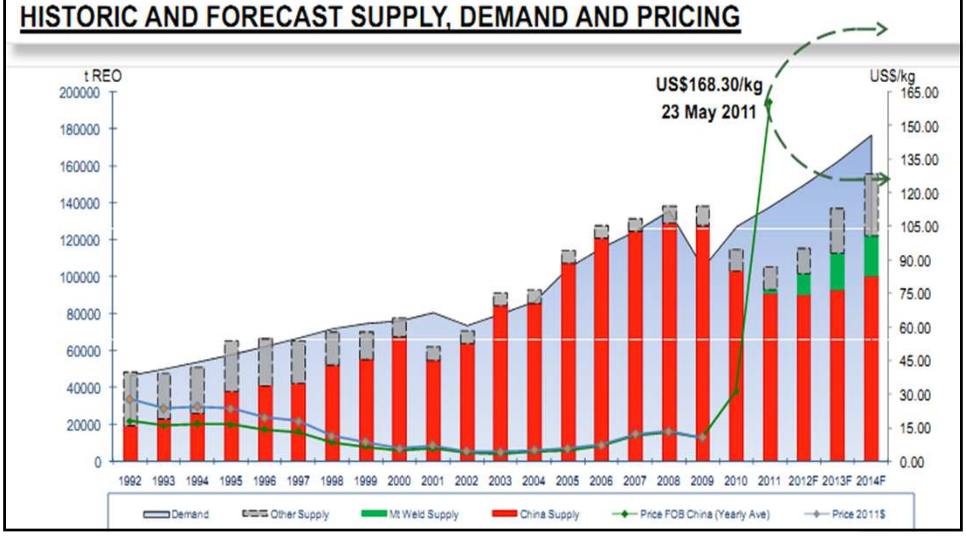


The world rare earth supply in 2009 (USGS 2010)

28

Supply shortfall and increasing prices are a result of structural change as China addresses environmental and mining issues

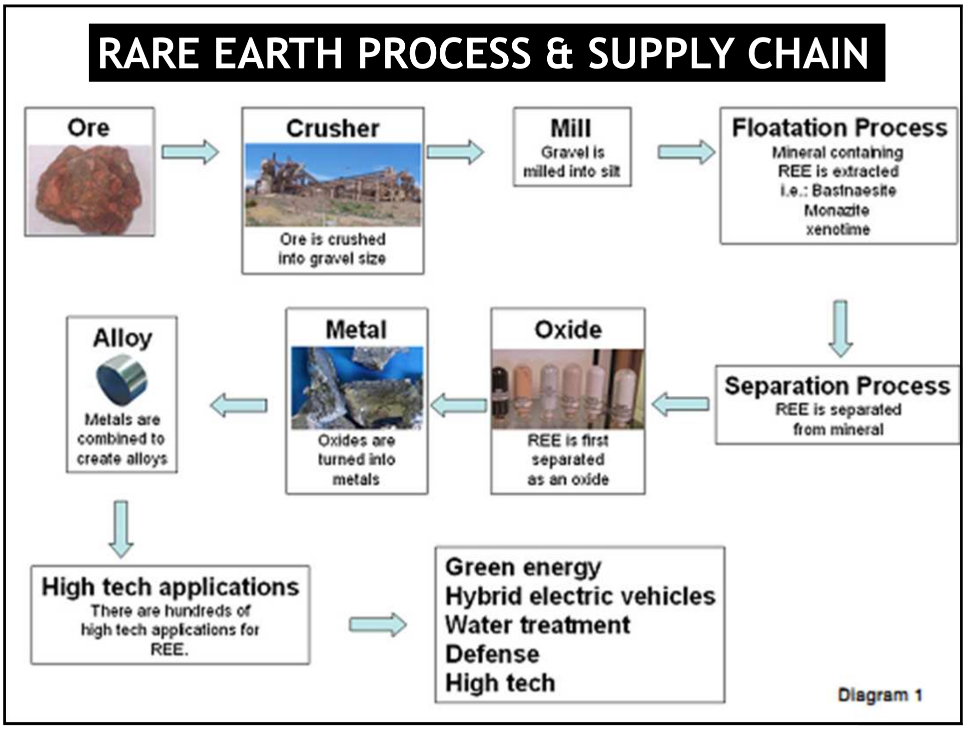
HISTORIC AND FORECAST SUPPLY, DEMAND AND PRICING

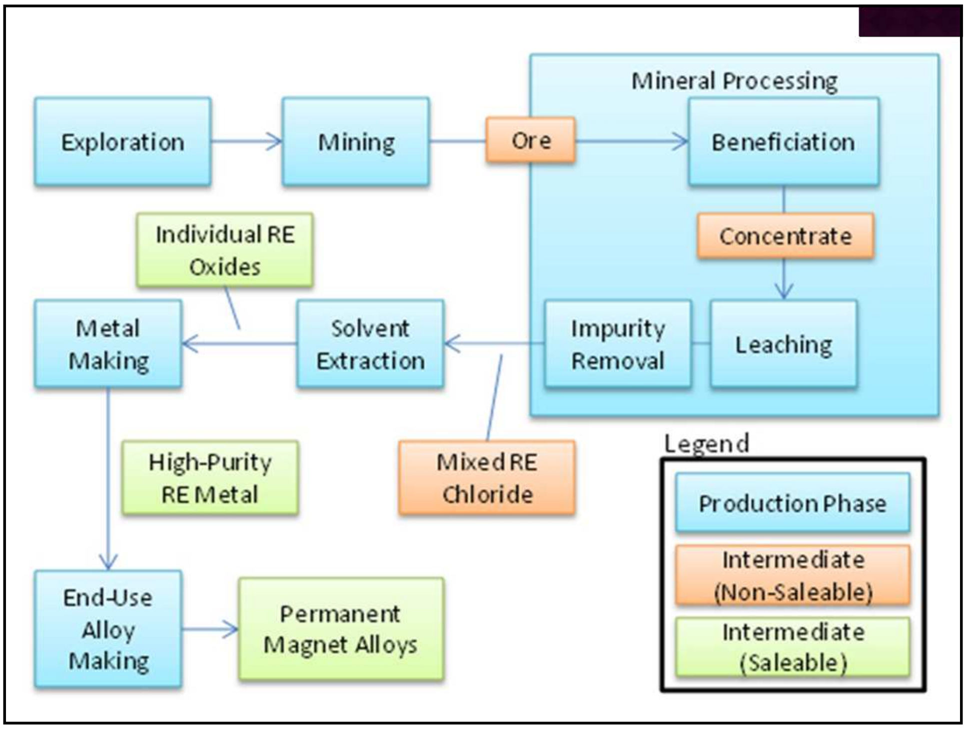


SAMPLE OF RARE EARTH PRICES

Oxide	January 2010 (US$/kg)	January 2011 (US$/kg)	July 2011 (US$/kg)	June 2013 (US$/kg)	% Change 20 mo (July '11 - June '13)	% Change 3 yr (Jan '10 - June '13)
Lanthanum	6	61	154	7	-95%	17%
Cerium	4	64	157	7	-96%	75%
Praseodimium	23	92	247	74	-70%	222%
Neodymium	24	93	328	57	-83%	138%
Samarium	5	49	127	11	-91%	120%
Europium	480	630	5560	883	-84%	84%
Terbium	350	618	4260	740	-83%	111%
Dysprosium	121	325	2591	475	-82%	293%
Yttrium	10	75	180	21	-88%	110%

Price Sources: Technology Metals Research derived from metal-pages.com for 99% REO FOB China


RARE EARTH PROCESS & SUPPLY CHAIN
Ore
Crusher
Ore is crushed into gravel size
Mill
Gravel is milled into silt
Floatation Process
Mineral containing REE is extracted i.e.: Bastnaesite Monazite xenotime
Separation Process
REE is separated from mineral
Oxide
REE is first separated as an oxide
Metal
Oxides are turned into metals
Alloy
Metals are combined to create alloys
High tech applications
There are hundreds of high tech applications for REE.
Green energy
Hybrid electric vehicles
Water treatment
Defense
High tech
Diagram 1


Exploration
Mining
Ore
Mineral Processing
Beneficiation
Concentrate
Leaching
Impurity Removal
Solvent Extraction
Individual RE Oxides
Metal Making
Mixed RE Chloride
High-Purity RE Metal
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
- Letters of intent
- Environmental approach
- Processing - beneficiation, extraction & separation
- Definitive feasibility study & funding
- Engineering, procurement & construction
- Commissioning & startup

33

DATA BY TECHNOLOGY METAL RESEARCH [AS OF FEB ,7 2014]

- 51 advanced rare earth projects
- 57 rare-earth mineral resources
- 16 different countries
- 49 different companies

34

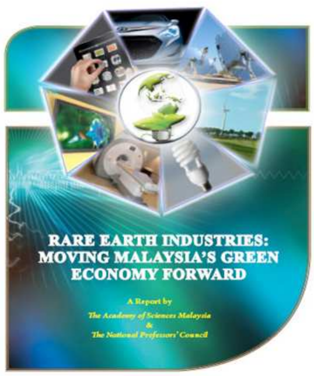
OPPORTUNITY FOR MALAYSIA

min 30,000 tons of RE deposit

High tech companies to Malaysia

PERSPECTIVES FROM

ACADEMY SACIENCES OF MALAYSIA (ASM)
&
MALAYSIAN PROFESSORS COUNCIL (MPN)



36

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

37

RECOMMENDED STRATEGIES

- 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

38

RECOMMENDED STRATEGIES

Strengthen the legal and regulatory framework to enable the effective functioning of the rare earths business

Undertake coordinated, comprehensive and continual public awareness program & community engagement

39

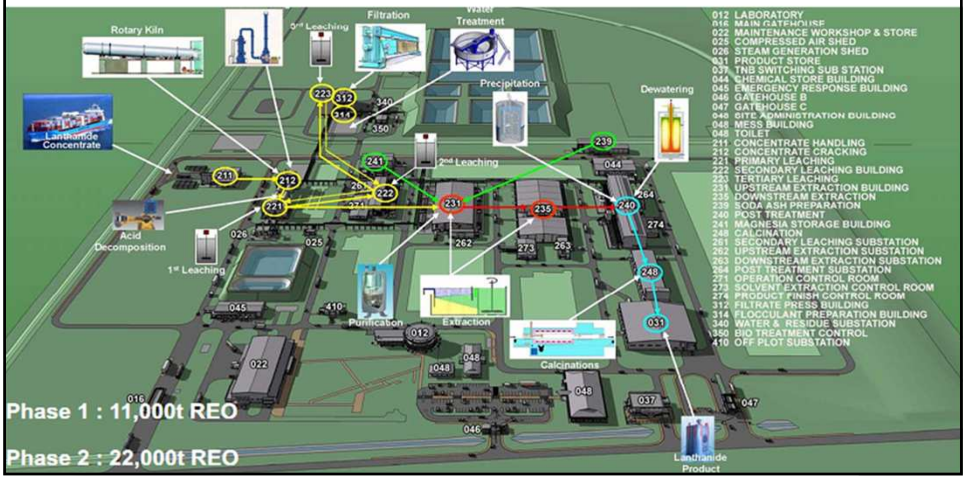
IMPACT ON TECHNOLOGY DEVELOPMENT AND ADVANCEMENT

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

40

CASE STUDY : LYNAS

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



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)

20

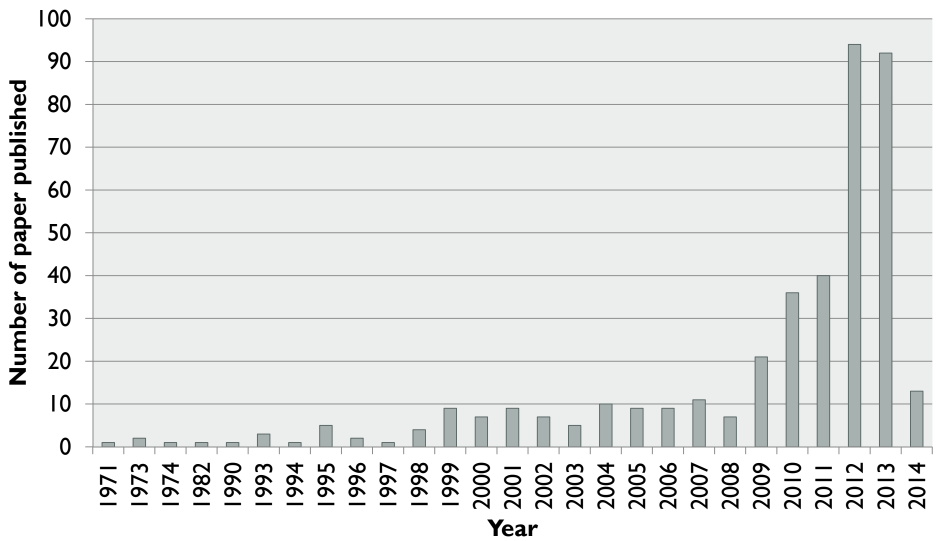
Lynas CORPORATION LTD

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**

43

- 401 paper published since 1971 from various universities; USM, UKM, UM, UTM, UPM and etc



RESEARCH WORK BASED ON PAPERS PUBLISHED IN MALAYSIA

FUNDAMENTAL [231]
- Characterization
- Spectroscopy
- Luminescence prop
- Superconducting prop
- Thermal studies
- Elastic prop
- Optical prop

APPLICATIONS [153]
- Laser
- Sensor
- Catalyst
- Solid fuel cell
- Biomedical
- OLED

TECHNOLOGY [6]
- Separation and extraction

ENVIROMENTAL [11]
- Distributions

MALAYSIAN RARE EARTH R&D GROUP

UNIVERSITIES

- UMP, UTEM, UTP, UKM

RESEARCH AREA

- Mining Engineering, Material Science & Engineering, Metallurgy, Processing, Environmental & Safety, Nuclear Fuel Technology, Automotive.

46

RARE EARTH R&D AT UMP

47

RARE EARTH RESEARCH FROM THE PERSPECTIVE OF PROCESS SYSTEM ENGINEERING

EXAMPLES OF RESEARCH PROJECTS

1) FLEXIBLE, MODULAR DESIGN AND OPERATION OF RARE EARTH PROCESSING PILOT PLANT
2) OPTIMIZATION IN THE SEPARATION OF RARE EARTH ELEMENTS VIA OPTIMAL SEQUENCE
3) PROCESS SIMULATION OF RARE EARTH PROCESSES
4) DATA MONITORING AND ANALYSIS OF AEROSOL MONITORING SYSTEM [AMS]

PILOT PLANT : QUEST RARE MINERALS ONTARIO CANADA

KVANEFJELD REE-URANIUM BENEFICIATION CIRCUIT PILOT PLANT

SEPARATION SEQUENCE

L. Wenli et al. / Analytica Chimica Acta 417 (2000) 111–118

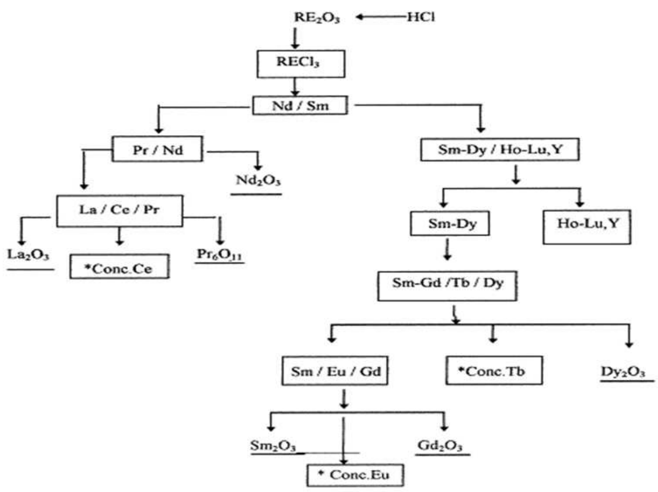


Fig. 2. General schema of HEH(EHP) extraction flow-sheet for Baiyunebo Bastnaesite rare earth separation.

SIMULATION VIA MATLAB

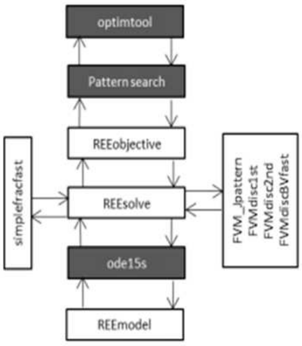


Figure 1. Structure of the code. *REEobjective* calculates the value of the objective function while *REEsolve* and *simplefracfast* calculate the amount of product with the 99% purity requirement. *REEmodel* contains system of differential equations. Auxiliary functions perform the Finite Volume Method 2-point backward discretization of the first derivative and 3-point central of the second derivative.

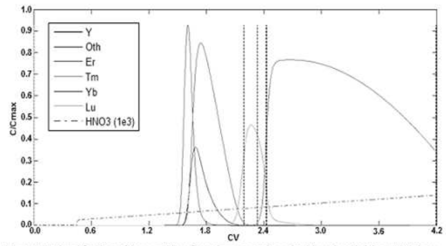


Figure 2 Retrieved fractions of the annual benefits optimum operation point. Eluent is scaled down 1000 times. Ytterbium and Thulium are successfully retrieved at a 99% purity.

Table 3 Different yield requirements for the operation points of the production costs optimization

point	Ho	Er	Tm	Yb
○	-	-	-	0.85
◆	-	-	0.85	0.85
▲	0.50	-	0.85	0.85
■	0.50	0.50	0.85	0.85
□	-	-	0.50	0.85
+	-	-	-	0.50
⋇		-	0.85	-
●	0.85	-	-	-

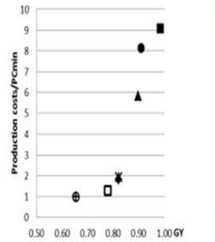
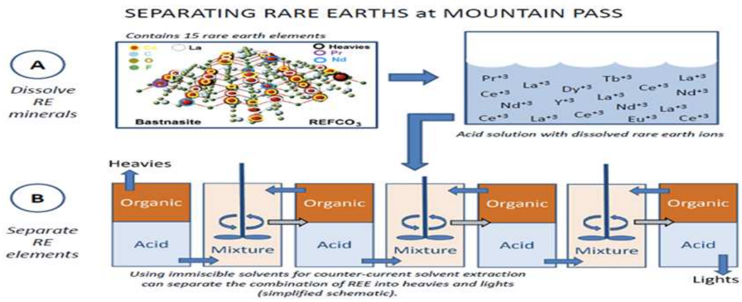
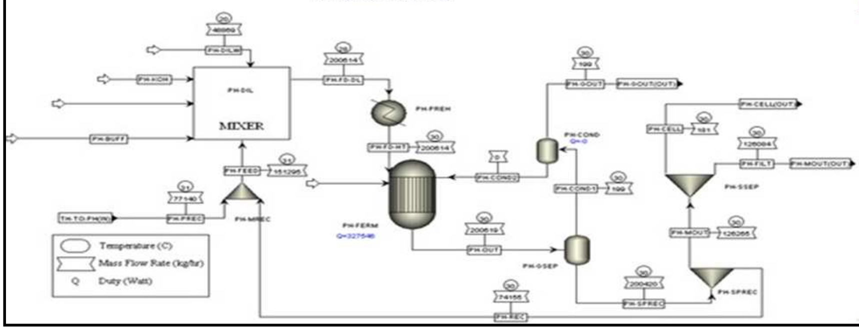


Figure 3 Normalized production costs vs global yield for the different operation points. Legend in Table 3.

SIMULATION STUDIES VIA ASPEN





DATA MONITORING & ANALYSIS

PARAS SINARAN DI LUAR TAPAK (*OFFSITE*) LYNAS

Radius	Purata Paras Sinaran (µSv/j)	Kesimpulan
1 km	0.139±0.012	**Tidak melebihi** had yang ditetapkan oleh AELB
5 km	0.210±0.009	
10 km	0.190±0.012	
20 km	0.206±0.005	

AIR EMISSIONS

Plant air emission – 100% compliance

Parameters	Unit	CAR 1978* Emission Standards	Limits imposed by DOE's for WGTS Stack	Results		
				May	June	July
Total Suspended Particulates	mg/Nm^3	400	100	42.4	55.3	34.1
Sulphuric Acid Mist or Sulphur Trioxide or Both	mg/Nm^3	200	50	ND	ND	1.58
Sulphur Dioxide	mg/Nm^3	-	500	14.9	25.2	24.4
Hydrogen Fluoride	mg/Nm^3	100	50	ND	ND	0.08

23

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**

SCENARIO	*RIA mSv y^{-1}	ACTUAL mSv y^{-1}	RELATIVE READINGS
Truck driver (Kuantan Port to LAMP: external radiation from Lanthanide concentrate (LC) : External radiation, 280 hr/y)	0.06	0.06	Equal (Background)
Workers handling LC stockpile in concentrate building: External radiation, 730 hr/y	2.19	0.77	2.8 x less
Truck driver handling WLP from filter press to RSF: external 576 hr/y	1.48	0.58	2.55 x less
Process Operator at WLP filter press: External radiation, 1332 hr	4.02	1.14	3.52x less
FEL workers at WLP RSF :576 hr/y	2.96	1.45	2.04x less

19

Water Discharged (critical parameters only): ALL BELOW LIMITS and 100% COMPLIANCE with DoE Standard B

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

Parameters	Unit	Std B	May	Jun	July
pH	-	**5.5 – 9.0**	7.57	7.55	7.58
Iron	mg/L	**5**	1.67	0.27	0.21
BOD_5 at 20°C	mg/L	**50**	ND	ND	ND
COD	mg/L	**200**	36.7	37.7	33.6
Suspended Solid	mg/L	**100**	5.7	11.2	7.0
Cyanide	mg/L	**0.10**	ND	ND	ND
Manganese	mg/L	**1**	0.07	0.19	0.14
Zinc	mg/L	**2**	0.10	0.08	0.04
Fluoride	mg/L	**5**	0.95	0.90	1.03
Barium	mg/L	**4**	ND	ND	ND

Lynas CORPORATION LTD

NATIONAL & INTERNATIONAL COLLABORATION

KARLSRUHE INSTITUTE TECHNOLOGY, GERMANY

PEKING UNIVERSITY, CHINA

UMP

UKM; UTP; UTAR; and UTEM.

UNIVERSITY OF QUEENSLAND, AUSTRALIA

THANK YOU

61