Economics of Rare Earth Projects

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Why rare earths?

Oil is the blood; steel is the body; but rare earth elements are the vitamins of a modern society (anon?)

Rare earth elements can be regarded as the "vitamins" required for the shift from a carbon based economy to the new 21st century electron economy (many references)

There is oil in the Middle East. There is Rare Earth in China (Deng Xiaoping Chinese President - 1992)

Improve the development and applications of rare earth, and change the resource advantage into economic superiority (Jiang Zemin Chinese President - 1999)

Not only has China taken the lead on rare earth production over the last 20 years and now holds a dominant position in the whole supply chain from mining to consumer end-products, it has a clear policy to secure other deposits elsewhere in the world and enhance that dominance.

Rare Earth Applications

Application	Rare Earths	Demand Drivers
Magnets	**Nd, Pr,** Sm, Tb Dy	Drives for computers, mobile phones, mp3 players, cameras. Hybrid vehicle electric motors. Electric motors for luxury vehicles. Mag-lev trains.
LaNiH Batteries	**La,** Ce, Pr, Nd	Hybrid vehicle batteries. Hydrogen absorption alloys for re-chargeable batteries
Phosphors	**Eu, Y, Tb,** La, Dy, Ce, Pr, Gd	LCDs. PDPs. LEDs. Energy efficient fluorescent lights/lamps.
Fluid Cracking Catalysts	**La,** Ce, Pr, Nd	Petroleum production – greater consumption by 'heavy' oils and tar sands
Polishing Powders	**Ce,** La, Nd	Mechano-chemical polishing powders for TVs, monitors, mirrors and (in nano-particulate from) silicon chips.
Auto Catalysts	**Ce,** La, Nd	Tighter NO_x and SO_2 standards – platinum is re-cycled, but for rare earths it is not economic
Glass Additive	**Ce, La,** Nd, Er	Cerium cuts down transmission of uv light. La increases glass refractive index for digital camera lens.
Fibre Optics	**Er,** Y, Tb, Eu	Signal amplification

Source: IMCOA

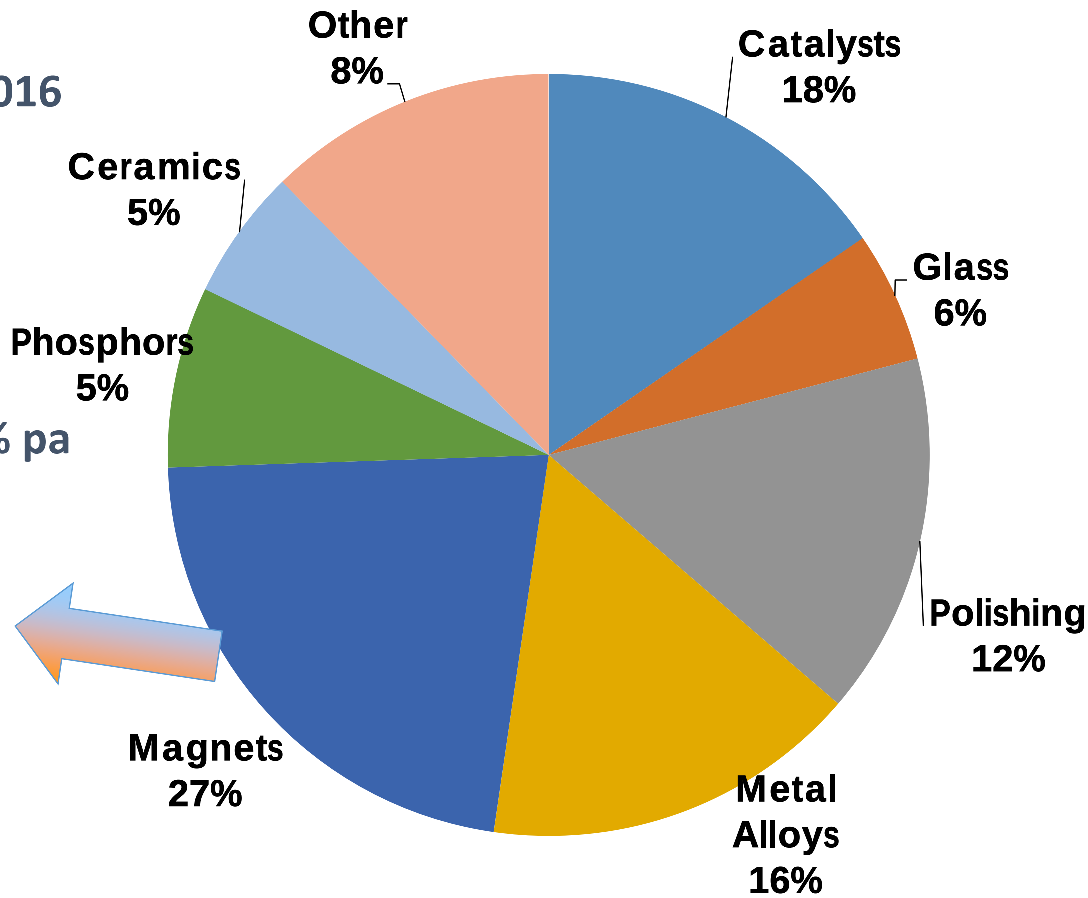
Rare Earth Demand Drivers

- US$3-5B Global market
- 159,500t Annual consumption 2016
- 6-8% Annual growth estimates
- 85-90% REE produced by China

- Permanent magnets dominate consumption and growth 6 - 12% pa
- Annual magnet market ~US$20B
- Major use for Nd, Pr, Dy and Tb
- 80% by value 20% by volume

- Growth in other REs for special metal alloys and ceramics

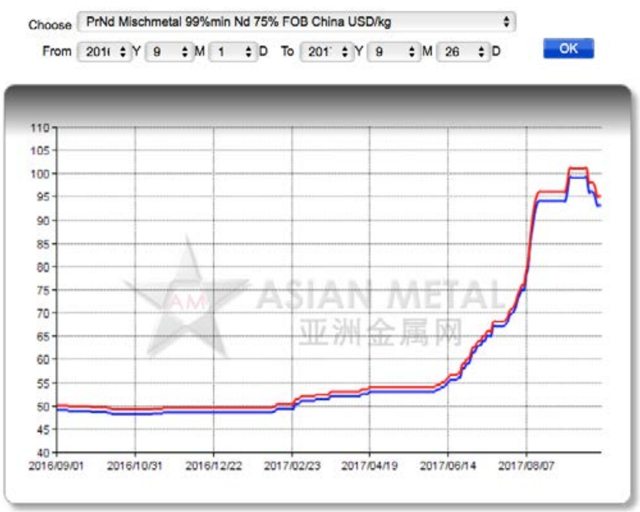
REE Demand 2016 by Application

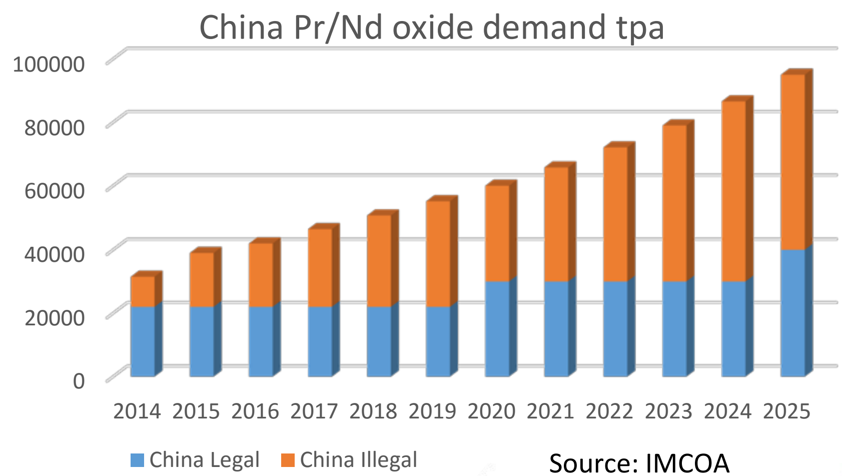


Rare earth permanent magnets (REPM)

1. **Luxury electric vehicle contains ~4.5 kg of REPM**
   - 2.0 kg for traction motor; 2.5 kg for other motors (windows, seats etc)
   - Contains 31% rare earth Pr/Nd alloys, or 1.4 kg
   - 1 million EVs require ~1,400 tpa of PrNd alloy
   - Annual growth +30%

2. **China will consume 46,500 t of Pr/Nd oxide for magnets in 2017, and is set to reach 60,000 tpa by 2020**
   - Magnet demand growth rate will increase further for EVs, wind power, and robotics
   - Crackdown on illegal Chinese production is reducing supply





Source: IMCOA

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China: Critical Supply Issues to 2025

1. **China Manufacturing 2025 is targeting 70-80% domestic supply by 2025 for key high value markets**
    - Critical supply risk for rare earths and zirconium chemicals as China supplies 90+ % of world supply
        - 50% of rare earths supply is non-quota or illegal

2. **Export & supply of rare earths magnets threatened**
    - High growth rates for magnets in China will reduce exports- preference will be given to Chinese companies

3. **China's rare earth industry is US$3-5 billion, with a US$30-40 billion environmental clean up legacy**
    - Rare earth prices will need to double in order to pay environment clean up costs over 10 years

Military Applications – strategic importance

REE	Technology	Function	Examples
Nd, Pr, Sm, Dy, Tb	Permanet Magnet	Guidance and Control Electric Motors and Actuators, Stealth/Noise Cancellation	Smart Bombs, Joint Direct Attack Munition (JDAM), Joint Air to Ground Missile (JAGM), Cruise Missiles, Unmanned Aerial Vehicles (UAVs), AIM-9x, AIM-120 AMRAAM, Helicopter Acoustic Signature Reduction (NdFeB plus Terfenol-D)
		Electric Drive Motors	Zumwalt DDG 1000, Joint Strike Fighter (JSF), Hub Mounted Electric Traction Drive, Integrated Starter Generator, Combat Hybrid Power System (CHPS)
Y, Eu, Tb	Amplification of Energy and Resolution	Targeting, Detection, Countermeasures	Nd-doped Yttrium Aluminium Garnet (YAG) Laser for targeting and underwater mine detection (e.g. Magic Lantern), Laser Targeting (Air- and Ground-based), Counter-Improved Explosive Device (IED) (e.g. Laser Avenger), SaberShot Photonic Disrupter
Nd, Y, La, Lu, Eu	Amplification, Enhanced Resolution of Signals	Communications, Radar, Sonar, Radiation and Chemical Detection	Sonar Transducers, Radar, Enhanced Radiation Detection, Multipurpose Integrated Chemical Agent Alarm (MICAD), Microwave Amplification for Satellite Communication, High-Capacity Fiber Optics
Ce, La	Displays and Optics	Enhanced Battlefield Displays	Driver's Vision Enhancer (DVE), Avionics Displays
Various	Energy Storage, Density Amplification, Capacitance	Electronic Warfare and Directed Energy Weapons	Jamming Devices, Electromagnetic Railgun, Ni Metal Hydride Battery, Area Denial System (e.g. Long Range Acoustic Device or LRAD)

Source: Critical Rare Earths, National security, and US China Interactions. David L An.2016

Weapon Systems	Army	Marine Corps	Navy	Air Force
AGM-114 Hellfire Air-to-Surface missile	✓			✓
Joint Direct Attack Munition (JDAM) Precision Guidance Kit	✓	✓	✓	
PAC-3 Anti-Ballistic Missile	✓			
AIM-9 Sidewinder Air-to-Air Missile		✓	✓	✓
AIM-120 Advanced Medium-Range Air-to-Air missile		✓	✓	✓
Harpoon Anti-Ship Missile		✓	✓	✓
Trident 5D Submarine-Launched Ballistic Missile			✓	
Minuteman-III Intercontinental Ballistic Missile				✓
Weapon Platforms	**Army**	**Marine Corps**	**Navy**	**Air Force**
M109 Paladin Howitzer	✓			
AH-64 Apahce Helicopter	✓			
M2 Bradely Fighing Vehicle	✓			
M1 Abrams Main Battle Tank	✓	✓		
Stryker Fighter Vehicle	✓			
Arleigh Burke-Class Destroyer			✓	
Nimitz-Class Aircraft Carrier			✓	
Littoral Combat Ship			✓	
Unmanned Underwater Vehicle			✓	
SSN-774 Virginia-Class Attack Submarine			✓	
B-52 Bomber				✓
F-15 Eagle Fighter				✓
F-16 Falcon Fighter				✓
F-18 Hornet Fighter		✓	✓	
F-22 Raptor Fighter				✓
F-35 Joint Strike Fighter		✓	✓	✓
MQ-1B Predator Drone				✓
Other Systems	**Army**	**Marine Corps**	**Navy**	**Air Force**
Laser Rangefinder	✓			
Laser Target Designators	✓			
Satellite Communication	✓			
Towed Decoys		✓	✓	✓
Aegis Radar			✓	
Firefinder Anti-Rocket/Anti-Artillery Radar			✓	
Underwater Mine Detection			✓	

Source: Adams et al. (2013)

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Where are the rare earths?

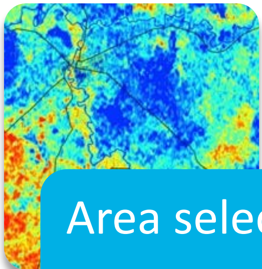
Deposits and mineralogy

The major deposits – alkaline intrusive complexes and rarely volcanic sequences. All have variable mineralogy and uranium and thorium content. Others in secondary surficial environments (ionic clays); or deep sea muds; fly ash.
Deposits are found in many world wide locations. Some examples are:

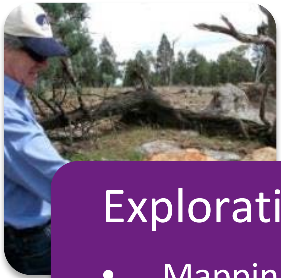
DEPOSIT	GEOLOGY	STATUS
Baiyun Obo – China	hydrothermal – skarn like (IOG ?) – bastnasite (LREE)	Production
Mt Weld – Australia	carbonatite – monazite (LREE)	Production
Mt Pass – USA	carbonatite sheets – bastnasite (LREE)	Moth balled
Longnan – China	ionic adsorption clays – heavy rare earths	Production
Dubbo - Australia	trachyte volcanic – eudialyte/bastnasite (Zr Hf Nb REE)	Financing
Browns Range – Australia	hydrothermal vein - xenotime (HREE)	Pilot plant
Nolans – Australia	carbonatite sheets – apatite (LREE)	Feasibility
Ngualla – Tanzania	carbonatite – bastnasite (LREE)	Feasibility

The ore and host rock mineralogy affects the recovery process, and hence flowsheet capex, opex and product output.

How do we get there? Deposit to product output

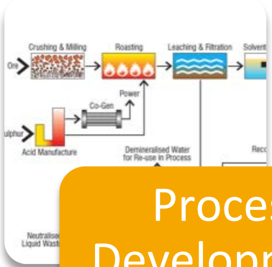


Area selection
- Geological
- Previous work

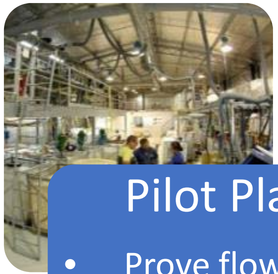


Exploration
- Mapping
- Drilling

Resource
- Definition
- Geo-metallurgy



Process Development
- Metallurgy
- Feasibility



Pilot Plant
- Prove flow sheet
- Samples for market evaluation

Environment
- Impact studies
- Social licence
- Regulatory time frames

Offtake
- Product certification
- Bankable feasibility

Financing
Construction

Production

The discovery to production usually takes 10 to 15 years and feasibility can cost in excess of $100 million

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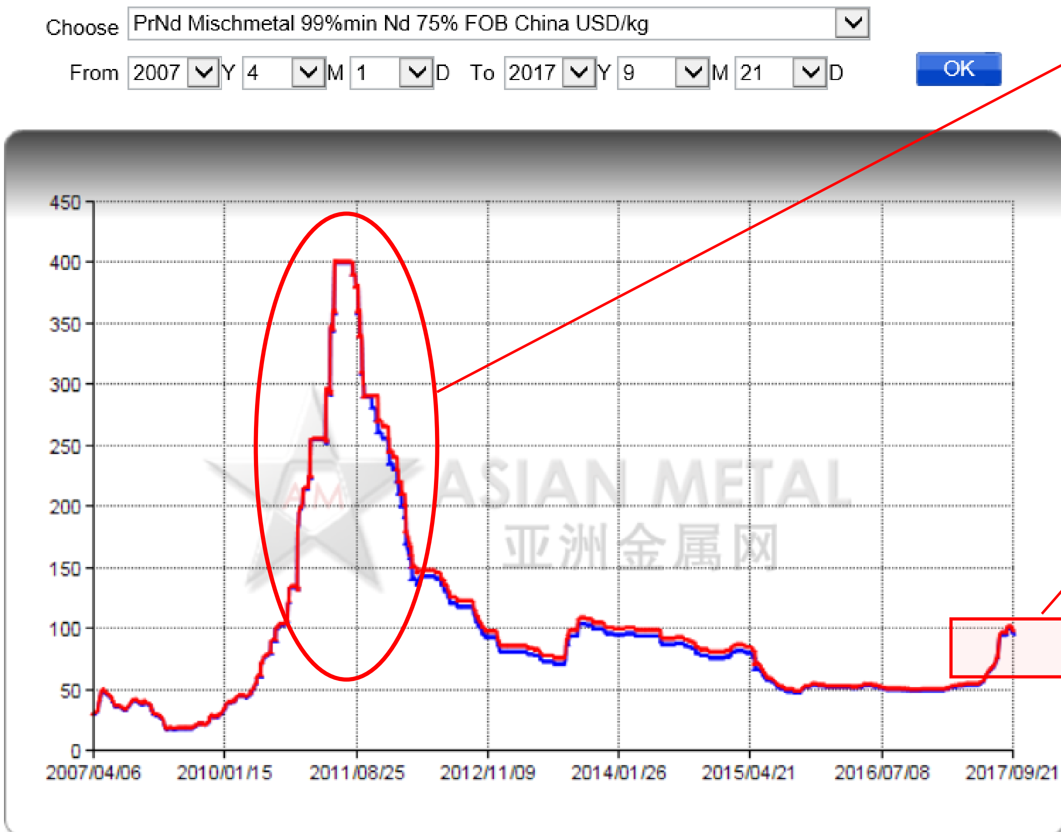
Capital Costs

- Most current rare earth production facilities include upfront mineral beneficiation followed by "cracking" and dissolution of the minerals; then separation by solvent extraction and refining of the individual rare earths. There are several other extraction and refining processes being trialed but none are yet used in commercial production.
- The plants are sophisticated chemical processing facilities, with multiple streams and potential recirculating loads that require careful management to ensure maximum recovery and product quality.
- Management (handling, storage and neutralization) for long term administration of waste stream costs are often large and under estimated.
- Large scale pilot plant proving of the flow sheet is essential to inform capital and operating costs, demonstrate mass balances and product recoveries, demonstrate sustainable environmental management and to minimizing process and financial risk.
- Capital costs will depend upon planned capacity and location. Currently there are several non-Chinese rare earth projects that have commenced operation during the last five years or are planning development.
- Recent capital cost estimates for projects have ranged from about US$400 million to US$2,000 million, and as a rough "rule of thumb" an approximate cost of US$50/kg of REO can be applied (excluding working capital).

Price Sustainability – the neodymium example



The "2011 boom", initiated by a geo-political event and exacerbated by rampant speculation (mostly traders)

Calls for rare earth substitutions, thrifting and some amazing "discoveries".

The sustainability window (?)
US$60-110/kg NdPr metal

A price that can allow western NdFeB permanent magnet consumers to compete on price/quality with Chinese producers

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“Economics”

Indicative valuations based upon industry generalisation with a +/- 15-20% accuracy

Product	Units	Current Price Range US$/kg FOB China	Source Basnasite ppm	Source Monazite ppm	Source Xenotime ppm	Source Apatite ppm	Source Ionic clay ppm	Source Polymetallic ppm	Recovery % Estimated global averge
Lanthanum Oxide	La_2O_3	2.53	22350	23320	174	5540	18	1800	75
Cerium Oxide	CeO_2	2.90	32075	46430	432	13340	4	3390	75
Praseodymium Oxide	Pr_6O_{11}	90.00	2760	5040	61	1630	7	375	70
Neodymium Oxide	Nd_2O_3	72.50	7690	17700	274	5950	30	1300	70
Samarium Oxide	Sm_2O_3	2.30	1	2	178	2	28	200	50
Europium Oxide	Eu_2O_3	80.00	85	518	37	110	1	6	50
Gadolinium Oxide	Gd_2O_3	43.30	0.2	1	476	1	69	200	60
Terbium Oxide	Tb_4O_7	580.00	30	88	106	22	13	30	50
Dysprosium Oxide	Dy_2O_3	185.00	30	224	719	93	67	190	65
Holmium Oxide	Ho_2O_3	40.00			150		16	40	50
Erbium Oxide	Er_2O_3	28.50			427		49	107	50
Thulium Oxide	Tm_2O_3	NA			59		7	15	50
Ytterbium Oxide	Yb_2O_3	30.00			344		25	92	50
Lutetium Oxide	Lu_2O_3	720.00			46		4	13	35
Yttrium Oxide	Y_2O_3	3.50	7	740	4810	370	650	1460	75
Chemical Zirconia	99.50% ZrO2	10.00						19000	85
Hafnium Oxide (95% HfO_2)	Hf Metal	500.00						400	50
Ferro-niobium (65% Nb)	FeNb	35.00						4400	65
Recovered value /kg			$14.19	$20.36	$20.30	$23.02	$26.73	$20.60	
Opex (average)			$15.00	$13.00	$25.00	$15.00	$15.00	$8.00	
Revenue			**-$0.81**	**$7.36**	**-$4.70**	**$8.02**	**$11.73**	**$12.60**	
Gross Margin %			-6%	36%	-23%	35%	44%	61%	

Operating economics for six RE type deposits applying global average recovery and current REO prices.

Opex calculated as globalized averages to generate an approximate US$ revenue per kilogram of output.

Gross margins range from negative to about positive 60%

Environmental management costs for Chinese operations not included in their costs (particularly ionic clay deposits)

Summary of Economic Drivers for REs

- ☑ Quality of the resource – grade, recovery, metal distribution
- ☑ Location and access to infrastructure
- ☑ % of "magnet metals" Nd, Pd, Dy, Tb and Sm in production that will drive revenue
- ☑ Volume and quality of off-take agreements
- ☑ Operating costs
- ☑ Capital intensity ($/kg per product capex)
- ☑ Sustainable product prices
- ☑ Demonstrable sustainable environmental practice

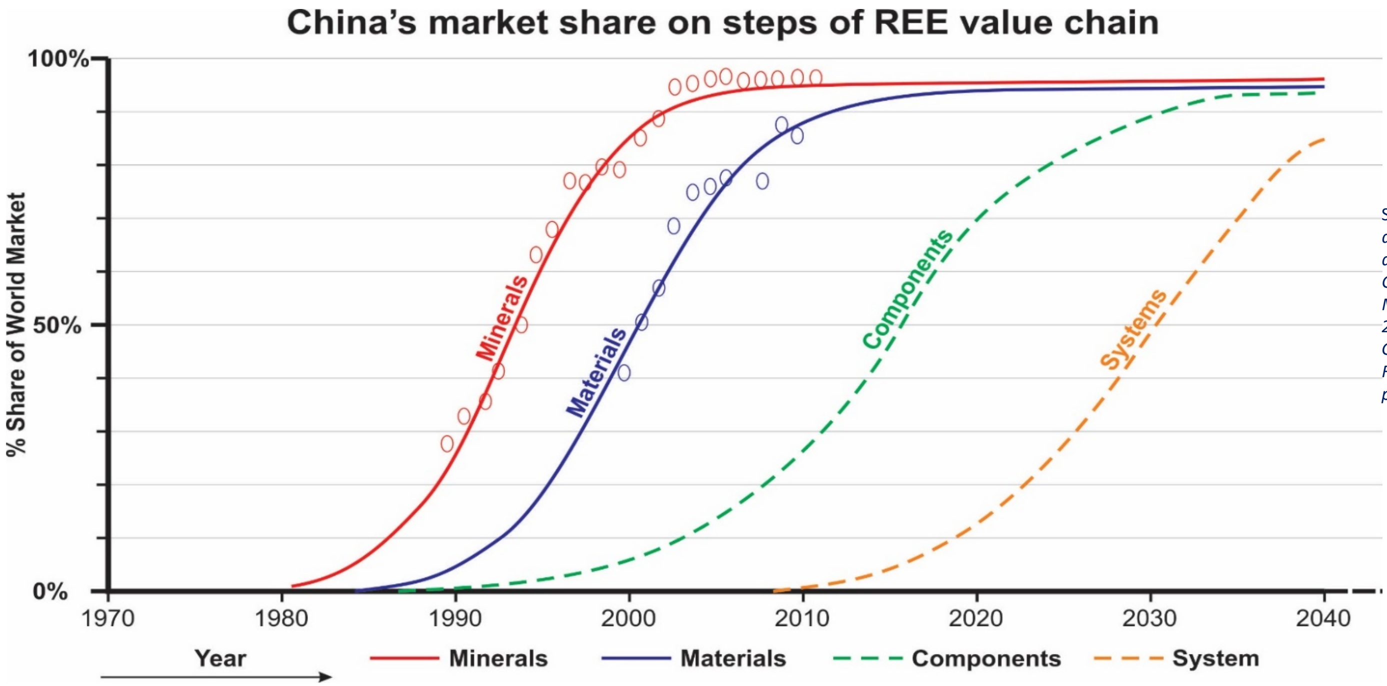
Financing

- **ECONOMICS**
  Rare earth (and rare metal) projects involve complex processing options to produce marketable products. To generate reasonable financial returns, these projects require stable and sustainable product prices, and economies of scale which usually relate to large upfront capital expenditure.
- **RISK MANAGEMENT**
  Minimising technical and financial risk is of primary importance and this requires a substantial investment in pilot plant proving and distribution of products to consumers for certification and off-take agreements.
- **OFF-TAKE**
  Historically rare earth sales were based on long term contracts. Currently difficulties arise when customers expect new suppliers to base their pricing on spot prices generated by traders who have no commitment to sustain the industry. These conditions are rarely satisfactory for normal financiers.
- **FINANCE**
  The equity markets struggle with these "exotic" metals, as they are perceived to be high risk and of relatively low cumulative value. The 2012 price "crash" reinforced these negative perceptions.

  These large complex projects will rely on innovative funding solutions needing the support of national financial institutions such as Export Credit Agencies and / or specific strategic agencies or companies that understand the national significance of the metal supply.
- **NICHE MARKETS**
  Few comparative and successful projects for peer comparison by financial institutions

Strategic Issues

China's dominance of the markets for rare earths, and for some specific rare metals, will continue with the clear public statements by the Chinese Government of the intention to maintain and expand China's advanced manufacturing capabilities.



Source: Karl Gerald van den Boorgart, Polina Klossek and Andreas Klossek, *"How Forward Integration along the Rare Earth Value chain Threatens the Global Economy", paper presented at 2014 Critical Minerals Conference, Denver, Colorado, August 3-5 2014. Referenced in "The Elements of Power, Gadgets, Guns and The Struggle for a Sustainable Future in the Rare Metal Age, David S Abraham, published by Yale University Press, October 2015*

The value increases from US$4B Minerals; US$40B Materials; US$400B Components; to US$4T Systems

Strategic Issues – Financing Perspective

Geopolitical and sovereign risk. Recent actions by African and South American governments demonstrate that this risk remains very high. What countries are "safe"?

Supply chain visibility. The large issue of product from illegal mining/production in China and other conflict regions. Interaction with the laws of the US and Europe.

National defence issues – potential for interruption to supply.

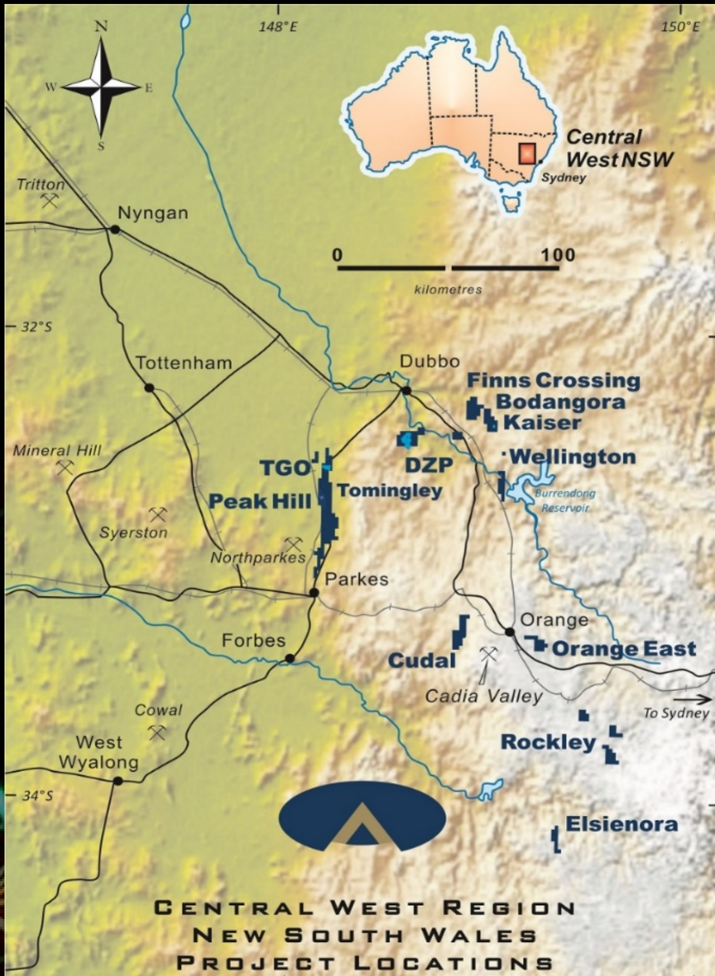
Corporate requirements for business continuity.

Are non-Chinese countries and companies prepared to accept that supply of many components and consumer products will be dictated by China?

Are these entities prepared to support project developments that may not qualify for normal terms of resource project financing – IRR, NPV and length of payback?

The rare earth supply chain outside of China needs to be acknowledged, supported and requires strategic investment.

Alkane Resources Ltd Thank You



Multi commodity mining company
Focussed in the Central West New South Wales

Two major projects through subsidiaries

Australian Strategic Materials Ltd (ASM)

- **Dubbo Project - technology metals**
  Production of Zr, Hf, Nb and REEs

Tomingley Gold Operations Pty Ltd (TGO)

- **Tomingley gold production**
  Cash flow generation

Market capitalisation	A$180M
Current cash + bullion	A$50M

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Acknowledgements

This presentation contains certain forward looking statements and forecasts, including possible or assumed reserves and resources, production levels and rates, costs, prices, future performance or potential growth of Alkane Resources Ltd, industry growth or other trend projections. Such statements are not a guarantee of future performance and involve unknown risks and uncertainties, as well as other factors which are beyond the control of Alkane Resources Ltd. Actual results and developments may differ materially from those expressed of implied by these forward looking statements depending on a variety of factors. Nothing in this presentation should be construed as either an offer to sell or a solicitation of an offer to buy or sell securities.

This document has been prepared in accordance with the requirements of Australian securities laws, which may differ from the requirements of United States and other country securities laws. Unless otherwise indicated, all ore reserve and mineral resource estimates included or incorporated by reference in this document have been, and will be, prepared in accordance with the JORC classification system of the Australasian Institute of Mining, and Metallurgy and Australian Institute of Geosciences.

Competent Person

Unless otherwise stated, the information in this presentation that relates to mineral exploration, mineral resources and ore reserves is based on information compiled by Mr D I Chalmers, FAusIMM, FAIG, (director of the Company) who has sufficient experience which is relevant to the style of mineralisation and type of deposit under consideration and to the activity which he is undertaking to qualify as Competent Person as defined in the 2012 Edition of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves. Ian Chalmers consents to the inclusion in the presentation of the matters based on his information in the form and context in which it appears.

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Many Alkane staff and consultants have contributed to the content in this presentation which has been compiled over twenty years during the study into the development of the Dubbo Project. Dudley Kingsnorth (Industrial Minerals Company of Australia) is thanked for his review of the information relating to global prices, operating and capital costs.

Dubbo Project Resources & Reserves

Dubbo Project – Mineral Resources

Resource Category	Tonnes (Mt)	ZrO_2 (%)	HfO_2 (%)	Nb_2O_5 (%)	Ta_2O_5 (%)	Y_2O_3 (%)	TREO* (%)
Measured	42.81	1.89	0.04	0.45	0.03	0.14	0.74
Inferred	32.37	1.90	0.04	0.44	0.03	0.14	0.74
Total	75.18	1.89	0.04	0.44	0.03	0.14	0.74

***TREO% is the sum of all rare earth oxides excluding ZrO_2, HfO_2, Nb_2O_3, Ta_2O_5, Y_2O_3,**

These Mineral Resources are based upon information which has been compiled by Mr Stuart Hutchin, MIAG, and an employee of Mining One Pty Ltd. Mr Hutchin has sufficient experience that is relevant to the style of mineralisation and type of deposit under consideration and to the activity that is being undertaken to qualify as a Competent Person as defined in the 2012 Edition of the 'Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves'. Mr Hutchin consents to the inclusion in this report of the matters based on his information in the form and context in which they appear. The full details of methodology were given in the ASX Announcement of 19 September 2017.

Dubbo Project – Ore Reserves

Reserve Category	Tonnes (Mt)	ZrO_2 (%)	HfO_2 (%)	Nb_2O_5 (%)	Ta_2O_5 (%)	Y_2O_3 (%)	TREO* (%)
Proved	18.90	1.85	0.04	0.440	0.029	0.136	0.735
Probable	0						
Total	18.90	1.85	0.04	0.440	0.029	0.136	0.735

***TREO% is the sum of all rare earth oxides excluding ZrO_2, HfO_2, Nb_2O_3, Ta_2O_5, Y_2O_3,**

These Ore Reserves are based upon information compiled which has been compiled by Mr Ievan Ludjio MAusIMM(CP) and Mr Mark Van Leuven FAusIMM (CP), employees of Mining One Pty Ltd. Mr Ludjio and Mr Van Leuven have sufficient experience that is relevant to the style of mineralisation and type of deposit under consideration and to the activity that is being undertaken to qualify as a Competent Person as defined in the 2012 Edition of the 'Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves'. Mr Ludjio and Mr Van Leuven consent to the inclusion in this report of the matters based on his information in the form and context in which they appear. The full details of methodology were given in the ASX Announcement of 19 September 2017.