



RARE EARTHS: SHADES OF GREY

Can China Continue To Fuel Our Global Clean & Smart Future

Last December in Paris, an epic agreement on climate change was reached, setting the world on the long road towards de-carbonizing global economic growth. Promising technological innovations on clean energy, energy storage and efficiency are considered major drivers of the upcoming “clean, green & smart” revolution.

A deep-dive into the underlying new technologies however, leads to a severe yet overlooked problem. Rare earths, a cluster of 17 elements often called the “vitamins of industry”, may prove to be a bottleneck to such “clean, green & smart” innovations like wind turbines, smartphones, electric cars and more.

Rare earth mining and processing is a polluting and toxic process impacting China’s water resources and arable land. It is really only economically viable because environmental costs are not taken into account. Naturally the black market hasn’t helped. China has been producing the lion’s share of rare earths since the mid-1990s. Not surprisingly pollution has spread all over the country’s major rare earth mining and processing cities. The question is, can we build a sustainable clean, green and smart future on the back of pollution and a black market? We take a close look at these issues in this report.

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About China Water Risk

China Water Risk (CWR) is a non-profit initiative dedicated to addressing business & environmental risk arising from China’s limited water resources. We aim to foster efficient and responsible use of China’s water resources by engaging the global business and investment communities. As such, we facilitate discussion amongst industry leaders, investors, experts & scientists on understanding & managing water risk across six industry sectors: Agriculture, Power, Mining, Food & Beverage, Textiles and Electronics. CWR also has been commissioned by financial institutions to conduct research analysing the impact of water risks on the Power, Mining, Agricultural and Textile sectors. These reports have been considered groundbreaking and instrumental in understanding China’s water challenges. Join the discussion at www.chinawaterrisk.org.

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OVERVIEW

Last December in Paris, an epic agreement on climate change was reached, setting the world on the long road towards de-carbonizing global economic growth. Promising technological innovations on clean energy, energy storage and efficiency are considered major drivers of the upcoming “clean, green & smart” revolution.

A deep-dive into the underlying new technologies however, leads to a severe yet overlooked problem. Rare earths, a cluster of 17 elements often called the “vitamins of industry”, may prove to be a bottleneck to such “clean, green & smart” innovations.

From offshore wind turbines to Apple or Xiaomi’s latest smartphones, rare earths are embedded in our clean energy, smart tech and more. Rare earths are essential to our non-fossil fuel, highly smart and climate-friendly future. Indeed, we can’t achieve a low-carbon future without these clean technologies, and they currently do not work without rare earths.

At the peak of China’s dominance in 2010, the country supplied almost all the world’s rare earth elements with a 92% share of the global market. Consequently, as the largest exporting country since the mid-1990s, China has been paying the environmental cost of massive, unregulated rare earth mining and extraction with low margins. In northern China, the radioactive rare earth tailings dam lying in Baotou, Inner Mongolia, has put a death-curse on nearby villages. Some say this is a time bomb for the Yellow River, which lies only 10 kilometres away.

Meanwhile, in southern China, where the majority of global heavy rare earths originate, small-scale mines with their severely polluting extraction activities have contaminated drinking water sources and agricultural fields of local communities. China’s mega-cities further downstream like Guangzhou, Shenzhen and Hong Kong may also be affected by the toxic contamination upstream.

Since 2006, China has launched a series of stringent policies to regulate rare earth mining and commercial activities. Amongst these are the production licensing and quota system and the export license and quota system. Resource tax and export duty were also introduced for rare earth mining and rare earth element exports, citing environmental concerns and the need to fund the clean-up, as well as curtail production to rein in further pollution.

In July 2010, China cut its export quotas by 22.5%. Understandably, this stirred protests from the largest recipients of China’s rare earth supply, the US, Japan and Europe. Complaints were brought to the World Trade Organisation (WTO) arguing that such policies were protectionist and against free trade. It was said that China was using the environment as an excuse to gain global market share in the downstream use of rare earths. In 2014, the WTO ruled against China¹, saying that the country’s quantitative control policies were “*not justified under the exception of conservation of exhaustible natural resources*” nor were the export duties “*necessary for the protection of human, animal or plant life or health*”².

Following the WTO ruling, China eliminated its export licensing and quotas on rare earths in 2015³. Today, a permit system is in place instead. But has this levelled the playing field for other global producers? Has it prevented China from global rare earth dominance?

According to the United States Geological Survey (USGS), China’s global rare earth share has fallen from the peak of 92% in 2010 to 85% in 2015. Absolute production has fallen by 12.5%. However, China’s own official quotas of rare earth production for the same period 2010-2015 rose by 18%. Prior to 2014, the Chinese official numbers were less than the USGS data - could this discrepancy be due to a growing black market of illegal rare earths? Is China raising its quota to quash the black market? Many say that the black market was fuelled by 1) the WTO dispute and 2) the doubling of the resource tax at the higher-end range in 2011 to pay for environmental pollution.

Today, China is still the largest producer of rare earths globally and pollution has worsened. China's waters are contaminated and a RMB38 billion environmental bill for damage in the southern mine area of Ganzhou city⁴ estimated by the Ministry of Industry and Information Technology (MIIT) remains unpaid with little media attention. The US, Japan and Europe appear to have written this off as necessary evils in the name of "free trade".

Meanwhile, after decades of wild growth, in 2013, China made a bold move to consolidate its domestic rare earth industry into six major groups⁵. These six groups will represent 99.9% of China's rare earth production quota for the first half of 2016. All six groups are state-owned enterprises, five of which are already listed on stock exchanges in mainland China and/or Hong Kong.

Under tougher environmental standards and more stringent market access criteria, the rare earth industry is marching towards consolidation and nationalisation that the iron and steel industry in China experienced decades ago. The backdrop of China's "most stringent" and updated Environmental Law, with harsh punishments including imprisonment may mean tougher enforcement in the rare earth industry. The reality is that once environmental cost is considered, the industry may only be economically viable for large state owned companies because of the increasing compliance and operational costs.

For example, the combined market capitalisation of five listed state owned rare earth companies (following industry consolidation) is only RMB154 billion (USD23.4 million). These five companies together have almost three quarters of the rare earth production quota of China for the first half of 2016. Factoring in the RMB38 billion environment cost in just one area of China with a quota to produce around 8.6% of China's rare earths would clearly change the economics of the market.

It appears that the only direction for global rare earth prices is up if environmental costs are factored in. Will this then translate into higher prices for green and clean tech goods, which then makes them less attractive and affordable? In turn, will manufacturers reduce their use of rare earths and so their goods perform less well and become less energy efficient?

Currently, China's treasury is bearing the clean-up costs to keep prices low but the ongoing environmental costs are paid for by the contaminated water and soil, as well as the health and lives of Chinese villagers. Can and should this be allowed to continue? What is the responsibility that we bear as consumers? Many of us use products powered by rare earths, many corporates profit from these, many countries' defence systems also use them. Can we all just sit back and watch China carry the costs? The global quest for a clean and green future amid China's worries over water scarcity, China's own pursuit of a "Beautiful China" where "*water runs clear*", "*land is green*" and there are "*blue skies*" has brought this paradox into the spotlight. Should our global clean and smart future be powered at China's expense?

In this report, we explore the various shades of grey in rare earths from how they power our low-carbon future to the black market and the environmental damage they paradoxically cause to the lack of global, national and corporate responsibility for this damage. By throwing light on these "shady activities", we hope that a responsible local and global governance structure relative to rare earths can be achieved.

Business leaders, policy makers and consumers, all need to rethink how we are going to achieve our low-carbon future in a more environmental and climate-friendly way. After all, building a sustainable future for all at the cost of the environment and people's lives in the sourcing countries is contradictory and unjust.

CHAPTER 1: CHINA'S RARE EARTHS: THE LIFE-SOURCE OF GLOBAL CLEAN & SMART TECH INNOVATIONS

1.1 85%-90% of rare earths are mined in China

Rare earths are not rare

Low labour & lax environmental standards made it much cheaper to mine & process rare earth ores in China

China has 23% of global rare earths reserves...

...but supplied 90% of rare earth products after refining and processing in 2010

In the last decades, China has achieved remarkable economic growth and modernization, in part on the back of excessive resource extraction. The price has been severe environmental pollution. Rare earth mining is one such sector.

To be clear, rare earths are not as "rare" as the name suggests. Rather the name reflects the difficulty finding commercially viable sources given labour needs and environmental costs. Low labour and lax environmental standards made it much cheaper to mine and process rare earth ores in China than in countries with abundant reserves such as the US, Brazil, Russia and Australia.

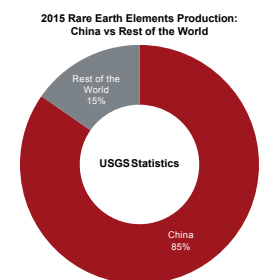
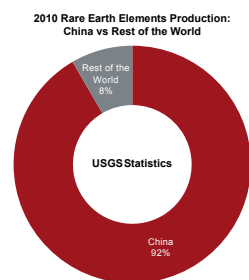
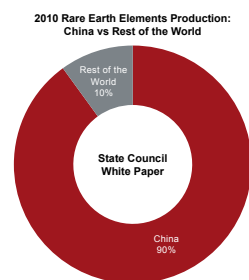
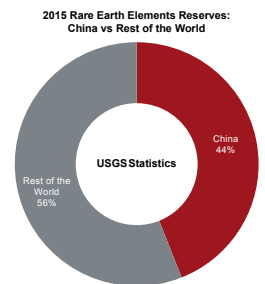
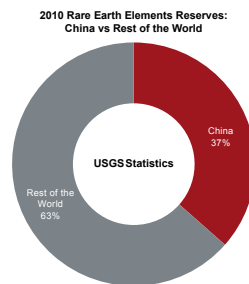
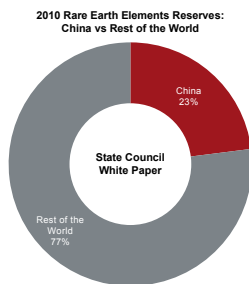
There are many shades of grey in the world of rare earths; even the amount of global reserves differs widely. According to China's latest official statistics, China only has 23% of global rare earths reserves but in 2010 supplied 90% of rare earth products after refining and processing⁶. Meanwhile, the USGS has China's reserves at 37% and production at 92% for the same year. While China has not released new reserve numbers, the USGS has China's reserves rising to 44% in 2015 with its share of production falling to 85% as shown in the charts below. However, what is consistent is that China's contribution to global rare earth production remains high at 85% to 90%.

"China contributes a large proportion of the global rare earth output, far exceeding its proportion of the global rare earth deposits."

Premier Wen Jiabao, 6th China-EU Business Summit, 6 October 2010

More on discrepancies in the rare earth supply & production market in **Chapter 2: China loses market share but still dominates by far.**

Reserves data varies but China production remains high



Source: China Water Risk based on State Council's White Paper "Situation and Policies of China's Rare Earth Industry" (2010)

Source: China Water Risk based on US Geological Survey (USGS) Rare Earths Statistics and Information

1.2 Rare earth elements: mostly unpronounceable but used everywhere every day

Rare earths refer to a cluster of 17 elements

Rare earths, often called the “vitamins of industry” – because of their indispensable contribution to improving product performance with only small amounts – are widely used in many manufacturing sectors and yet many people are unable to name a single rare earth element.

REEs are now easily found in our lives from energy saving lamps, to smartphones

The term rare earths typically refer to a cluster of 17 rare earth elements (REEs). Traditionally, the majority of these REEs were used in the production of catalysts, polishing, ceramics and phosphors. However, demand changed drastically in the 21st century, driven by the rapid growth of clean tech and high tech related applications such as magnets, metal alloys, electronics and batteries. This means that they are easily found in our everyday lives from our energy saving lamps to our smartphones, or allowing us to enjoy a movie on our iPad/tablet.

China has been the near-exclusive global supplier of rare earths

In the early 1990s, China overtook the US to become the largest rare earth producing and exporting country. Since then, China has been the near-exclusive supplier of the global rare earth market across the 17 REEs. For some REEs, China is the only global supplier. In short, almost every fluorescent lamp, a majority of wind turbines, hybrid cars, smartphones and many other high-tech personal devices, have the DNA of ‘mined in China’ REEs. Invisible and mostly unpronounceable, they are used everywhere, every day.

17 REES are split into Light, Medium & Heavy rare earths

The cluster of 17 REEs comprise 15 lanthanides (atomic number 57-71), Scandium (atomic number 21) and Yttrium (atomic number 39). The 15 lanthanides are generally grouped depending on their atomic weights into “Light Rare Earth Elements” (LREEs) and “Heavy Rare Earth Elements” (HREEs), with Scandium (Sc) and Yttrium (Y) classified separately⁷.

In some contexts, there is an additional category - “Medium Rare Earth Elements” (MREEs). In China, MREEs, HREEs and Yttrium are often grouped together as “Medium and Heavy Rare Earth Elements” (MHREEs). However, there are various group classifications with different splits on which elements are a LREE and which are MHREEs. The various classifications are shown in the table below. The data used in this report is that given by government or statistics departments. The Ministry of Land and Resources (MLR) production quota data, for example, is already split into LREEs and MHREEs though it does not specify the rare earth elements.

China & Rest of World definitions vary...

Classification of Rare Earth Elements - Light (LREE), Medium (MREE) & Heavy (HREE)

Element	Symbol	UNCTAD	China MLR		China State Council White Paper
			I	II	
Lanthanum	La	LREE	LREE	LREE	LREE
Cerium	Ce				
Praseodymium	Pr				
Neodymium	Nd				
Promethium	Pm				
Samarium	Sm	MREE	MREE	HREE	
Europium	Eu				
Gadolinium	Gd	HREE	HREE		
Terbium	Tb				
Dysprosium	Dy				
Holmium	Ho				
Erbium	Er				
Thulium	Tm				
Ytterbium	Yb				
Lutetium	Lu				
Yttrium	Y				
Scandium	Sc				

Source: China Water Risk, United Nations Conference on Trade and Development (UNCTAD) Report “Commodities At A Glance: Special issue on rare earths” (2014), China’s Ministry of Land Resources (DZ/T 0204-2002), Situation and Policies of China’s Rare Earth Industry, Information Office of the State Council, PRC, June 2012 (“White Paper”)

1.3 China REEs: Light in the North, Medium & Heavy in the South

Largest rare earth mine in the world is in Northern China...

In China, LREEs are largely mined in the North whereas MHREEs are in the South. The North of China hosts the largest rare earth mine in the world – the Baotou Baiyan Obo mine. Located in Inner Mongolia, this mine is also locally known as “the Capital of Rare Earths”. Today, Inner Mongolia still accounts for over half of China’s official total rare earth production quota⁸. In the South, lies China’s “Rare Earth Kingdom” – Ganzhou city. Though the city’s MHREEs deposits have reduced after decades of unregulated exploitation, in 2015 the city still accounted for 45% of the national MHREE production quota⁹. These northern LREE & southern MHREE mining belts played a pivotal role in the development of the global rare earth market.

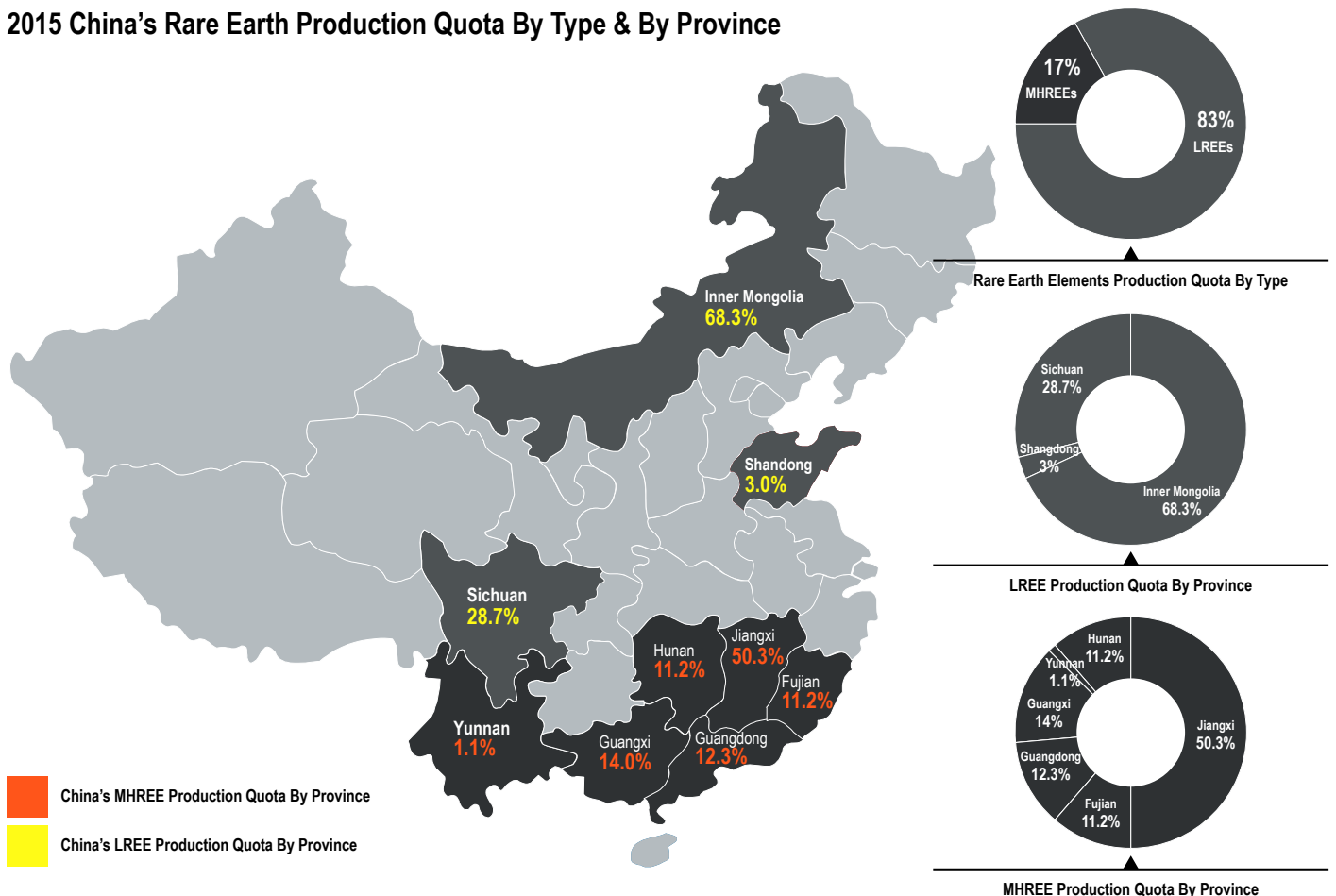
...while “ion-absorption rare earths ores” found in South China made MHREEs commercially viable

In the late 1960s, Chinese geologists discovered a unique type of rare earth ores in Longnan County within Ganzhou city¹⁰. It was this new ore type, later named “ion-absorption rare earths ore” that opened the door to commercially viable exploitation and production of MHREEs. Although these only account for 17% of China’s total production in 2015¹¹, they are critical across the clean tech, lifestyle, defence and power sectors¹².

Most MHREEs, critical to defence & to power, are solely mined & exported from China

Until today, the ion-adsorption rare earth clay in Southern China remains the dominant source of MHREEs produced globally. As a result, many MHREEs are solely mined and exported from China. Amongst those are critical elements like Europium (Eu), Dysprosium (Dy), Thulium (Tm) and Terbium (Tb)¹³.

2015 China's Rare Earth Production Quota By Type & By Province



Source: China Water Risk based on the annual production quota figures release by the Ministry of Land and Resources

1.4 MHREEs: small domestic production but big global exposure

When China cut its rare earths export quota in 2010 by 22.5%, there was an instant global scare about the ability to source rare earths and potential alternates. Prices of REEs rose sharply especially Dysprosium (Dy) and Neodymium (Nd). Some product designs were changed so as not to rely on certain REEs or fewer REEs were applied across various products. Other supply sources were also found. The mothballed Mountain Pass mine, owned by Molycorp Minerals Inc. in the US was brought back on line. The “scarcity” factor of rare earths mined outside of China made the sector attractive again and investments to open other mines were made.

The world breathed a sigh of relief as rare earth prices normalised when other producers came on line. Then in 2014, the WTO ruled against China's multiple export controls including export quota. China's global market share fell from 92% in 2010 to 85% in 2015¹⁴.

The WTO ruled against China in August 2014

WORLD TRADE ORGANISATION – CHINA RARE EARTH DISPUTE

In March 2012, the United States, later joined by the European Union, Japan and Canada, requested consultations with China through the World Trade Organisation (WTO). Their case to the Dispute Settlement Body was against China's various controls on its export of rare earths, tungsten and molybdenum and that they did not comply with the General Agreement on Tariffs and Trade (GATT – part of the WTO framework), as well as China's Protocol of Accession.

The dispute arose following China's decision to reduce its rare earth export quota by around 20% in 2010. This sent international markets soaring.

China's defence against the case was that it was protecting its natural resources, environment and safety of its people. The Chinese government stressed that it had the right to implement a protection policy for its rare earth resources, which it considers “an exhaustible natural resource” and so should fall under the exception for the conservation of such resources.

By March 2014, the WTO ruled against China, deciding that the Chinese rare earth export quotas and tariffs violate WTO rules. On 7 April 2014, China filed an appeal, though not to the final conclusions of the ruling but to some of the reasoning and findings items.

The WTO ruled against China's appeal in August 2014. According to the recommendations and rulings China agreed to remove its controls on trading rights of enterprises exporting rare earths and molybdenum, including its export quota system and export duties before May 2, 2015.

Source: Dispute DS431: China - Measures Related to the Exportation of Rare Earths, Tungsten and Molybdenum by the WTO (implementation notified on 20 May 2015), China Water Risk analysis based on export quotas from China's Ministry of Commerce, China – Rare Earth (DS431, 432, 433) by the WTO 2015, Reports of the Appellate Body - China - Measures Related to the Exportation of Rare Earths, Tungsten and Molybdenum, AB-2014-3/4/5 August 7 2014

New global capacity is almost entirely in LREEs...

...this means China is still the champion of MHREEs

But is it too early to celebrate? A closer look shows that the new global capacity is almost entirely in LREEs. This means China is still the champion of MHREEs production. Dysprosium (Dy) & Terbium (Tb) were supplied only by China in 2013¹⁵. Most of the global Thulium (Tm) & Europium (Eu) supply comes from China. These critical MHREEs are almost exclusively mined from Jiangxi, Guangdong, Fujian and a few other southern provinces as shown in the map on the previous page. The official production quota for these provinces account for 17% of the total rare earth production quota for the whole of China but these MHREEs are essential to the production of multiple items.

MHREEs may be a small share of the global market but they matter enormously. The same could also be said for the entire rare earth market. Many global institutional investors and financial institutions do not pay attention to the rare earth market precisely because it is small.

China has consolidated its rare earth industry into six groups which have 99.9% of China's rare earth production quota

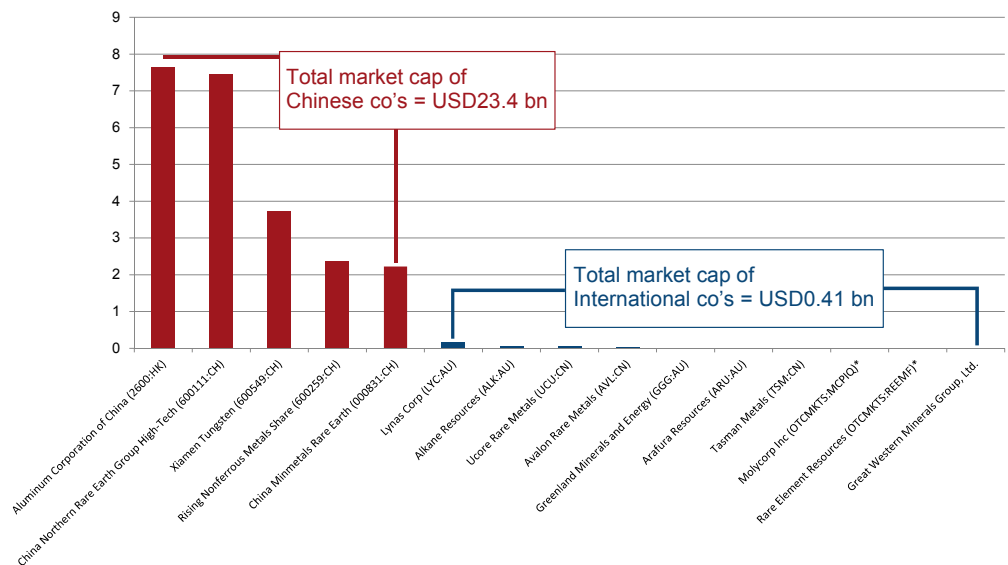
In an attempt to rein in the black market and pollution (discussed in detail in Chapters 3 and 4), China has consolidated its rare earth industry into six major groups. According to the MIIT, these six groups now represent 99.9% of China's rare earth production quota for the first half of 2016¹⁶. All are state owned, and five of these are listed with the exception of China Southern Rare Earth Group. The five listed Chinese rare earth mining companies have 74% of the rare earth production quota for the first half of 2016, yet they only have a combined market capitalisation of RMB154 billion (USD23.4 million)¹⁷. In reality, some of these five listed companies also produce other goods such as aluminium, tungsten and so on. Therefore, the actual market value of China's rare earth industry may be lower.

All six are state owned; five are listed

Elsewhere, the 10 leading global players ex-China identified by the UNCTAD rare earth report represent only USD409 million¹⁸. Since the UNCTAD report published in 2014, Great Western Minerals Group has gone bankrupt and completed a Companies' Creditors Arrangement Act filing, according to Newswire on December 3 2015. Additionally in June 2015 Molycorp also filed for bankruptcy as reported by the Wall Street Journal on June 25 2015. The market capitalisation of Chinese and international companies producing rare earths are set out in the chart below:

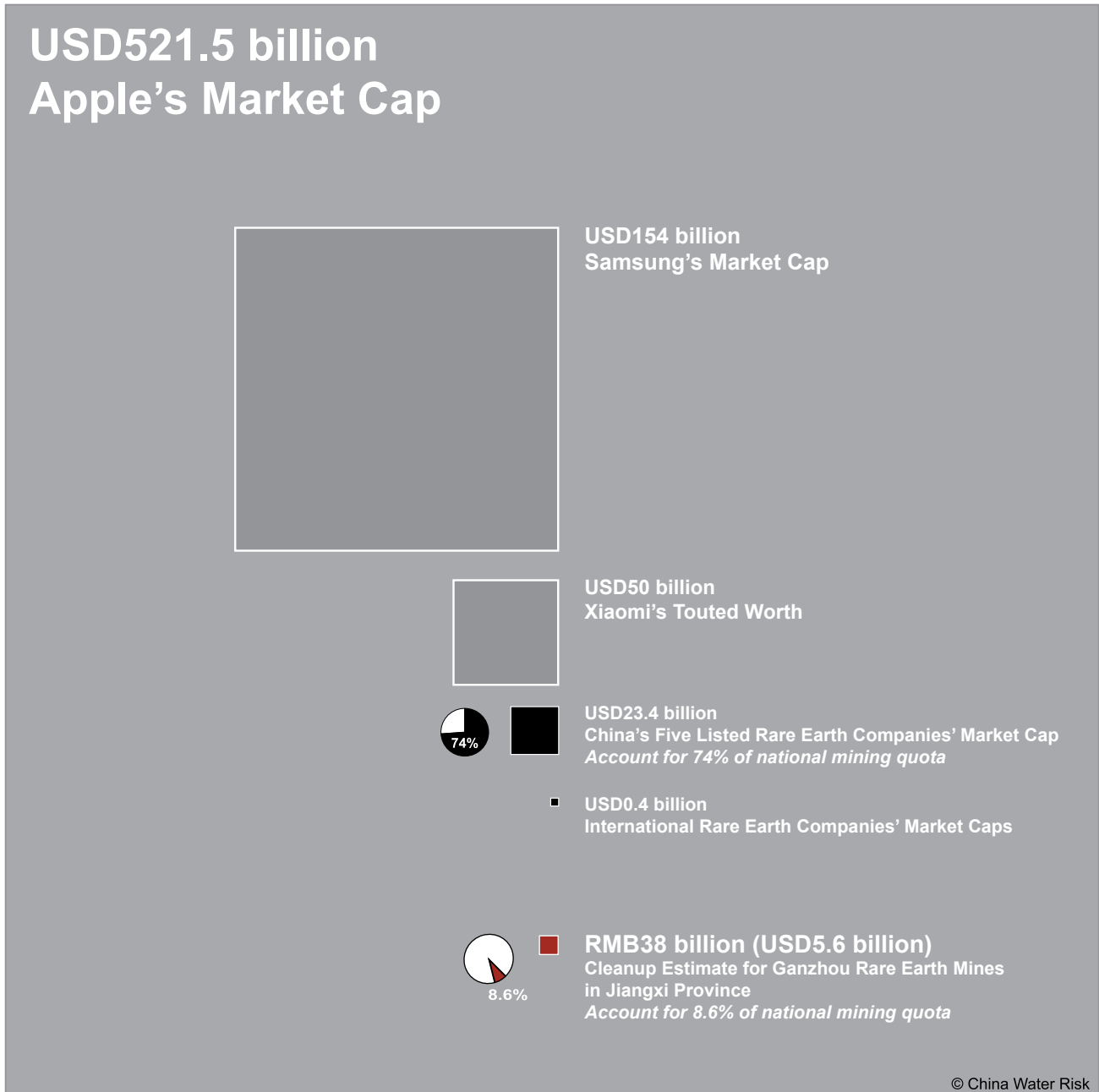
Market cap of China's five listed rare earth co's of USD23.4 bn is 56x that of Top 10 international co's

Market Caps of Leading Global Rare Earth Companies (USD bn)



Sources: China Water Risk based on data from Bloomberg & Google Finance as of May 23 2016
*Over-The-Counter Market

In comparison, companies that produce smartphones and tablets such as Apple and Samsung, which rely on these REEs, have a market capitalisation of USD521.5 billion¹⁹ and USD154 billion²⁰ respectively. Even Xiaomi, China's own smartphone maker is touted to be worth USD50 billion²¹.



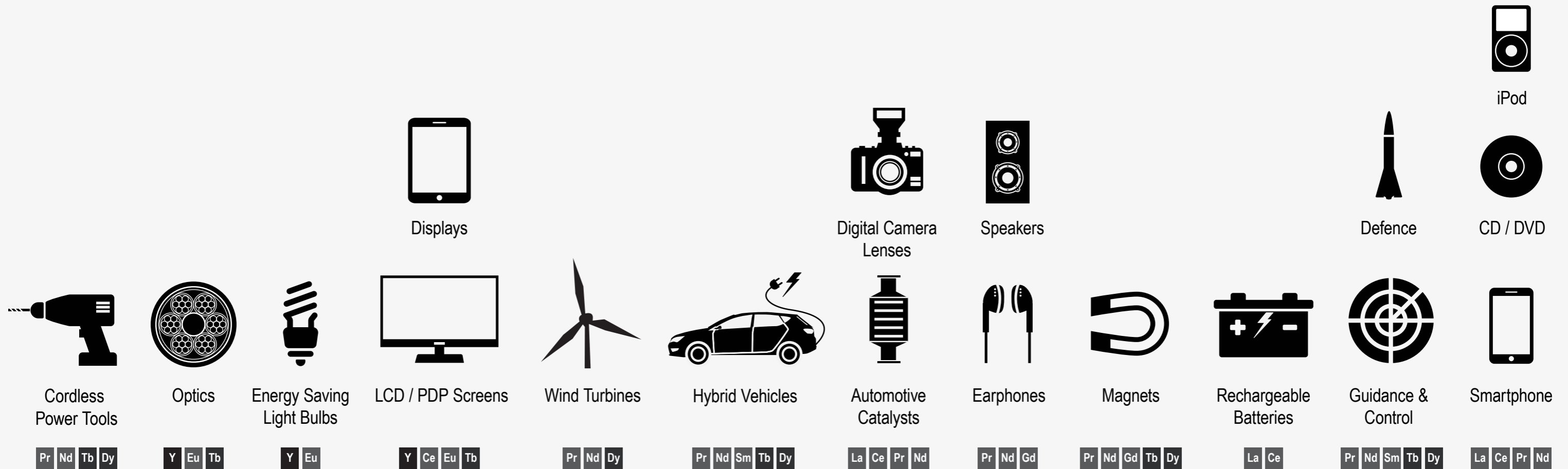
Source: <http://www.bloomberg.com/quote/AAPL:US> as of May 23, 2016 ¹⁹ <http://www.bloomberg.com/quote/005930:KS> as of May 23, 2016, <http://www.bloomberg.com/news/articles/2014-11-03/xiaomi-said-to-look-for-funding-at-valuation-of-about-50-billion>, MIIT

Worryingly, some of these REE applications have no substitutes at the moment

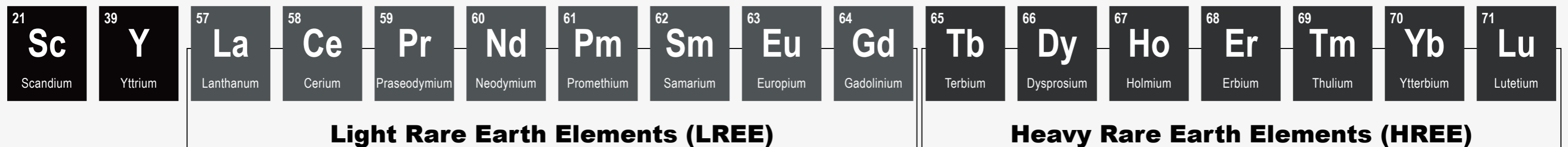
Most of these companies' products would not work without REEs – Yttrium (Y), Lanthanum (La), Terbium (Tb), Praseodymium (Pr), Europium (Eu), Dysprosium (Dy) & Gadolinium (Gd) make screens shiny; Neodymium (Nd), Terbium (Tb) & Dysprosium (Dy) make your phone vibrate; Praseodymium (Pr), Gadolinium (Gd) & Neodymium (Nd) make your speaker and earphones lightweight and so on²². Worryingly, some of these REE applications have no substitutes at the moment, and if there are substitutes, they tend to compromise performance or cost²³.

RARE EARTHS AT A GLANCE

APPLICATIONS



CLASSIFICATION



1.5 The rare earth paradox: our global clean future fuelled by water contamination, black markets & cancer villages

Rare earths are only rare due to the difficulty of finding commercially viable sources and their intensive extraction process. Not only is extraction costly, it is also highly polluting and toxic. Case and point is Australia's Lynas Corporation Limited, which has located its processing plant in Malaysia where environmental regulations are more lax. Australian authorities refused to accept the radioactive waste from processing rare earths. This includes Thorium and Uranium. This means that the rare earths are shipped from Australia to Malaysia to be processed and the toxic waste is disposed of in Malaysia. There is widespread opposition by Malaysians and many are calling for a stop to the plant²⁴. But in Australia, where the waste is no longer an issue, the company continues with business as usual.

Pollution is an inconvenient truth of rare earths often "swept under the carpet"

Herein lies the rare earth paradox: many REEs are used in products that are essential components of our clean, smart, low-carbon and climate-resilient future, but they come with a pollution tag. This polluting and often toxic nature of mining rare earths and REEs processing is an inconvenient truth often "swept under the carpet".

Can China afford to continue supplying its own growing demand...let alone global needs?

What if China were to adopt a clean-up or get out attitude to the extraction of REEs? With its watersheds contaminated and health of citizens threatened, China may have to seriously consider scaling back production. Can it afford to continue supplying its own growing demand, let alone global needs?



© Liu Hongqiao - A board in Ganzhou saying "Conserve water and soil is to protect human life"

Ganzhou has an RMB38 bn clean-up bill in Jiangxi province, which only has 8.6% of China's total quota

The environmental cost is astonishing. Based on local investigations, the MIIT estimated an initial RMB38 billion (~USD6 billion) was needed to clean-up the polluted rare earth mines in Ganzhou city alone²⁵. This RMB38 billion bill is around a quarter of the total market capitalisation of China's five listed rare earth groups²⁶. What's worse is that Jiangxi province (where Ganzhou city is located) only has 8.6% of China's total rare earth quota. Clearly, the "commercial viability" of all these mining companies would be questionable if environmental costs were to be factored in. Prices for green and clean tech goods may well have to rise for rare earth production to be "green and clean". Tough decisions will have to be made in China.

HREEs extraction costs considerably less in China than abroad if compliance & tax costs are avoided

In a speech at the 2013 International Rare Earths Conference, Zhang Zhong, General Manager of Inner Mongolia Rare-Earth Hi-Tech (now named the China Northern Rare Earth (Group) High-Tech Co), estimated that extraction cost of HREEs abroad could be as high as RMB200,000 (~USD30,000) per tonne, far exceeding that of domestic mines²⁷. According to an interview with a rare earth processing company in Ganzhou, extraction costs of earths can be as low as RMB30,000 per tonne (~USD4,500)²⁸. This amount excludes the payment of various resource taxes, permits, third party services and other compliance costs. Clearly the disparity is large but if regulations are met and taxes paid, this disparity narrows. Therefore, if the global black market in rare earths persists, then it is likely that China's dominance of the industry will continue.



© Liu Hongqiao - Weeds growing over abandoned leaching ponds and PVC pipes in Zudong Mine site

Radioactive waste has turned communities around the Baiyan Obo tailings dam into “cancer villages”

But can China’s environment afford this dominant position? In Baotou, China’s “*Capital of Rare Earth*”, Baiyan Obo operates one of the largest tailings dam in the world. Radioactive toxic waste combined with non-permeation proof treated grounds has turned communities around the dam into “cancer villages”²⁹. The dam is still growing in size. It is a ticking time bomb that could spell disaster for the Yellow River that flows only 10 kilometres away. Any leakage of contaminated water, soil and dust could threaten drinking water safety and the health of millions of people who rely on the Yellow River watershed.

In the South, Ganzhou city is not only the “*Rare Earth Kingdom*”, but also the source of two important rivers:

- The Dongjiang River: one of the three tributaries of the Pearl River; its upper reaches flows through major rare earth mining counties in Ganzhou city; and
- The Ganjiang River: the seventh biggest tributary of the Yangtze River, also originates from the “Rare Earth Kingdom”.

Guangzhou, HK, Dongguan & Shenzhen at risk from water contamination from upstream rare earth activities

Both these rivers are important drinking water sources for millions of Chinese living downstream. The Dongjiang River supplies water to seven cities including Guangzhou, Shenzhen, Dongguan and Hong Kong. Reliance is high. Depending on rainfall, 70% to 80% of Hong Kong’s freshwater is supplied by the Dongjiang River. Elsewhere, the capital of Jiangxi province, Nanchang, sits on the Ganjiang River, while further downstream in the Yangtze River Delta is Shanghai. More on environmental hazards and costs in **Chapter 4: Rare Earth Kingdom’s cost to the environment**.

1.6 The price of global inaction comes at a high cost to Chinese waters

The turning point in China’s development when the nation seeks to walk “the path of economic growth and environmental protection” has come. Its push towards a “Beautiful China” is also happening at the same time as a domestic drive for clean and green energy development. Ambitious targets on developing renewable energy capacity and electronic cars can be translated into expanding domestic demand for rare earth metals (a semi-final good made from REEs).

The pressure to supply REEs to meet rising domestic demand is enormous, let alone satisfying the anticipated increase in global demand. As it stands China is not only the largest producer but since 2003, has also been the largest consumer of REEs globally. According to a State Council “White Paper”³⁰, China also manufactures over 70% of rare earth permanent magnet materials, luminescent materials, hydrogen storage materials, polishing materials and other end products for the world³¹.

Several fundamental questions arise – both for China and also the rest of the world:

- Does China have enough medium and heavy rare earth reserves and can it continue to meet rising domestic and global demand?
- Even if China has the reserves, should it increase production at the expense of its environment?
- Can China safeguard drinking water sources for its people while aggressively exploiting rare earth mines in upper watersheds?
- Who should pay for China’s environmental and social costs? Should this be just China’s cross to bear?

Chinese demand for clean and green development = expanding domestic rare earth demand

China is not just the largest supplier but also consumer of rare earths

The WTO-China rare earth dispute has dominated the news but thousands of tonnes of rare earths have been illegally mined

So far, the WTO-China rare earth dispute has dominated the news but there are many other untold stories. Thousands of tonnes of rare earths have been illegally mined, traded and trafficked out of China through the black market. When we happily drive our Prius or use our smartphones, there is a good chance that we are using products that contain illegally mined and trafficked rare earths. Rare earth trafficking activities are no different from that of drugs or wildlife products like ivory or rhinoceros horn.

The value of environmental crime is 26% more than previous estimates, at USD91-258 bn

The value of environmental crime is 26% more than previous estimates, at USD91–258 billion compared to USD70–213 billion in 2014, according to report by the United Nations Environment Programme (UNEP) and Interpol in June 2016 “The Rise of Environmental Crime”. The report links rare earths to environmental crimes under the “Illegal extraction and trade in minerals”, along with gold and diamonds. Impacts include: resource depletion as well as livelihoods and loss of raw material for local industry. We explore the impacts of the black market in **Chapter 3: The black market: an open dirty secret.**

How can large import countries like Japan and the US continue to turn a blind eye to rare earth trafficking? Surely end users like Apple, Xiaomi and Samsung should acknowledge their role in this toxic supply chain - after all their phones would not vibrate or the screens have vivid images without them?

Top global IT brands like Dell have promised to eliminate “conflict metals” from their supply chain, so then why do they continue to turn a blind eye to the issues of rare earths?

More questions than answers due to the many shades of grey in the rare earth market

There are more questions than answers due to the many shades of grey in the rare earth market. But the hidden “unseen” risks pose the greatest threat. China is on the case: water security comes first. The State Council is adamant it will get the rare earth market under control. China is also bent on its transition to a developed nation with its ‘Made In China 2025’ policy (list of ten forward looking industries that need rare earths) and by making certain resource intensive industries transition to a circular economy. It is also committed to meeting the targets set at COP21. In light of these shifts can the rest of the world afford not to pay closer attention? Read on.

CHAPTER 2: CHINA LOSES MARKET SHARE BUT STILL DOMINATES BY FAR

2.1 The “Chinese Era” of rare earths

China’s rare earth industry started to boom in the early 1990s...

China’s rare earth industry only started to boom in the early 1990s. During the famous “Southern Tour” in the spring of 1992, Chairman Deng Xiaoping, the “chief architect of China’s reform, opening up and modernization”, concluded that rare earth resources were unique to China and could be comparable with the crude oil resources in the Middle East.

The Middle East has crude oil, while China has rare earths.

Deng Xiaoping, 1992 “Southern Tour”

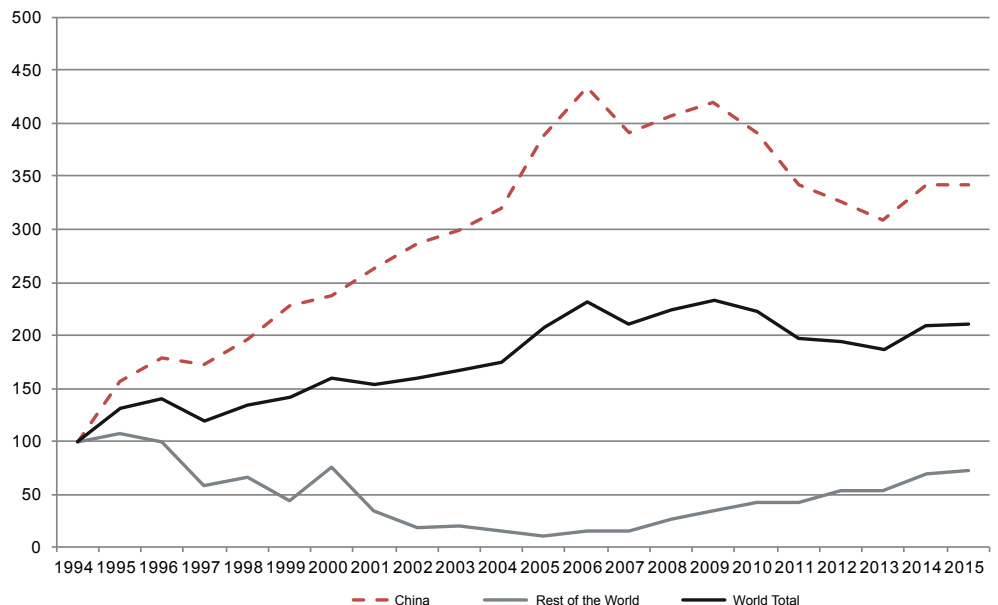
...by 1994 China produced half of global production; by 1999 it had an 86% market share

Since then, US dominance in the rare earth market exemplified by the “Mountain Pass Era” gave way to the “Chinese Era”. According to USGS, by 1994 China was already producing nearly half of global production with 30,700 tonnes. Since then, China’s share and absolute production has grown dramatically. It took China another five years to double its production; dominating global production with an impressive 86% market share by 1999. By then, the Mountain Pass mine in the US was closed due competition from China and rising environmental concerns in the US, including leaking pipes that spread contaminated wastewater from the processing factory³².

The chart below shows the growth in the global production. There is no doubt that China has powered the global rare earth market in the last two decades with the rest of the worlds’ supply picking up from 2010 after China cut its export quotas.

1994-2015 Rare Earth Production Growth: China vs Rest of the World

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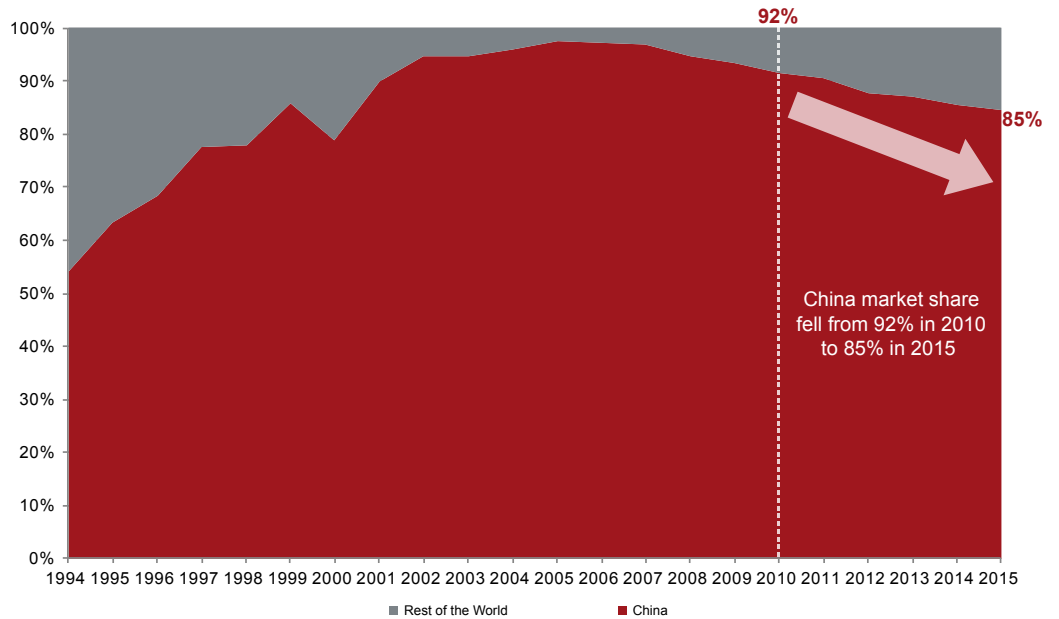
Sources: China Water Risk based on US Geological Survey (USGS) Rare Earths Statistics and Information

China has powered the global rare earth market in the last two decades

In 2010 China supplied 92% of the market with 120,000 tonnes - almost 3x the amount in 1994

In 2010, China supplied almost the entire global market and USGS data has China’s production at 120,000 tonnes – almost 3x the amount in 1994. Given its near 100% ownership of the global market at 92%, there was understandable widespread panic when China announced it would cut its export quotas. However, in the last five years, as other mines came on line, China’s market share in global rare earth production has fallen by around 7% – back to the 1999 level.

1994-2015 Rare Earth Production Growth: China vs Rest of the World



Sources: China Water Risk based on US Geological Survey (USGS) Rare Earths Statistics and Information

In 2015 China supplied 85% of the global market with 105,000 tonnes

Today it appears that the global rare earth industry is finally shifting away from the monopoly of a “Chinese Era” to a somewhat more diversified international market. That said, China remains the dominant player in the global market. In 2015, China still supplied 85% of the global rare earth market with an annual production of 105,000 tonnes.

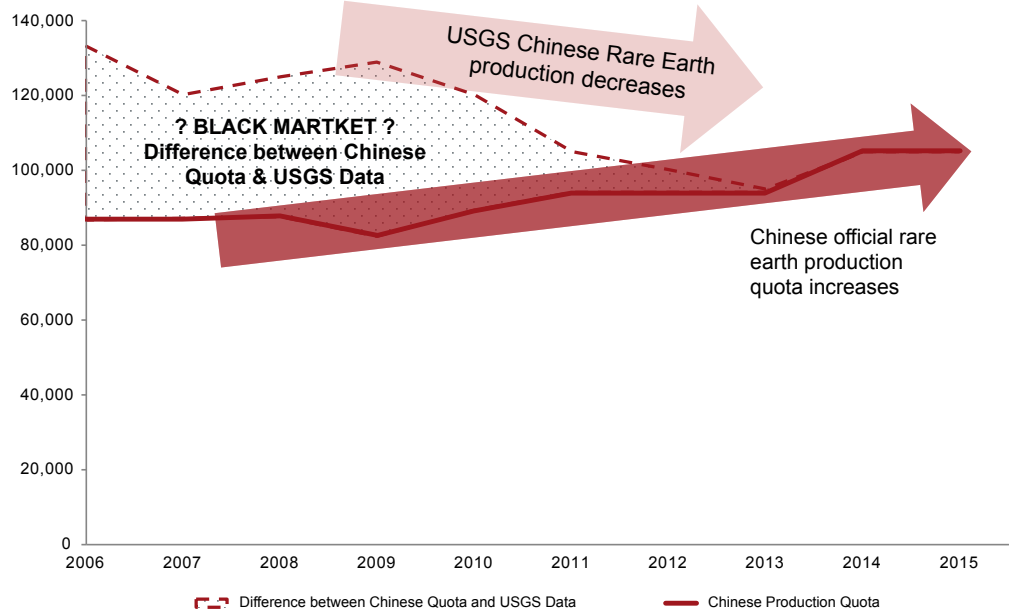
2.2 China & US numbers don't match! Grey matters & black market?

The trends above are based on USGS data but these do not match with the official Chinese production quotas. Historic production amounts recorded by the USGS are significantly higher than the maximum production allowed by the Chinese government. The surplus gap averaging +30% from 2006-2010, peaking at a difference of +36% in 2009, could be an indication of the size of the black market – refer to the chart below:

Is the surplus gap averaging +30% from 2006-2010 between USGS & China an indication of the black market?

2006-2015 Rare Earth Production: Chinese Quota vs USGS Data

Unit: tonne



Sources: China Water Risk based on US Geological Survey (USGS) Rare Earths Statistics and Information

Aside from the potential size of the black market, the other interesting point of note is that the USGS data has production of rare earths falling while according to China, the amount of official rare earth production quota is rising.

Gap between Chinese & US data closes in 2014...

Another interesting point is that the two lines meet in 2014, closing the gap. But this doesn't mean the black market vanished. One potential factor is the change in USGS methodology for reporting on China; previously it used estimates from leading Chinese rare earth companies but from 2014 onwards it changed to the production quota of the MLR. Still, this doesn't explain everything. Demand could have fallen or did the gap close because China has raised its production quota to meet the additional demand fed by the black market?

... but this doesn't mean the black market vanished

Still differences between data as China numbers are only production quotas not actual production...

Finally, it is worth noting here that the official China number is the production quota and not actual production. China's actual production remains a mystery, especially with illegal mining activities. China's official "production volume" is calculated by the authorities collecting data from legally operating companies. For example, in 2013, the actual extraction volume of rare earths was only 80,400 tonnes, which is less than the 93,800 tonnes production quota set by MLR. The actual smelting and separating volume that year was 83,300 tonnes – also less than the quota issued by MIIT³³. So despite the closing of the gap there is still a discrepancy between USGS data and China's actual production.

...actual production remains a mystery

Given this, it seems hardly correct to say that China's production is falling. Officially, Chinese rare earth production has technically grown not shrunk. Perhaps it is more correct to say that the black market supply of rare earths from China has shrunk; or has it? More on the black market in **Chapter 3: The black market: an open dirty secret.**

2.3 Current rare earth quotas – can they meet rising domestic & global demand?

The Chinese government has implemented three quota systems for the rare earth industry – the production quota issued by MLR since 2006, the smelting and separating quota issued by MIIT since 2010, and the export quota issued by Ministry of Commerce (MOFCOM), which can be traced back to the export licencing system in 2002³⁴. China eliminated the export quota in 2015 after the WTO ruled against it³⁵, but both the production quota and the smelting and separating quota remain.

China's production quota has risen y-o-y; whereas the export quota has fluctuated

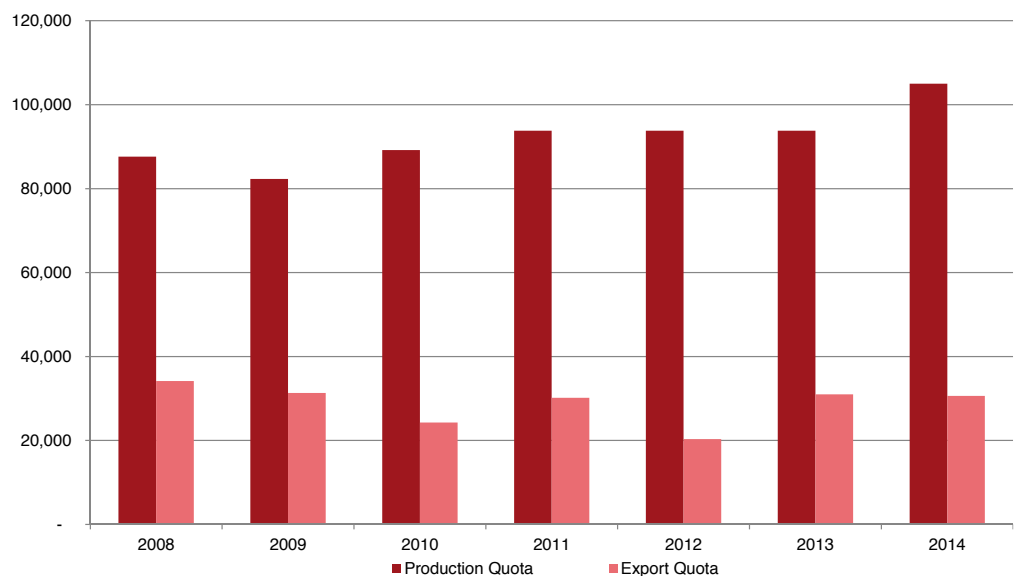
The below chart illustrates available Chinese data for production and export quotas since 2008. The production quota released has risen year-on-year whereas the export quota has fluctuated. Between 2008 and 2015, the production quota increased from 87,620 tonnes to 105,000 tonnes. With the production quota released in the first half of 2016 at 52,500 tonnes, the maximum production for 2016 looks set to be the same as that of the previous year.

China has cut export quotas since 2008 with big cuts in 2010 & 2012...

...by 2013 it raised the quota

2008-2014 Rare Earth Quotas in China: Production vs Export

Unit: tonne



Source: China Water Risk based on the annual production quota figures released by the Ministry of Land and Resources and export quota published by the Ministry of Commerce

As for exports, it is clear from the chart above that China has cut export quotas since 2008 with a dramatic cut in 2010 to 24,280 tonnes and the biggest cut in 2012 to 20,316 tonnes. However, by 2013 China had raised its export quotas back to over 30,000 tonnes.

Global demand for rare earths by 2020 will be around 200,000 - 240,000 tonnes

A key point to note here is that in 2008, China's official planned domestic consumption (production quota less export not taking into account stockpiling) was envisaged to be at least 61%. This grew to 71% or to 74,390 tonnes by 2014³⁶. The UNCTAD report on rare earths released in 2014, estimated that global demand for rare earths by 2020 will be around 200,000 – 240,000 tonnes. It also expects

Chinese demand for rare earths to reach 70% of the world's REEs demand by 2020

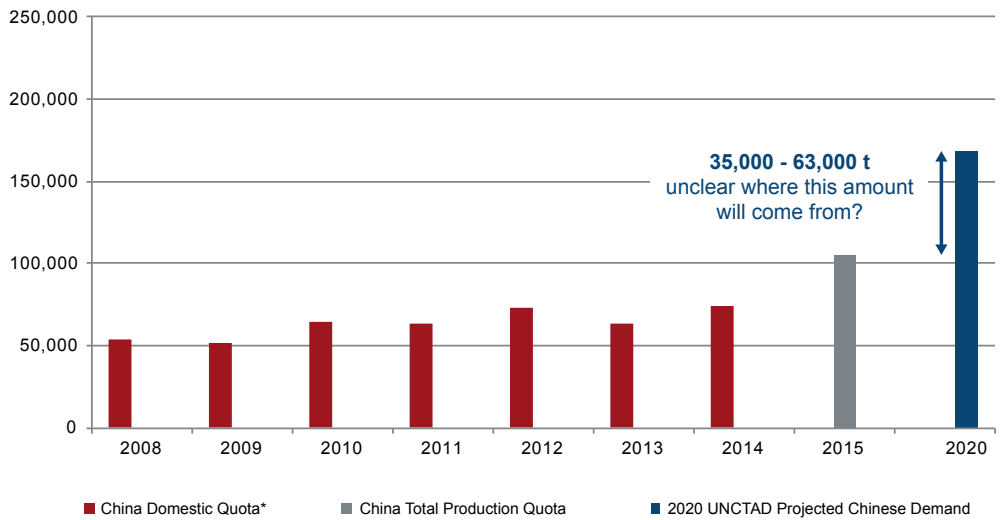
There is currently no mention that China intends to step up production

Chinese demand for rare earths to reach 70% of the world's demand by 2020. This translates to around 140,000 – 168,000 tonnes of China demand. There is currently no mention that China intends to step up production. With its official maximum production likely to stay flat at 105,000 in 2016, it remains unclear where the additional 35,000 – 63,000 tonnes will come from in the 13th Five Year Plan (13FYP) (2016-2020). What is clear is that if production remains flat, it will no longer be able to supply the rest of the world (more on the demand later).

If China's production remains flat it will no longer be able to supply the rest of the world

Potential Supply Gap For Future Chinese Domestic Rare Earth Demand

Unit: tonne



Sources: China Water Risk based on the annual production quota figures released by the Ministry of Land and Resources, export quota published by the Ministry of Commerce, UNCTAD
 *China Domestic Quota is calculated as the difference between its Production Quota & its Export Quota

Unclear who will supply the gap...

...less of an issue for the oversupplied LREEs but could prove difficult for the less supplied HREEs

Will China need this amount by 2020? Likely, as REEs application is widespread throughout the State Council's 'Made In China 2025' released in May 2015. The plan prioritizes 10 sectors in its transition towards a global manufacturing power including: new IT, robotics, energy savings & new energy vehicles, aerospace, high tech ships and others – clearly many with REE requirements. In light of these ambitious pursuits, if business continues as usual, China will likely use up its own supply of rare earths by 2020 and the rest of the world will have to secure its supply from somewhere else. This may not be an issue for the oversupplied light rare earths, but could prove difficult for the less supplied heavy rare earths.

2.4 Exposure to MHREEs has doubled over the last decade

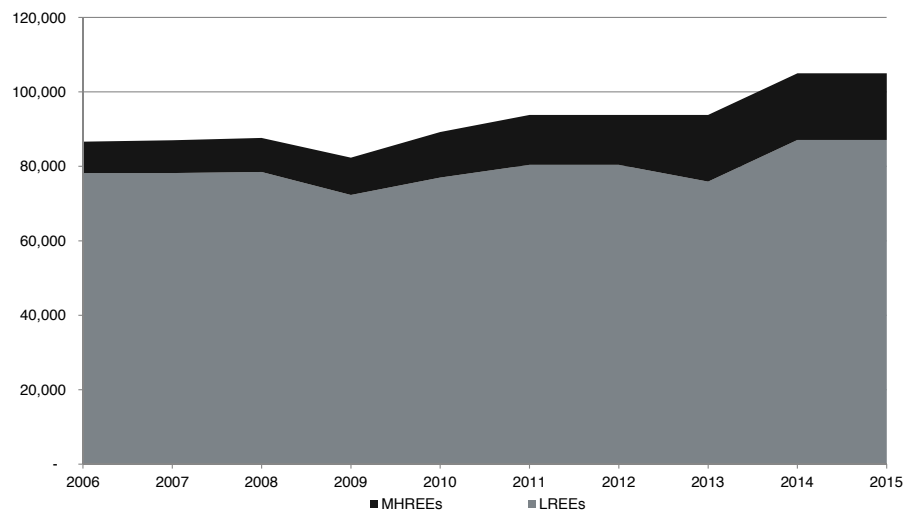
Chinese official statistics show that China has not unilaterally reduced the amount of rare earth supply, neither has China limited the production of MHREEs, which not only carry more strategic value but are also more scarce.

LREEs dominate China's production quota

The general trend of China's rare earth production quota has been increasing since 2006. LREEs dominate the production quota as clearly seen in the chart below.

2006-2015 Rare Earth Production Quota in China: LREE vs MHREE

Unit: tonne



Source: China Water Risk based on the annual production quota figures released by the Ministry of Land and Resources

China has not unilaterally reduced the amount of rare earth supply

It is worth noting here that LREEs dominance in rare earth production has masked the higher growth rates in the production of MHREEs.

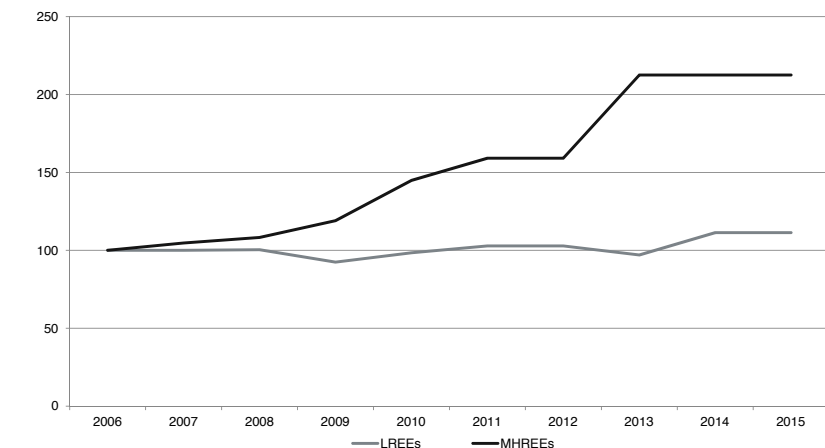
But LREEs quota increases are small

Over the past decade, mines in Inner Mongolia and Shandong representing 97% of China's LREE production quota, increased production quotas steadily, whereas the growth in production quotas of MHREEs mines in the South increased radically, more than doubling in the last decade as shown in the chart below. Incidentally, two provinces, Guangxi and Hunan, which have quotas of 2,500 tonnes and 2,000 tonnes respectively, switched out of LREEs and now use their quota to produce the more expensive MHREEs.

Guangxi and Hunan switched out of LREEs and now use their quota to produce the more expensive MHREEs...

2006-2015 Rare Earth Production Quota Growth in China: LREE vs MHREE

INDEXED TO 100



Source: China Water Risk based on the annual production quota figures released by the Ministry of Land and Resources

...MHREEs quota has more than doubled in the last decade

MHREEs account for 17% of China's 2015 production; up from <10% in 2006

So, although China's total rare earth production quota only grew by 21% between 2006 and 2015, the growth rate of MHREEs is more than 5 times higher at 113%. This meant that MHREEs that accounted for less than 10% of China's production back in 2006 are now 17% of production in 2015. Can China sustain this growth in MHREE production? Are there enough reserves?

2.5 Over-exploitation: MHREE reserves-to-production ratio down to 15 years?

China's reserves could be anywhere from 23% to 55% of global reserves

China allegedly has the largest rare earth reserves in the world. However, as discussed in **Chapter 1: China rare earths: the life-source of global clean & smart tech innovations**, China's contribution to the global supply of rare earths significantly exceeds its level of resource endowment. Moreover, the proportion China's reserves as a percentage share of global reserves is also subject to much dispute. Data from China's MLR in 2010 indicated that, China's rare earth reserves account for only 23% of global reserves. The USGS number was 37% in 2010 and 44% in 2015 but 48% in 2013. In 2012, the UNCTAD secretariat estimated China's share at 50%. Meanwhile a US Congressional Research Service report released in the same year considered China's rare earth reserves to account for 55% of the global total. Nevertheless, whether China's share of global reserves stands at 23% or 55%, it does not match its supply levels of over 85% for the same period.

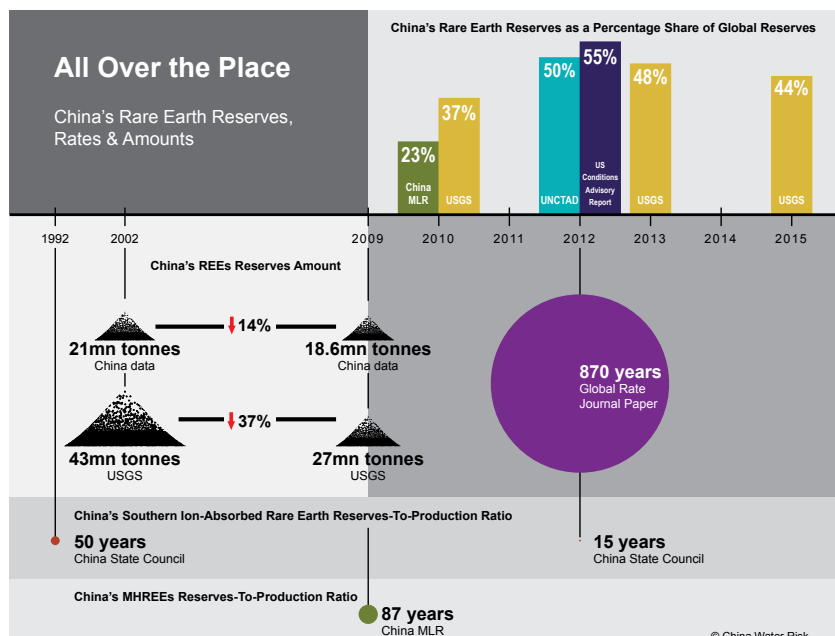
Reserves have shrunk rapidly...

Are there enough reserves to meet global demand? Thanks to the so-called "Chinese Era" in the global rare earth market, China's domestic rare earth reserves have shrunk rapidly. Although the amount of reserves available differ significantly depending on Chinese or US statistics, both sets of data show a downward trend. According to Chinese official data, from 2002 – 2009, China's rare earth reserves have fallen 14% from 21.5 million tonnes to 18.6 million tonnes. For the same period, the USGS has Chinese reserves falling even more drastically by 37% from 43 million tonnes to 27 million tonnes.

...China or US data, both sets show a downward trend

The reserves-to-production ratio of rare earth reserves is estimated to be approximately 870 years³⁷. But don't be lulled into a false sense of security as China appears to be running out of its precious MHREEs. The "Rare Earth Kingdom" is crumbling. According to the MLR the reserves-to-production ratio for MHREEs was only 87 years in 2009³⁸. Worse still, in 2012, the State Council warned that this ratio for the Southern ion-absorbed rare earth deposits has fallen dramatically from 50 years to 15 years in the last two decades³⁹.

State Council warns the reserves-to-production ratio of MHREEs in China down from 50 years to 15 years



Over-exploitation alarm bells should be sounding globally...

Over-exploitation alarm bells should be sounding globally across supply chains that rely on MHREEs, especially since most of them are almost 100% supplied by China. Yet, rare earth recycling is in its infancy and commercially viable alternative sources/sites are still not approved for mining (more on this later).

...Dysprosium (Dy) & Terbium (Tb) are produced only in China

2.6 Global MHREE demand - alternate supply?

MHREEs are clearly playing an increasingly bigger role in China. As one of the few countries capable of producing MHREEs on an industrial scale, China's dominance of the industry is likely to continue. According to EU data, China supplied 99% of the global heavy rare earth raw materials and 87% of the light rare earths from 2010 to 2012⁴⁰. So far, Dysprosium (Dy) and Terbium (Tb) are produced only in China⁴¹.

They are essential "additives" of high temperature permanent magnets

The growth of the MHREEs production quota is closely tied to increasing demand from high tech, clean energy and other green and smart industries. Among the rare earths, HREEs Dysprosium (Dy), Thorium (Tb), and Europium (Eu) are the main strategic elements. Dysprosium (Dy) and Terbium (Tb) are the indispensable "additives" of high temperature permanent magnets. Adding rare earth alloys also make permanent magnets more lightweight, which has applications for electric and hybrid cars, as well as wind turbines⁴².

The extraction of heavy rare earth minerals from hard rock is more difficult & costly

Although some overseas projects in processing heavy rare earth ores have shown promising potential, progress has been slow. In rare earth mines outside of China that have resumed production, such as the Mountain Pass Mine in the US, the extraction of heavy rare earth minerals from hard rock is more difficult and costly⁴³. In other words, it is very unlikely that alternate suppliers of heavy rare earth outside of China can be found in the near term.

Elsewhere, progress has been slow...

Greenland Mineral and Energy Ltd may be an exception. "With the world's largest JORC-compliant resource of REEs" at the Kvanefjeld Project in southern Greenland, the company is confident that it's "positioned to become the most cost-competitive critical rare earth producer for many decades"⁴⁴. Initiated in 2007, the project is set to produce products containing Praseodymium (Pr), Neodymium (Nd), Dysprosium (Dy) and Terbium (Tb), making it a potential alternate supplier for MHREEs outside of China. After eight years Greenland Mineral and Energy has finally completed feasibility studies factoring in environmental and social impact assessments. The company has completed its mining license application and is now waiting for approval from Greenland and Danish governments⁴⁵. The quota of the license was not disclosed but Kvanefjeld is known as one of the world's largest under developed rare earth mines so it could significant⁴⁶.

...except for Greenland Mineral & Energy Ltd is now waiting for approval for a mining license

Studies show rare earth demand will continue to grow. A study by Xie Feng Bin of China University of Geosciences predicted that by 2020, demand of Neodymium (Nd), Yttrium (Y), Dysprosium (Dy), Terbium (Tb), and Europium (Eu) will increase 3-fold, 2.4-fold 3.3-fold, 2.7-fold, 2.7-fold respectively, based on the consumption level in 2010⁴⁷. Another study in 2012 by Kirchain et al. from Massachusetts Institute of Technology predicted that by 2035, the demand driven by electric cars and wind turbines would lead to a 7-fold and 28-fold demand increase in Dysprosium (Dy) and Neodymium (Nd) respectively. These growth levels were calculated prior to the COP21 agreement, which mean demand may be even more than the previous estimate.

As part of the search for alternate sources Japan is looking to the deep sea. In 2010, Japanese researchers Kato et al. found that deep sea ocean mud in the eastern Southern Pacific Ocean and central Northern Pacific Ocean can contain significant amounts of HREEs and Yttrium (Y). The grade of HREEs they found in some mud is even higher than that of the “southern ion-absorbed ore” in China. Research by Hein et al. have also discovered abundant rare earth resources in seabed polymetallic nodules and cobalt-rich crust. According to USGS, deep sea rare earth reserves are more abundant than the overall land reserves detected so far.

China is also actively exploring deep sea rare earth resources, according to news from the MLR. However, neither country has yet published a roadmap on commercialising the exploitation. This may be due to the increased risks including political, economic and environmental. Furthermore, international laws on commercial developments in deep seas and on ocean beds are still being negotiated. All of this means the future of deep sea rare earth mining remains uncertain.

CHAPTER 3: THE BLACK MARKET: AN OPEN DIRTY SECRET

Rare earths smuggled out of China is a crime

There is a significant gap between official rare earth production quotas issued by the Chinese government and the production amounts reported by USGS. Part of this gap is assumed to be the rare earth black market, one of the many grey shades of rare earths.

...no different to the illegal drug trade

A black market supply chain means even more pollution; illegal miners do not bother with mine operation guidelines and related standards, especially environmental ones, no one holds them accountable. Moreover, black market producers use basic and primitive smelting as well as separation processes & technology, that cause more environmental damage as they are less efficient than new technologies. Toxic waste is discharged without treatment or supervision, directly into the surrounding environment.

Rare earths smuggled out of China travel far, reaching many international destinations. This is a crime; no different from the illegal drug trade or endangered animal trafficking. Yet, there is little action to combat this black market. With environmental, social, political and economic ramifications, we take a look at who suffers? Who benefits? Are companies aware they are using illegally mined rare earths? Finally we look at ways to make accountability and traceability stronger.



© Liu Hongqiao - When it rains untreated residual chemicals from abandoned leaching ponds flow into surface water in Ganzhou

3.1 Sizing China's rare earth black market

Despite being an open secret there is limited data on the rare earth black market

The rare earth black market is an open secret. Despite this, there is limited data on the scale of the market and its worth. Actually, not only is data limited but there are also significant disparities among available data, as well as comparative issues, making it even harder to size the black market.

One of the disparities is the 32,980 tonnes production gap between USGS and China's official data.

USGS reported a 15,000t decline in China's production from 2007- 2015...

According to USGS, global rare earth production in 2015 of 124,000 tonnes was the same as in 2007. For the same period USGS reported that rare earth production in China dropped by 15,000 tonnes. However, according to China's official data, during this period China's rare earth production quota actually increased by 17,980 tonnes. Hence the 32,980 tonnes gap.

... but at the same time, China reported a 17,980t increase

Whilst the black market is assumed to be a main cause of this gap, it can also be assumed to include domestic Chinese producers that are under reporting in order to pay less resource tax.

There are also comparative issues – actual production vs production quota...

It needs to be noted that regardless of the gap above, there are still comparative issues. The only consistent official Chinese data available is the MLR's production quota, emphasis on the word "quota". This number is not the actual amount of rare earth China produced but the maximum amount it can produce. China's actual production amount (whilst assumed lower than the official quota) remains a mystery. This means that with production lower than the official quota, what appears to be a closing in the USGS- China data gap in 2013 (as shown in **Chapter 2: China loses market share but still dominates by far**) isn't actually that. There is still a gap.

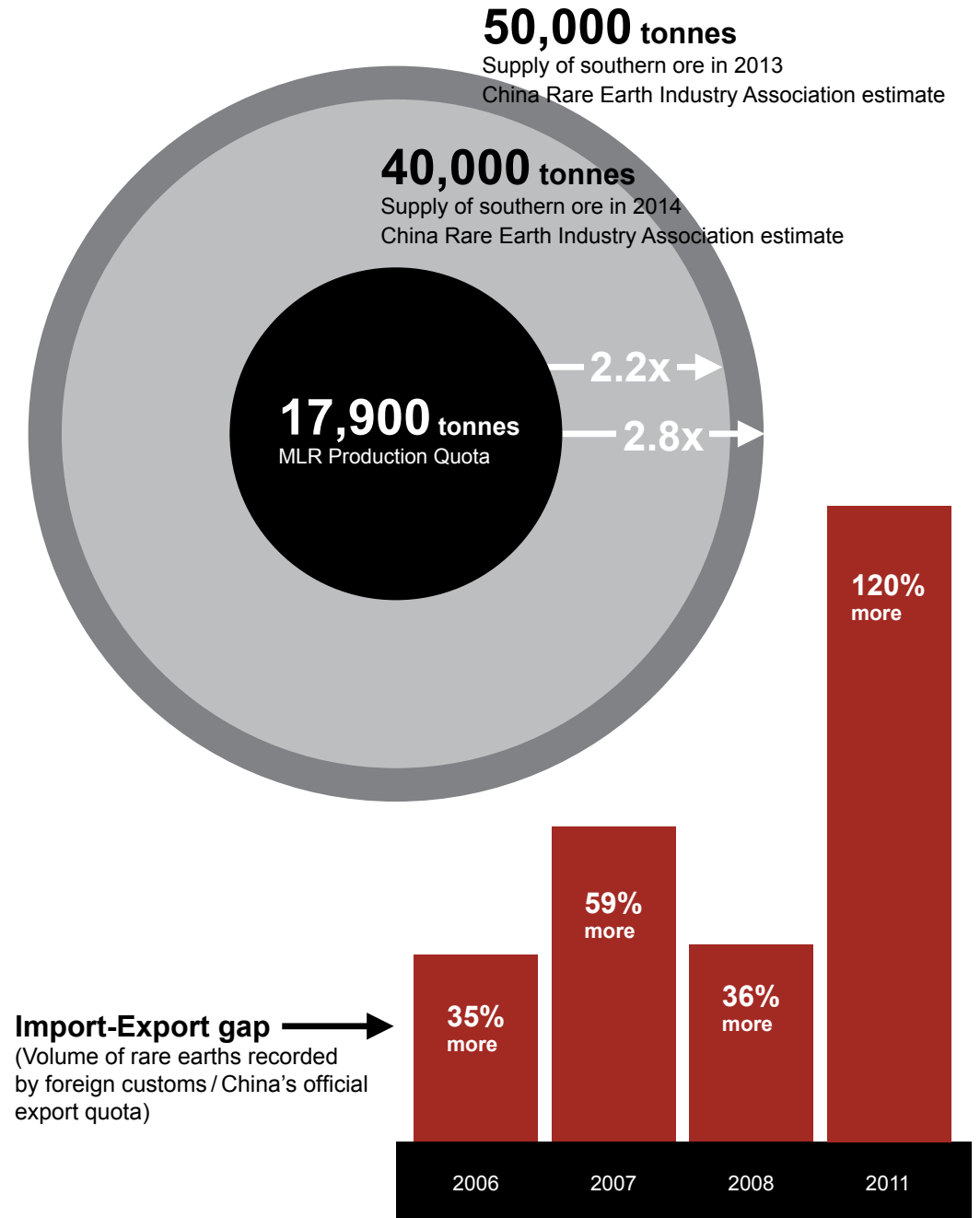
...MHREEs black market is even worse: estimated supply is 2.2-2.8x the quota

The black market situation for China's "Southern ore" (ion-absorbed rare earths), essentially MHREEs, is even worse. The China Rare Earth Industry Association estimates that in 2013 and 2014, the actual supply of southern ore was more than 50,000 and 40,000 tonnes respectively⁴⁸. The MLR production quota was only 17,900 tonnes: indicating a potential 2.2-2.8 times larger market than the legal one. Conflicting data doesn't end there.

Foreign customs data & China export volumes don't match

Another way to gauge the size of the black market is by comparing countries' import data with that of Chinese customs. According to China's State Council 2012 "White Paper", the volumes of rare earth products imported from China as collected from foreign customs were 35%, 59% and 36% higher than the official volumes exported in 2006, 2007 and 2008, respectively. This import-export gap peaks at 120% in 2011⁴⁹.

The Black Market



Sources: China Water Risk based on Chen Zhanheng, et. al., December 31, 2014, Situation and Policies of China's Rare Earth Industry by the Information Office of the State Council, June 2012 ("White Paper")

3.2 China's crackdown on illegal mining & trafficking

China began its crackdown in mid-2010

In mid-2010 China began its crackdown on its rare earth industry and the black market. The impact from the rare earth industry had reached a tipping point; it was time to take action. A five-month campaign by the MLR began to clean-up unlicensed mining of rare earths. *"The target of our crackdown was illegal mining and excessive mining above given quotas"*, said Jin Yuzhong a MLR mining admin official⁵⁰.

Various other crackdown campaigns ensued...

Then in February 2011, China's State Council announced it would strengthen oversight of the industry. Various other crackdown campaigns and standards followed.

In May 2011 the State Council said the industry was "disorderly" & that there had been "rampant trafficking activities"

The biggest blow to the black market came in May 2011, in the form of the Chinese government's most stringent rare earth policy "State Council Opinions on Promoting the Sustainable and Health Development of Rare Earth Industry". According to the document, the rare earth industry was "disorderly", adding there had been "ecological & environmental deterioration" and "blind expansion and rampant trafficking activities". Six months later, MIIT, MLR, Ministry of Environmental Protection (MEP) and the General Administration of Customs launched a joint crackdown on the industry and illegal trafficking.

The crackdown resulted in various seizures & arrests...

The crackdown has resulted in various seizures and arrests. Some of these seizures were in major production areas of Baotou in Inner Mongolia and Ganzhou – more details in the graphic on the next page. In most cases the rare earths had been mixed with other minerals or raw materials and only the other minerals had been declared to customs.

Lax industry regulations were also addressed with special campaigns. According to the State Council "White Paper" released in 2012: more than 600 cases of illegal prospecting and mining were investigated and rectified, more than 100 cases were placed on file for further action, and 13 mines and 76 smelting and separation enterprises were ordered to cease production for rectification⁵¹.

The crackdown isn't over. In August 2015, MIIT announced it would ratchet up efforts to stop illegal production and sales of rare earths⁵². And in December 2015, China announced it plans to set-up a certification system⁵³.

Given China is the dominant rare earth producer it is safe to assume that it is also the largest producer of illegally mined rare earths. Countries like Japan, the US, EU, South Korea and Vietnam benefit from this black market⁵⁴. China cannot fight this black market alone; beneficiary countries and companies must play a role. Are they acting?

CRACKDOWN

Illegal Rare Earths Seizure Cases

August 2012

Baotou

Customs seized over 130 tonnes of rare earths

After a one year investigation, the Anti-Trafficking Office of Baotou Customs seized 130 tonnes of trafficked rare earths, with an estimated total value (including tariffs) of RMB14 million. The case was the first of its kind, in that the seizure was at the origin of the trafficked goods and not further along the supply chain; commonly seizures happen at harbour cities like Shenzhen where they are to be transported further. According to intelligence information, a private rare earths material company in Baotou was suspected of trafficking rare earths via Nanning city (the capital of Guangxi province), Pingxiang and Dongxing city (China-Vietnam border trade areas), to KAD, a Vietnamese border trade company. A total of 6 batches were sold (without VAT) to KAD, totalling 130 tonnes of rare earth products - including 20 tonnes of cerium carbonate and over 110 tonnes of lanthanum-cerium mixture rare earth metals. An investigation revealed that KAD and the traffickers communicated online, with no paper contracts and transferred money through illegal private bank transfers. Five suspects were arrested in the seizure.

March 2010

Nanning

Customs arrest 9 people for trafficking 4,196 tonnes of illegal rare earth metals abroad

Nine people were arrested for trafficking 4,196 tonnes of high purity rare earth metals and oxides in 69 batches via containers. The nine came from Shanghai, Chengdu, Nanning, Fangchenggang and Wuzhou city. The group used a company, Nanning Aotian Company, as a cover to send the illegal rare earth products abroad. Details showed that the company hired three customs clearance agent companies to fake documentation that described the illegal rare earths as diatomaceous earth, aluminium sulphate, hot briquetted iron or glass forming agent - depending on the appearance and weight of the shipment. The total value of seizures was around RMB109 million with an extra RMB13 million in tax evasion.

August 2014

Qingdao

Customs seize one tonne of rare earths destined for South Korea

The Weihai Customs branch of Qingdao Customs seized a shipment of ferromolybdenum destined for Incheon in South Korea. The total value of the goods involved in the case was estimated over RMB 110 million, with extra RMB15 million in export tariffs. The trafficking group is suspected to have smuggled over 1,500 tonnes of rare earths, ferromolybdenum and ferrotungsten. In the single seizure in early August 2014, the Weihai Customs seized 1 tonne rare earth and 5 tonnes ferromolybdenum in a container that originated from Yiwu city in Zhejiang Province. Reports said the trafficking group was led by a Korean national and involved a Chinese import and export corporation in Yiwu city, which provided faked document to cover the illegal goods.

Early 2015

Shenzhen

Customs, Guangdong Public Security Bureau & others seized 61.5 tonnes of rare earths

An anti-trafficking taskforce, named "ZY01", successfully cracked down on four large criminal groups. The crackdown resulted in 21 arrests and the seizure of 61.5 tonnes of rare earth products and other mineral resources. The total value of the seizure was estimated at nearly RMB100 million.

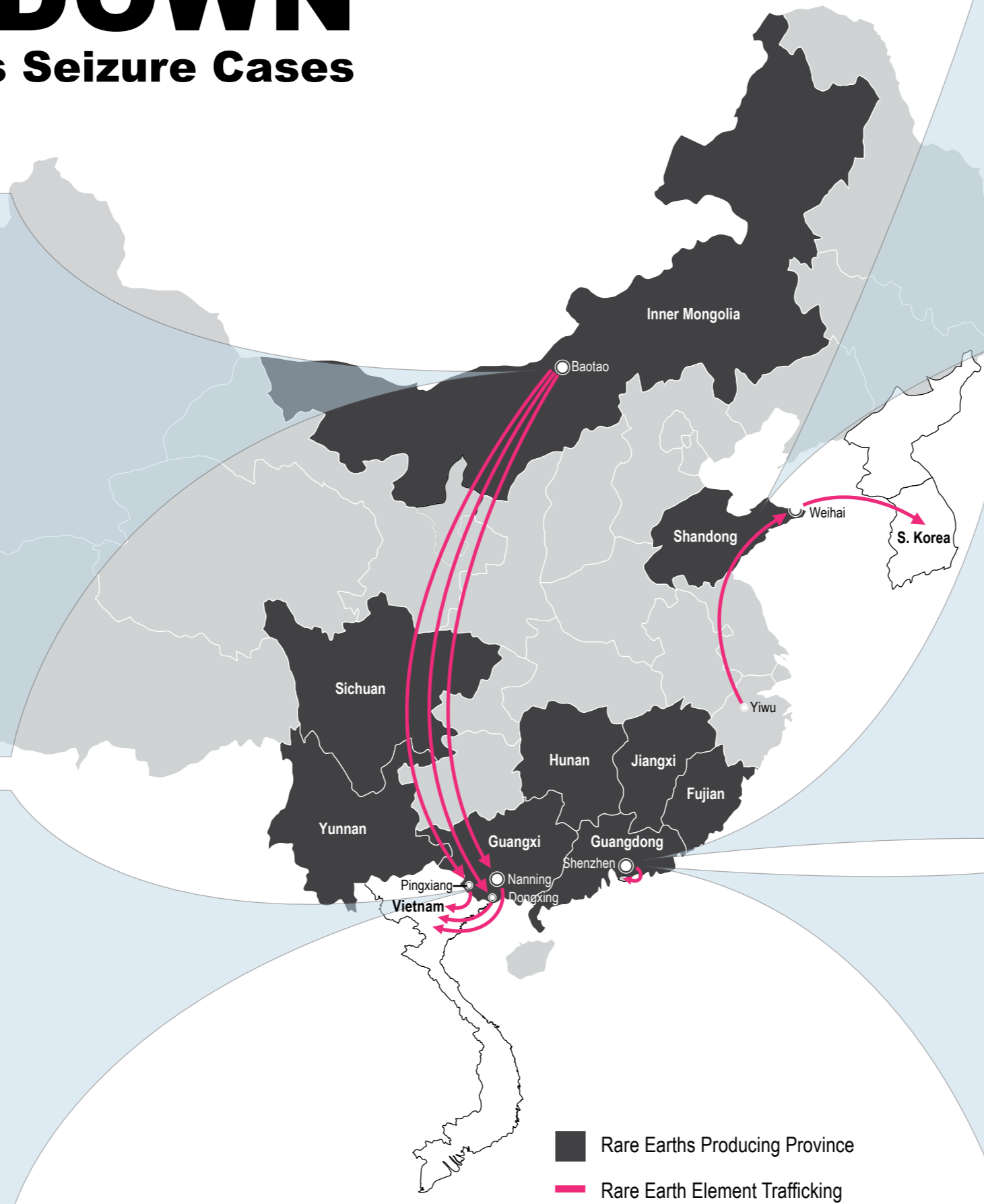
The anti-trafficking taskforce was made up by many organisations including: Shenzhen Customs and Guangdong Public Security Bureau, as well as local anti-trafficking offices in Xiamen, Gongbei & Huangpu city as well as major rare earth mining and separating centres like Nanchang city (provincial capital of Ganzhou city, the "Rare Earth Kingdom" and Hohhot city - a 2 hour drive to the "Capital of Rare Earth" Baotou city),

August 2014

Shenzhen

Customs seize first individual traveller trafficking case

Shenzhen's Huanggang Customs seized a small car at a checkpoint on the Shenzhen-Hong Kong boarder after finding that it was transporting four barrels of silver objects. Upon closer inspection, 210 kilogrammes of Neodymium alloy (made from the rare earth Neodymium - Nd) were found among the barrels. This is the first seizure by Shenzhen Customs in which it was just an individual trafficker.



Source: General Administration of Customs of China, Guangdong Coastal and Anti-Smuggling Office, Qingdao Customs District of China, Shenzhen custom conduct "ZY" crackdown actions against rare earth smuggling, General Administration of Customs of China, January 26, 2015, Huanggang custom crack the first traveller smuggling case on rare earth, Guangdong Coastal and Anti-Smuggling Office, August 6, 2014, Qingdao Customs Crackdown a Big Case On Rare Earth Smuggling, Qingdao Customs District of China, May 8 2015, Xinhua News Agency, Legal Daily, General Administration of Customs of China, Original Source Appeared Astonishing Rare Earth Smuggling Case, Economic Information Daily of Xinhua News Agency, December 9, 2013, Rare earth "experts" apply all means to smuggle rare earth, Legal Daily, July 16, 2010

3.3 Global authorities & countries fail to address illicit trade & punish beneficiaries

Like other black markets, the rare earth black market is driven by demand...

Like other black markets, the rare earth black market is driven by demand. However, it receives less attention and when discussed, it tends to become 'stuck' due to issues of natural resources rights and trade disputes. Transnational trafficking activities of rare earth have neither gained action from WTO, nor are regulated by the United Nations Office on Drugs and Crime (UNODC).

...however, it receives less attention as it is not a commodity nor is it used or traded in relatively large volumes

Three aspects of rare earths drive this failure to act. First, rare earths are not a commodity. This means they are not regulated globally. Second, relatively small amounts of rare earths are used in the production of smartphones, tablets and then larger amounts in electronic cars (around 30 kg in a Toyota Prius⁵⁵) and wind turbines (171kg per MW of installed capacity⁵⁶) but these are still much smaller than compared to amount of coal used to create energy. As described in Chapter 1 the rare earth industry is often called the "vitamins of industry", one only needs a small amount to have a big impact. Since only small amounts are required, small amounts can be trafficked, making it hard to detect. Lastly, the nascent nature of environmental crime does not help. Although environmental crimes are gaining attention globally, but clearly global governance structures to deal with such still lag those of traditional cross-border crimes like arms or drug trafficking.

The rare earth black market shares similarities to the wildlife black market...

The rare earth black market shares many similarities to the illicit wildlife trade. In China, the source country, dealers collect rare earths from illegal mines and sell them to middlemen, who take care of transport, fake licenses and other aspects. After arriving at the destination, middlemen transfer and resell the rare earth products – ores, elements or concentrates.

...yet, it is overlooked

Corruption is rampant throughout the process. But unlike the "global war" on ivory or rhino horn, there is no war on the rare earth black market, which is overlooked. Even with the war on ivory, only around 10% of illegal ivory is seized, according to the International Criminal Police Organization. With little or no attention, the rare earth black market will likely continue and could proliferate as demand continues to rise.

Trafficking of mineral goods like rare earths is excluded from the UNODC's watch list...

In 2013 the UNODC published a threat assessment, "*Transnational Organized Crime in East Asia and the Pacific*", which identified four categories of cross-border organised crimes: 1) human trafficking & illegal trafficking, 2) illicit drugs & crime, 3) pollution of resources, and 4) goods trafficking⁵⁷. However, the trafficking of mineral goods like rare earths is excluded from the UNODC's watch list.

...yet, "Conflict minerals" from the Congo Basin, however, are monitored by United Nations Security Council

"Conflict minerals" from the Congo Basin, however, are monitored by the United Nations Security Council and leading IT brands such as Intel, Apple and others have signed the Commitment to Conflict-Free Minerals. Why the discrepancies?

The UNODC concludes in its assessment of resource-related crime, "*the threat goes beyond borders, jeopardizing the world's environmental heritage. These are therefore crimes of inherent international significance, though they are frequently dealt with lightly under local legislation*"⁵⁸.

"Illegal extraction and trade in minerals" is an environmental crime according to UNEP & Interpol

Finally, in June 2016, the UNEP and Interpol released a report identifying trafficking in illegal rare earths as environmental crime. Rare earths are mentioned under the "Illegal extraction and trade in minerals", along with gold and diamonds. Impacts include: resource depletion, livelihoods challenges and loss of raw material for local industry⁵⁹.

Is this a case of double standards?

What's ironic is China, often framed as the "resource predator", is blamed for "neo-colonialism" in Africa or Latin America; whereas the rest of the world's exploitation of China's resources is under-reported. Is this a case of double standards? A more balanced perspective should examine not only China's resources inflow but also the outflow as well as supply chain practices of multinationals.

The "extra supply" from the black market has contributed to "cabbage prices"

3.4 Low prices & high environmental damage feed the black market

For decades, rare earths from the black market have flooded the manufacturing industry. This "extra supply" has contributed to low prices. During the WTO dispute, Chinese officials argued that rare earths are severely under-priced, being sold at "cabbage prices".

Illegally mined rare earths are 60-70% cheaper...

As illegally mined rare earths do not fall under any monitoring system, they avoid resource tax, mineral resource compensation fee, Value Added Tax (VAT) and other expenses, making them much cheaper than those mined legally.

Since June 1 2012, all REOs and separated products are required to have a verification invoice for VAT purposes⁶⁰. This is a way to reflect actual costs that would boost low prices and fight the black market. According to China's Rare Earth Industry Association one tonne of illegally mined ores generally costs RMB100,000, whilst market prices per tonne in Ganzhou as of September 2014 ranges from RMB160,000 to RMB170,000⁶¹ - around 60% to 70% more expensive than the illegal ores.

Industry groups like the China Rare Earth Association have been advocating for an increase in China's production quota. They argue that the illegal mining activities are driven by the imbalance between demand and supply; demand is greater than supply. By increasing the legal production quota there would be less need for rare earths from the black market. However, these views often fail to mention any environmental considerations relative to an increased quota.

Perhaps more relevant than simply increasing quotas would be improving the traceability of rare earths? Surely improved transparency would make it harder for the black market to operate?

Illegal mining & the black market mean long-term woes for China

Illegal mining and the black market mean long-term woes for the country. China is not financially compensated for its strategic rare earth resources, as they are sold at such low prices. Worse still, the health of its population is at stake and the environment suffers. We take a closer look these in the next **Chapter 4: Rare Earth Kingdom's cost to the environment.**

CHAPTER 4: RARE EARTH KINGDOM'S COST TO THE ENVIRONMENT

China tried to reduce exports of rare earths but failed

In 2012, amid the WTO-China rare earth dispute, the Chinese government stressed it had the right to implement a protection policy for its “*exhaustible natural resource*”, which should fall under the WTO exception for the conservation of such resources. However, in 2014 the WTO ruled against China, arguing that the export quota system was a way to control the rare earth market and protect China's domestic industry.

The dispute has since subsided and as shown in **Chapter 2: China loses market share but still dominates by far**, China is continuing to develop its rare earth industry for both domestic and international markets. The Chinese government in May 2015, based on the WTO ruling, cancelled its rare earth export quotas, tariffs and other additional taxes.

It remains unclear who should pay for environmental damage caused

Despite the WTO ruling, many questions remain unanswered: Who should bear the costs of environmental damage caused by rare earth mining? Should companies that use and profit from China's rare earths not bear some of the cost? Should they not be held accountable for irresponsible behaviour? If the license and quota system cannot be applied to manage extraction, processing and export, then what kind of policies and systems should be used?

Since mid-2010 China has been cracking down on the industry, in particular the black market. Nationwide month-long campaigns and inspections have been undertaken, with new and more stringent industry standards introduced. In May 2011, the Chinese government released its most stringent rare earth industry standard, the State Council's “Opinions on Promoting the Sustainable and Health Development of Rare Earth Industry”. The crackdown continued into 2015 with the MIIT announcing its ratcheting up efforts to clamp down on illegal activities⁶².

New standard & new direction set for industry in 2011

Another big change to the rare earth industry came in May 2011, when the State Council announced the industry will follow a new development pattern, which included consolidation⁶³. In January 2014, the State Council approved the detailed implementation plan for core mining and separating capacities in China. This meant the industry would be consolidated into six State-Owned Enterprises (SOEs)⁶⁴. China has and continues to take action but there are still decisions for it to make. As discussed in Chapter 2, it is not clear if China can cater to its growing domestic demand, let alone satisfy rising global demand. Given environmental damage already suffered, should China pull back on its production to allow the environment to recuperate?

The rare earth industry consolidated into 6 SOEs, but questions remain for China

For a closer look,
we explored local
issues in Ganzhou city,
the "Rare Earth Kingdom"

To gain a deeper insight into what's really happening with rare earths in China, we dive into local issues in the "Rare Earth Kingdom", Ganzhou city, in Jiangxi province.

Ganzhou was officially named the "Rare Earth Kingdom" by the Chinese government in 2012⁶⁵. The city located in southern Jiangxi province, is the discovery site of the southern ion-absorbed rare earth ore and the birthplace of ion-absorbed mining technology (which makes HREE extraction commercially viable). Ganzhou city alone contributed 45% of China's MHREE production quota in 2015⁶⁶ and is the centre of rare earth smelting, separating, refining, alloy and permanent magnet manufacturing in Southern China⁶⁷.



© Liu Hongqiao - An abandoned rare earth factory in Zudong mine site in Ganzhou

4.1 Ganzhou: A kingdom in decay & rehabilitation

The best & the worst practices can be found in Ganzhou

Ganzhou is home to the largest rare earth production base and comprehensive utilisation base of the province; NdFeB magnets, light and ceramic materials production capacity account for 20%, 40% and 50% respectively of the national total⁶⁸. The city also houses 70% of national in comprehensive rare earth waste treatment capacity⁶⁹.

Both the dark and light side of the Chinese rare earth industry are evident in Ganzhou.

There are large mining restoration projects...

Here are several large mining restoration projects. According to MIIT, central government funds supporting the mine restoration projects in Ganzhou has exceeded more than RMB1 billion over the past three years⁷⁰. This is a drop in the bucket compared to a conservative estimate by MIIT in 2012 that stated total remediation funds will reach RMB38 billion.

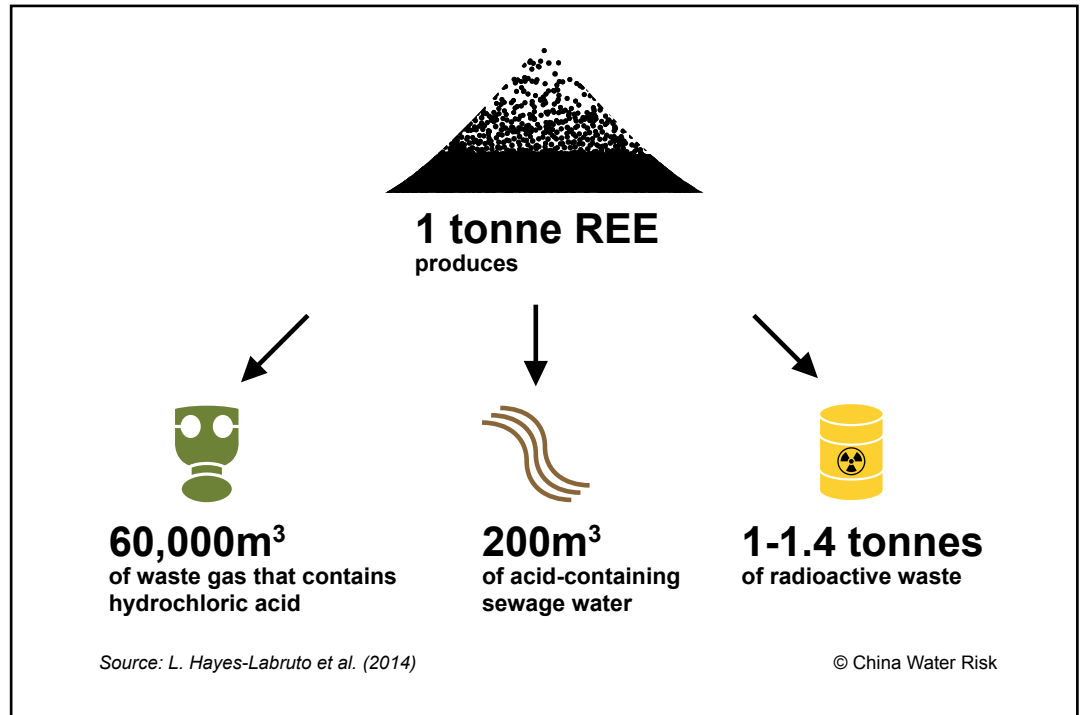
...but also 302 abandoned mines, 191mt of tailings & 97.34km² of destroyed land

China Environmental News reported in April 2012 that a multi-ministry team investigation into rare earth mining in Ganzhou revealed that the number of abandoned rare earth mines had reached 302 with accumulated tailings (waste soil) amounting to 191 million tonnes, and 97.34 km² of destroyed land. The report added that the processing of the 190 million tonnes of tailings would take 70 years⁷¹.

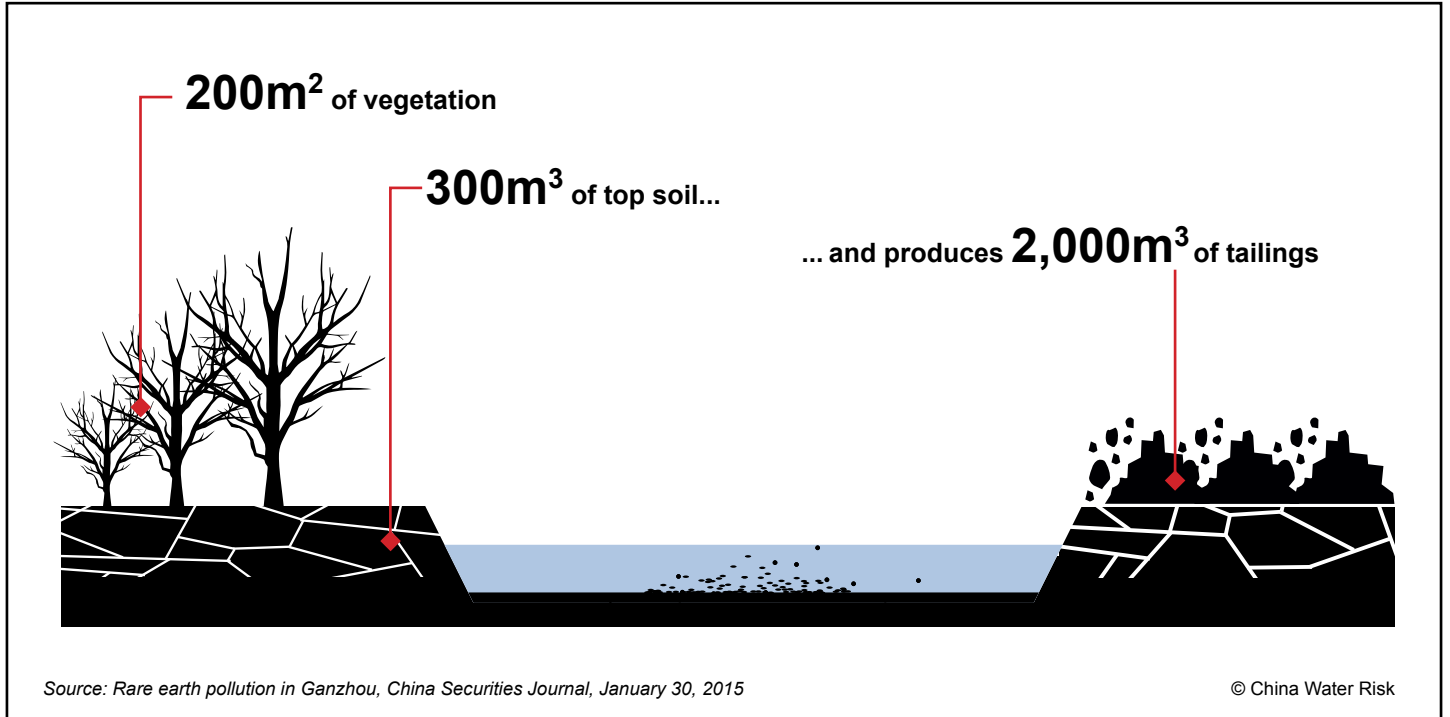
Rare earth production & processing comes with toxic waste

As reported by L. Hayes-Labruto et al. (2014), to produce one tonne of REE can produce 60,000m³ of waste gas that contains hydrochloric acid, 200m³ of acid-containing sewage water, and 1-1.4 tonnes of radioactive waste⁷². In addition to water pollution, rare earth extraction, separation and refining consume significant quantities of water, acidic substances and electricity.

Rare Earth Production Comes With Toxic Waste



Pond Leaching for 1 Tonne of REOs Destroys



4.2 Rare earth's pollution legacy: lax standards & late regulation

Many mines in secluded hills make monitoring difficult

Visit Ganzhou and you can see why it is difficult to monitor mining sites. Mines are located in secluded mountain areas with dense forest. The scattered nature of these numerous mines makes environmental supervision difficult.

Longnan County, once a land of beauty, is now bare

Tailings (waste soil) mainly result from the “pond leaching” process of surface mining, the stage where rare earth ions are processed. Research shows that using the pond leaching process to produce one tonne of Rare Earth Ores (REOs) destroys 200 m² of surface-vegetation require 300m³ of top soil to be dug-up and ultimately results in 2,000m³ of tailings⁷³. In Longnan County, for example, 17.7 km² of forest has been destroyed by rare earth mining, accounting for 20% of the county's total deforestation⁷⁴. Once a land of beauty, the area is now bare, trees are sparse and soil lies exposed.

Pond leaching for 1 tonne of REOs destroys 200m² of vegetation & 300m³ of top soil...

... and produces 2,000m³ of tailings

RARE EARTH MINING PROCESSES: “MOVING MOUNTAINS” & IN-SITU LEACHING

Historically, the initial rare earth mining method used in Ganzhou was heap leaching, which was then followed by pond leaching. These two methods are commonly known as “moving mountains”, as they entail digging up and removing topsoil. The soil is then transported to the heap/pond where it is usually soaked with ammonium bicarbonate, oxalic acid or other chemicals to extract rare earth concentrates. The rare earth recovery rate using these methods is less than 50%.

In 1996 “in-situ leaching” technology was introduced to Ganzhou and is now the dominant mining method in all southern provinces.

In-situ leaching entails liquid injections into wells perpendicular to the mines of ammonium sulphate, ammonium chloride or other displacer chemicals. Then, when fresh water is injected to the wells, rare earth ions react with the ammonia chemicals and separate from the ores, then, they ultimately flow out through drains into ponds. Further extraction of REE concentrates occurs in various ponds with additional chemicals.

Compared with heap leaching and pond leaching, the in-situ leaching method requires far less soil excavation, fewer tailings and is less labour intensive. It was endorsed by various ministries for its improved efficiency and recovery rate. However, in-situ leaching is still polluting.

Although practiced since 1996, in-situ leaching technical standard was only introduced in 2016.

Source: Gao Zhiqiang, et. al., Chinese Journal of Ecology, 2011, 30(12):2915-2922

Although practiced since 1996, in-situ leaching safety production standard was only introduced in 2016

The National Standard Administration of China (NSA), the State Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) and MIIT only started to formulate technical specifications and safety production specifications for “in-situ leaching mining process” in 2014. Accordingly, two standards were made available for public consultation: “*The National Standard On Ion-Absorbed Rare Earth Ore In-Situ Leaching Mining Technology*” and “*The National Standard On Rare Earth Products Packaging, Trademark, Transportation and Storage*” on 20 October 2014. Separately, drafting of a safety production standard was also undertaken. This means that in-situ leaching practices in ion-absorbed rare earth mining have been conducted for almost two decades without industry specific national standards.

Finally, in March 2016, MIIT approved the safety production standard: “*Ion-absorbed Rare Earth Ore Safety Production Specification for In-Situ Leaching Mining (XB/T 904-2016)*”. Whilst positive, it is around twenty years late. However, as of 16 June 2016, the other two standards (technical and packaging) are yet to be approved.

Some could also call the “*Soil Pollution Control and Prevention Action Plan*” (“Soil Ten Plan”), released by China’s State Council on 1 June 2016⁷⁵, late, but soil pollution is complicated. The “Soil Ten Plan” is the third prong of China’s war against pollution, the “Air Ten Plan” came out in late 2013 and the “Water Ten Plan” in April 2015. China is planning its development comprehensively now, giving equal weight to the economy and the environment - economy & environment, no longer economy then the environment.

The Soil Ten Plan will impact the rare earth industry

Rare earths will be impacted by the Soil Ten Plan as it details special supervision of eight industries, which includes non-ferrous metal extraction & processing and non-ferrous metal smelting. In China, rare earths are categorised under non-ferrous metals⁷⁶. More on the specific impacts in **Chapter 5: Global action needed to remove the grey from our clean & smart future.**

Industrial accidents lead to water contamination...

Beyond regular pollution from rare earth mining & processing, there is additional damage from industrial accidents. In mid-April 2015, the Longnan Environmental Protection Administration (EPA) reported that a rare earth mining operation located in Lintang, Ganzhou, had been illegally using and managing abandoned ponds. A pond burst, which resulted in acid leaching into surrounding soil and water. The operator did not take effective emergency measures and the acid infiltrated downstream water sources, where 4,000 fish died⁷⁷.

...4,000 fish died in one case

Data collected show indicator levels at >200x & 300x China’s Drinking Water Standard

Water contamination around mine sites can be significant. Data collected from environmental monitoring showed that ammonia nitrogen and total nitrogen levels in surface water at Zudong Mine, the single largest ion-absorption rare earth mine in China, failed to meet China’s Grade III Surface Water Standard, which means the water is not suitable as a drinking water source. Moreover, in the Wojiang River in the Lintang basin, for the same indicators, levels were 295 and 358 times higher respectively than the maximum allowed amount for Grade III of the standard. And in the Lianjiang River Guanxi Basin, levels exceeded the Grade III standard by 209 and 244 times respectively⁷⁸.

Such pollution doesn’t disappear over time

Such pollution doesn’t simply disappear over time. Downstream from the Zudong Mine, which was using the more advanced “in-situ leaching” process, the average ammonia nitrogen level of surface water was still 50 times over the standard. Even after decades of rainfall and erosion, the level of ammonia nitrogen was 20 times above standard⁷⁹. This means that despite the best mining methods employed, abandoned mine sites are still polluting surface water.

Groundwater at mine sites usually do not meet standards

Groundwater pollution is even more complicated. Groundwater quality at mine sites and surrounding areas is far from Grade III (the lowest standard for drinking water sources) of the “Ground Water Quality Standard”. In some parts of the river basin around Zudong Mine, 100% of groundwater samples failed to meet acceptable levels for indicators of the Grade III standard, including lead, cadmium, sulphate, total dissolved solids, nitrite, ammonia and pH. In addition, nitrate, sulphate, iron, zinc and other indicators were also in excess.

4.3 On-the-ground: villager's drinking water sources under threat & related health impacts

Mining activities pose serious threats to drinking water sources

Rare earth mining activities can contaminate both surface and groundwater. This poses serious threats to drinking water safety, particularly for residents in mining areas. According to China Environmental News, in 2012, the drinking water of more than 30,000 people from Huangsha and Dongjian towns was affected due to contamination from mining sites located upstream. Additionally, 41,365 acres of farmland in the two towns either failed to produce crops or suffered from reduced yields⁸⁰.

The “disposable” mentality towards rare earth mining puts villagers at risk...

Ganzhou's rare earth mines are decentralised, many operate at relatively small scale. On top of this, miners tend to mine the easily accessible ores and leave the more difficult ones. This means the mining period at a site can be quite short and results in a “disposable” mentality – when one mine is done, move onto another. With this attitude and costs involved, it's not surprising that mining companies generally do not relocate residents away from the sites. This leaves the residents exposed to the environmental damage from mining activities, especially water contamination. They have little or no choice to relocate with minimal financial resources.

...villagers in Huangsha & Guanxi say many lose their teeth before they reach 50

In Huangsha and Guanxi some villagers, still today, live around and inside mine sites. It's difficult to find a villager between the age of 30 to 60 with a full set of teeth. Villagers say many of them lose their teeth before they are 50 years old. Villagers suspect this is related to rare earth mining. Rare earth mining does cause nitrogen and fluorine pollution⁸¹. Although the correlation cannot be confirmed, the villagers concerns are not groundless; yet there is no public record of any Chinese Centre for Disease Control and Prevention (CDC) investigation.

Long list of water contaminants can be broadly grouped into 3 types...

The long list of contaminants found in surface water and groundwater from mining sites can be roughly divided into three types:

- Conventional: Ammonia, pH, and total dissolved solids;
- Heavy metals: Cadmium and Lead; and
- Other pollutants: Nitrite and Fluorine.

YELLOW RIVER “CANCER VILLAGES”

Dalahe village, a Mongol minority village located two kilometres in the West of the Baotou tailing dam in Inner Mongolia is well-known as a “cancer village”.

The cancer story of this village starts in 1988 when goats and horses started to develop odd growths, only then to die suddenly. Sometime later, men and women of the village started to experience issues with their jaws. This was followed by many falling severely ill and ultimately being diagnosed with cancer.

A list collected by a village committee recorded 61 deaths from cancer from 1999 to 2006 in Dalahe village. Surrounding villages have no such records but do have similar stories.

Source: Tailing Dam Crisis in Baotou, Caixin Weekly, January 21, 2013

...long-term exposure can lead to serious health risks

Long-term exposure to these contaminants from drinking water, body contact or inhalation can lead to serious health implications that aren't always obvious. Poisoning by heavy metals is not easy to detect, whilst fluorosis poisoning has more apparent symptoms, such as dental fluorosis and

osteofluorosis. Ammonia nitrogen in water can be converted to nitrite under certain conditions and when combined with human proteins can turn into highly carcinogenic nitrosamines. The health risks are significant.

Xie Risheng, a farmer from Lipo Village in Wenlong Town, Longnan County, said in 2013 that since the Lintang rare earth mine went into operation in 1995, the water of more than 20 downstream households' had been polluted. He added that the stream flowing down the mountain now had a strange, sour smell.

Villagers abandon arable land as it is no longer fertile or they fear contaminated produce

As a result, the villagers had to lay pipes to channel water from two kilometres away. According to Xie, most of the arable land close to the mines had been abandoned, either because it was no longer fertile or villagers feared their produce would be polluted. Few parcels of "pure land" remain – a small patch outside one household's door where rice would still grow. But even then, they can only do one planting season due to arable land degradation and contamination.

Many mines are now "semi-idle" but are still a curse on drinking water...

Due to either economic difficulty or a government crackdown in 2010, many rare earth mines are now "semi-idle", but the pollution from these mine sites remains a curse on drinking water in nearby villages.

...villages have petitioned to close illegal mines

In September 2015, villagers of Caiyang, Longtou Town of Dingnan County in Jiangxi province sent an anonymous petition to the Ganzhou Mineral Resources Bureau, calling for a stop to illegal mining in the area⁸². They also voiced their concerns that the newly developed Shuikeng rare earth mine would pollute their last remaining local water source.



© Liu Hongqiao - Mine repairing site in Zudong mine

4.4 Ganzhou's far-reaching impact on China's Rivers: Donjiang, Ganjiang, Yangtze & et al

Water easily spreads pollution downstream...

Rare earth mining brings pollution, especially water pollution. But unlike the "visible" pollution at the mines, the environmental impact downstream is not always so "visible".

...many rivers flow through provinces with rare earth resources

It is difficult to trace exactly how downstream water sources are impacted and to what extent. However, preliminary data shows that rare earth elements range from 0.01 to 1 microgram per litre in water samples from the Yangtze River, which is significantly higher than the ambient value of the Yangtze River and the average proportion in global fresh water⁸³.

Key Rivers in Ganzhou are the Ganjiang & the Dongjiang

China's rare earth resources have been identified in more than a dozen provinces. These include Inner Mongolia, Shandong, Sichuan, Jiangxi, Hunan, Hubei, Guangdong, Guangxi, Fujian, Yunnan and Hainan. Many of China's major rivers flow through these provinces and are exposed to pollution from rare earth mining.

For example, in Ganzhou there are more than a thousand rivers and streams, thanks to the hilly terrain. The most notable rivers are the Ganjiang River, a tributary of the Yangtze River and the Dongjiang River, the eastern tributary of the Pearl River. The former, flows northward through Poyang Lake into the Yangtze River, providing drinking and industrial water for major cities in Jiangxi province. The latter flows southward and after leaving Jiangxi province, enters a tributary of the Pearl River, a major drinking water source for Guangzhou, Shenzhen, Hong Kong and other large cities. Clearly the stakes are high.

The source of the Dongjiang River spans three counties....

Taking a closer look at the Donjiang River, its source spans three counties: Xunwu, Anyuan and Dingnan. All three are rich in ion-absorbed rare earth resources. Dingnan County, as one of "three Nans" together with Longnan and Quannan, is an important rare earth producing area. Meanwhile, Xunwu has long enjoyed the reputation of the "Rare Earth Kingdom" before the name was officially given to Ganzhou city. According to the Jiangxi provincial Department of Land and Resources, Xunwu, Anyuan, Dingnan's production quotas for 2015 were 360, 220 and 2,700 tonnes respectively, which together accounted for around 47% of Ganzhou's total mining production quota in 2015.

...which account for 47% of Ganzhou's mining quota

Is it best to cease mining to protect the rivers? What about jobs?

Although the source of the Dongjiang River within Jiangxi province accounts for almost 10% of the total Dongjiang River basin⁸⁴, it is critical as the birthplace of the river, and thus crucial to its quality. While there is no reported incident of surface water pollution from rare earth mining in Ganzhou, the city already suffers from ecological damage including soil pollution and erosion which costs at least RMB38 billion to remediate.

If mining were to cease to protect the river, there are trade-offs: what about jobs? There needs to be a balance between environmental protection and economic development. In 2015, Ganzhou's per capita GDP was the lowest of Jiangxi province⁸⁵ and the three counties comprising the river's source ranked the lowest three within Ganzhou⁸⁶.

Trade-offs are everywhere – already 800 rare earth mines have been closed

Trade-offs are everywhere and efforts have been made to clean-up. Jiangxi has been implementing measures to protect water sources since 2009 when it set up "the Dongjiang River Source Protection Zone"⁸⁷. To mitigate pollution of the river, it also shut down more than 800 rare earth, tungsten ore, fluorite and gold mines in the source regions.

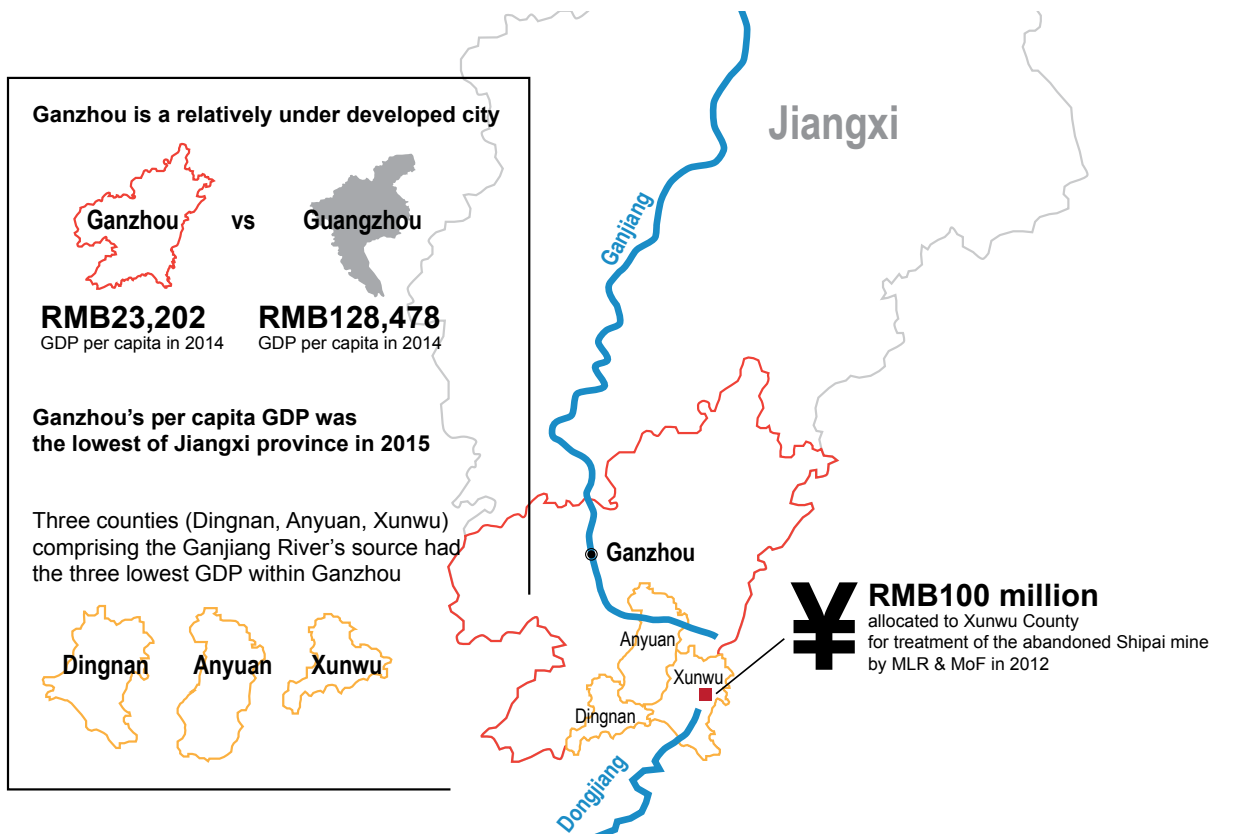
Additionally, Jiangxi province has been returning farmland to forest and relocating residents at key water conservation areas. Other measures are being implemented in the source region of the Dongjiang River⁸⁸.

Estimates to treat pollution in Ganjiang & Dongjiang River source areas is nearly RMB3bn...

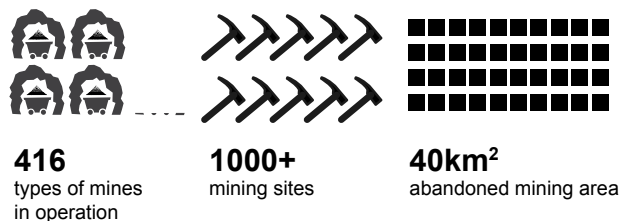
In 2012, the Ministry of Finance (MoF) and the MLR jointly allocated RMB100 million for the treatment of the abandoned Shipai mine in Xunwu County. The Ganzhou EPA preliminarily estimated that mining legacies and tailings management would cost nearly RMB2 billion and an additional RMB1 billion in reforestation⁸⁹. This is just for Ganjiang River's and Dongjiang River's source counties.

...but govt funds only RMB100 mn

Unfortunately, rare earth mining activities continue to persist outside the "protection zones". According to China Environmental News, at the end of 2013 there were 416 various types of mines in operation with thousands of mining sites and nearly 40km² of abandoned mining areas in the Dongjiang River and Ganjiang River source regions. This damage and costs are for just two river sources, what about other rivers? Are they as polluted? How much will it cost to clean-up other Chinese river sources?



Dongjiang River & Ganjiang River source regions as end of 2013 had:



Ganzhou EPA preliminarily cost estimates:



Source: Ministry of Finance, Ministry of Land and Resources, Dongjiang Source Region Looking for Water to Relief Thirsty, China Environmental News (December 20 2013), 2015 GDP Statistics in Cities Has Been Examined and Approved, Jiangxi Statistics Bureau (February 16 2016), Jiangxi Statistical Yearbook 2015, China Statistics Press 2015, Guangdong Statistical Yearbook 2015, China Statistics Press 2015

RARE EARTH MINING

Impact on China's Rivers

The Yellow River

In the Bayan Obo mine in Inner Mongolia, a large number of coarse ores are discharged with the tail slurry into the tailings, creating a giant tailing lake of 11km². This holds 135 million tonnes of tailings slurry and 70,000 tonnes of the radioactive metal, thorium.

As environmental protection procedures were not taken into account when the tailings dam was built decades ago, no seepage control measures nor any waterproof layer lining was put in place. It has been impossible to rehabilitate the area. The large size of the dam has also made it more difficult.

Less than 20m west of this tailings dam is the Shanshuiqu River, a small tributary of the Yellow River. The Yellow River itself is less than 10km away. During the rainy season or also in heavy rains, the tailings are carried via runoff into the Shanshuiqu River and so by default, the Yellow River.

Adding to the already precarious situation is that the tailings dam is located on an active fault zone. Scientists are worried that an earthquake could result in a severe tailings dam break accident. Impact to the Yellow River could be worse than the 2006 Songhuajiang River pollution accident which leaked more than 100 tonnes of benzene and nitrobenzene into the river. In Shanxi in 2008, a tailing dam broke due to heavy rain, causing 227 deaths and an economic loss of RMB100 million.

The Jinsha River (Upper Yangtze River)

There are many exposure sites for the Yalong River and so Jinsha River. Downstream of the Yalong River, the largest tributary of the Jinsha River, lies the second largest LREEs reserve in China - the Maoniuping rare earth mine in Liangshan Autonomous Prefecture of Sichuan province. A short distance from Maoniuping lies another large rare earth reserve, the Dalucao rare earth mine. Both mines are only around 10km from the Yalong River.

According to the MLR, once more than 100 companies operated in Maoniuping in a mining area of nearly 3km².

Maoniuping frequently experiences heavy rains. In a major storm in the summer of 2013, more than 100,000 tonnes of mineral waste residue as well as tens of thousands of tonnes of tailings were swept away into Anning River, the largest tributary of Yalong River in the west branches.

At the Jinsha-Yalong River junction lies Panzhihua City, which is known as the "the Capital of Vanadium and Titanium Rare Earth". It is also home to the largest rare earth smelting and separation processing centre in western China.

Eastern route of the South-to-North Water Diversion Project (Huaihe River Basin)

Weishan rare earth mine, China's third-largest LREEs reserve is located in the South of Shandong province. It lies close to the largest freshwater lake in northern China - Nansi Lake, part of the Huaihe River Basin. Nansi Lake was once the most polluted freshwater lake in China.

Nansi Lake plays a very important role in the South-to-North Water Diversion Project as a transfer reservoir of the eastern route. All water diverted from the Yangtze River is stored in Nansi Lake before heading for Beijing, Tianjin and Shandong province.

The Yangtze River

In addition to potential contamination from the Ganjiang River as stated previously, the Yangtze River can also be the recipient of rare earth related contaminants through Hunan province.

Hunan province is one of the main areas for southern ion-absorbed rare earth mines. Lianyuan city, located in northeast Hunan province is a main production area for these ores. Lianshui River flowing through Lianyuan city feeds into the Yangtze River thus ultimately connecting the mine sites to the Yangtze River.

The Pearl River

The Pearl River is the second largest river in China, second only to Yangtze River. As shown above, the Pearl River is at risk through the Dongjiang River but there is more. The Pearl River flows through the major ion-absorbed rare earth production provinces in southern China, known as the "Lingnan rare earth belt". In 2015, three provinces along the Pearl River basin, Jiangxi, Guangxi and Guangdong, together had a 13,700 tonnes of ion-absorbed rare earth production quota, accounting for 76.5% of the total production quota on ion-absorbed rare earth.

Within China's major river systems, rare earth mining activities are most intensive in the Pearl River Basin. Ganzhou's rare earth development has a long history, which includes polluting the Dongjiang River (a tributary of the Pearl River). In Wuzhou of Guangxi province, upstream of the Xijiang River, rare earth development is similarly active. Many illegal miners moved to Guangxi, following the reorganisation of mine sites in Guangdong.



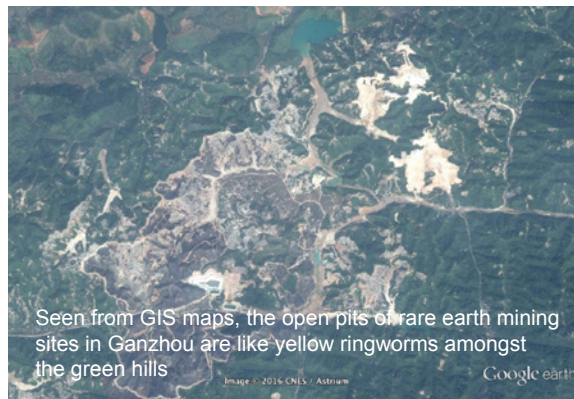
- Legends**
- Cities
 - Provinces with large rare earth reserves
 - Areas with rich rare earth deposits
 - Rivers
 - Eastern route of the South-to-North Water Diversion Project

Source: Annual Rare Earth Production Quota Distribution by Provinces(District), MLR, 2015, Illegal Mining in Cangwu County of Guangxi Province Caused Landslide with 9 Fatal Victims, Sanlian Lifestyle Weekly, December 9, 2011, "The Capital Of Rare Earth" Has Become A "Radiation Zone" But Who Will Pay For The Environmental Cost?, Peoples Daily Online, August 4 2011, Xu Guangxian, et. al, Emerging Call On Conserving Thorium and Rare Earth Resources in Baiyun Obo Mine and to Avoid Radioactive Contamination in The Yellow River and Baotou City, Bulletin of Chinese Academy of Sciences, 2015, The Duty Officer of the Shanxi Dam-Break Incident Which Caused 277 Deaths Was Sentenced Death Reprieve, Chinese Radio Network, September 30, 2010, Sichuan Province to Boost Pollution Recovery in Maoniuping Rare Earth Mine in Mianning County, Sichuan Daily, November 12, 2013, The Pollution Situation in Nansi Lake and Pollution Control, Huaihe River Governance Journal, Volume (6), 1992

4.5 Mine rehabilitation: is it too late?

Looking at southern Ganzhou with Geographic Information System (GIS) maps, rare earth mines are easily distinguished from the rolling green hills. The mines are distributed as narrow bands, the “yellow ringworms” among the green. The largest mine, Zudong Mines, has left large, bare areas, from land subsidence and erosion among the wooded hills. In addition to the “yellow ringworm” bands are leftover leaching ponds, sometimes more than 20, like scars.

GIS mapping show rare earth mines as “yellow ringworms” among the green



These GIS maps as well as local knowledge, helped navigate some major rare earth mine sites in and around Longnan County. Some of the sites are semi-idle.

To enter and exit the mine sites one still needs to pass through checkpoints, which have been in place for more than 10 years and were originally set-up to combat stealing and illegal trading, though with limited success. When entering a still active mine site, staff at checkpoints symbolically check cars and their trunks.

Different from 2013, some of the abandoned mines are being rehabilitated...

A notable difference in the past years, is that many of the once abandoned mines were being rehabilitated, at least to some degree.

It's clear that environmental protection of mine sites is much stronger than it was three years ago. The success of some mine rehabilitation projects and comprehensive improvement projects is showing, with fewer bare mountain areas.

...but the number is small compared to the total

However, the number of reclamation/rehabilitated mines is only a small portion of the total. Moreover, the projects undertaken so far include very little decontamination or mitigation of surface and/or groundwater pollution, as per their published Environmental Impact Assessment (EIA) reports. The majority of action instead focuses on land reclamation & levelling, slope reinforcement and reforestation.

Rehabilitation actions mainly focus on land...

The once dug-up mountains are now mostly covered with a layer of thick grass. Meanwhile, injection holes from in-situ leaching are filled with sediment, soil and fertilizer with some grass coverage, as well as acid-resistant pine trees (though still in their infant stages).

...with nothing or little on water



© Liu Hongqiao - A warning sign saying, "new forest trees have been planted so mining activities are not allowed, nor is smuggled oxalic acid and absolutely no illegal mining"

Many mines are not included in the rehabilitation fee mechanism...

...as they were illegal or owners shirked responsibility

Thus the concept of "comprehensive utilisation" was put forward

Still, rehabilitation projects are just remedial solutions; a band-aid

MIIT says a RMB38 bn to clean-up Ganzhou

Chinese media says it could be as much as RMB1 trn

RMB38bn is ~1/4 of the total market cap of China's 5 listed rare earth co's...

... do co's have the money to clean-up?

The Ganzhou mines & govt are unable to meet the bill...

In Ganzhou such reclamation projects were launched in 2010 but only really picked up in 2012. Mine site rehabilitation is required in China under the "rehabilitation fee mechanism" introduced by the State Council, MLR, MoF and other departments⁹⁰. Due to rampant illegal mining, hundreds of illegally exploited mines were not included in these projects and remain in their shut-down state. Even for many legitimate mines, owners shirked rehabilitation responsibilities.

The concept of "comprehensive utilization" was also put forward by the Ganzhou government. This means that leftover tailing sand needs to be reused. The mine tailings from the Zudong Mine have blocked a river within the mining area. As a result, the riverbed has narrowed and the river has changed shape.

Comprehensive utilisation rehabilitation projects - large or small - are being conducted among the main rare earth producing areas in Ganzhou. For example, in Longnan, multiple projects such as abandoned rare earth mine management, environmental restoration and rare earth wastewater recycling are being undertaken. In Anyuan County, landslide control is managed in parallel with abandoned mines.

Still, these measures are just remedial solutions – band-aids. Ganzhou, the "Rare Earth Kingdom", once supplying nearly 80% of China's MHREEs resources has now had to take a step back and deal with the environmental fallout from its decades of mining. So who is going to foot the clean-up bill? China's central government? The Ganzhou government? The companies using REEs like Xiaomi or Toyota, Bang & Olufsen or Dell? The list goes on.

4.6 Who should foot the clean-up bill?

As mentioned previously, MIIT estimated a RMB38 billion clean-up bill for mines in Ganzhou. Of this, RMB2.6 billion is for the preliminary treatment of mines and the remainder for comprehensive rehabilitation solutions. The media has reported that the total rehabilitation cost could actually be closer to RMB1 trillion⁹¹. Can this cost be passed onto end-users?

As part of China's crackdown on the rare earth industry and illegal mining it consolidated the industry into six main SOE companies, of which only 5 are listed. The RMB38 billion MIIT estimate is around a quarter of the combined market capitalisation of China's five rare earth companies, which amounts to RMB154 billion⁹². It's more than the total market capitalisation of three of the five companies: Xiamen Tungsten Co (RMB24.6 bn) (#3), Rising Nonferrous Metals Share Co (RMB15.6bn) (#4) and China Minmetals Rare Earth Co (RMB14.6 bn) (#5). What's worse is that Ganzhou only has 8.6% of China's total rare earth production quota.

With such a significant clean-up bill for only a single mining region, can rare earth mining companies even afford to clean-up? This raises important questions about the entire business structure of the rare earth industry, not just in China but globally. The combined market capitalisation of the Top 10 international rare earth companies is even smaller, at around RMB2.7 billion⁹³. If companies don't have the money to pay, who will? Governments? Corporates? Consumers?

Ganzhou is a relatively under-developed city with a per capita GDP of RMB 23,202⁹⁴ compared to Guangzhou with a per capita GDP of RMB128,478 in 2014⁹⁵. The reality is that the financial resources of the Ganzhou government are unable to meet this large bill. In 2011, revenue from Ganzhou's rare earth industry exceeded RMB30 billion, which resulted in RMB10 billion in profits⁹⁶. By 2014, profits had dropped to RMB 6 billion⁹⁷.

...so far RMB43.7 mn is allocated; a mere drop in the bucket

Nearly all clean-up funds come from central/provincial govt...

...but this could change with new standards

As of the end of 2010, Longnan and Xinfeng Counties of Ganzhou city had been allocated RMB43.7 million of special funds for cleaning up from Jiangxi province⁹⁸; representing a mere drop in the bucket.

Currently, nearly all of the clean-up funds come from either the central government or provincial governments. But this could change. With tougher environmental standards and pollution prevention laws, operators and developers may need to foot some of the bill.

Mr Wu, principal of one rare earth production workshop of Zudong Mine in Guanxi Town, Longnan County, said that the more stringent environmental standards meant he had to invest over RMB500,000 last year for a new wastewater recycling equipment. Under the new requirements, water in mining sites must be recycled and wastewater cannot simply be discharged⁹⁹.



© Liu Hongqiao - A pre-treatment pool at a mine site (required after the new environment standard)

Something is wrong; costs are going up but rare earth prices are still low

Much of China's "Rare Earth Kingdom" has been pillaged; it's time to act!

Rare earth mining companies in China are having to spend more but not the companies buying and using the REEs like Apple & Xiaomi. If anything, prices are going down, not up. Clearly something is wrong. Rare earth prices should be going up as the cost of operations increase to be compliant with China's more stringent environmental standards.

It's time to re-evaluate, and soon. Already much of China's "Rare Earth Kingdom" has been pillaged. It's crucial to ensure future mining is at a fair price that values the resource and also covers the cost to the environment.

Mine rehabilitation projects and related clean-up funds are positive signs. But with what seems like no one with the money to foot the bill – not companies, nor government – is it too late to rehabilitate the damage done? It's a grey future for the "Rare Earth Kingdom".

4.7 An uncertain future for the “Rare Earth Kingdom”

Abundant MHREEs reserves once made, and still do today (though to a lesser extent), Ganzhou a key strategic mining area in China and even the world.

Ganzhou’s reserves have rapidly declined...

But after intense mining, Ganzhou, the “*Rare Earth Kingdom*”, may not be a kingdom for much longer as reserves have rapidly declined. In 2009, the Management Division on Mining and Exploitation of the MLR released a reerves-to-production ratio for MHREEs of 87 (meaning if developed at present production rate, the remaining MHREE deposits would last 87 years)¹⁰⁰. More on reserves in **Chapter 2: China loses market share but still dominates by far**.

In the 1980s, under the development guideline issued by the Chinese government, “*big mines, a wide opening; small mines, a small opening; see the water and promote its flow*”, mining activities flourished. In the heyday, there were more than a thousand mines in Ganzhou distributed in each of the 18 counties. A kingdom was born but so was a rare earth black market, accelerating the exhaustion of reserves.

Ganzhou now faces resource depletion & economic instability, on top of pollution

Ganzhou, as a typical resource-driven city, is now facing a fate common to many resource-reliant cities of resource depletion. That means economic loss & instability, as well as a severe pollution. Worse still, with rare earth prices low and a black market in minerals, Ganzhou’s per capita GDP remains low despite exploitation of its strategic rare earth resources.

China has made it clear: pollution must go!

China, has been fighting air, water and soil pollution since Premier Li Keqiang declared a war in 2014. China’s latest development aim is to build a “Beautiful China” by the end of the 13FYP, with blue skies, green land and clear running water.

Clearly in order to be successful in the war and to build a “Beautiful China”, pollution must go (as much as possible). What does this mean for the future of rare earths? We already saw in 2010 the Chinese government crackdown on rare earths. Will more stringent laws be passed? Will this trigger another global rare earth scare?

What happens in China impacts all of us, especially with its 85% of the global rare earth market

An uncertain future for Ganzhou and a “Beautiful China” translates to an uncertain rare earth future for the world. Whilst there are rare earth operations elsewhere, China remains dominant with 85% of global rare earth production.

What happens in China impacts us all. Our smartphones, TVs, renewable energy technology and even some military applications all use rare earths. Toxic pollution and the rare earth black market go hand-in-hand. China can neither clean-up nor crackdown on the black market alone. We all have a role to play and we look at what can be done in the next Chapter.

CHAPTER 5:

GLOBAL ACTION NEEDED TO REMOVE THE GREY FROM OUR CLEAN & SMART FUTURE

'Clean' & 'smart' on the back of a black market & toxic waste is neither clean nor smart

China's rare earth industry supports our global clean energy and smart technology. But how clean and smart can these technologies and energy be if they are damaging people's health and the environment? Without serious action to reduce environmental damage from rare earth mining, without international efforts to clampdown on the black market, pollution will continue to be the dirty secret staining our clean and smart future.

5.1 China's rare earth industry to face increasing domestic challenges

The Chinese govt has been trying to regulate the industry with various policies since 2006

Since 2006, the Chinese government has been trying to regulate the rare earth industry through various systems and policies. These include: industry and energy emissions standards, permit systems, EIA, rehabilitation & restoration accountability mechanisms and others. Many of these systems and policies are set to continue but as demand for rare earths continues and so does China's war on pollution, more stringent rules could likely be implemented.

...REOs listed in 2015 by MEP as "double high" products – high pollution & high environmental risk

The Chinese government is also testing the water with market mechanisms that encourage more environmentally friendly and low-carbon methods of rare earth mining. In December 2015, the MEP released the *"Comprehensive Directory on Environmental Protection (2015 Edition)"*, which listed ion-absorbed rare earths and REOs as *"high pollution and high environmental risk products"* ("double high" for short)¹⁰¹. Only four new processes for rare earth extraction and separation are exempt from the "double high" classification, as they result in either lower or zero ammonia nitrogen wastewater discharge.

MEP says "double high" products will be at disadvantage in upcoming green economic policies...

The Chinese government is using a "stick and carrot". According to Bie Tao, Deputy Director of the Environmental Policy and Regulation Department of the MEP, double high products will be at a disadvantage in China's environmental economic policies like green tax, green trade, green finance and so on. For example, the government's "green procurement" and "green consumption" policies, recommend that enterprises avoid purchasing double high products¹⁰².

...green procurement to also avoid these products

China continues to fight its war on pollution with the "Soil Pollution Control & Prevention Action Plan", ("Soil Ten Plan"), as we discussed briefly in **Chapter 4: Rare Earth Kingdom's cost to the environment**.

China released its last affront on pollution, the Soil Ten Plan in June 2016

The Soil Ten is China’s third and previously missing prong (pollution action plan) to combat rampant pollution. It was delivered by the State Council on 1 June 2016¹⁰³ and follows the “Air Ten Plan” of late 2013 and the “Water Ten Plan” of April 2015.

CHINA’S “SOIL TEN PLAN”

It’s clear why there is a soil pollution action plan. According to the latest data from the MEP & MLR, 16.1% of China’s surveyed soil samples are contaminated with various heavy metals including; 7% with heavy metal cadmium, 2.7% with arsenic, 1.5% with lead and 1.6% with mercury. Some samples were contaminated with multiple heavy metals. Additionally, 19.4% of surveyed arable land had pollution levels higher than the national standard.

The Soil Ten Plan aims to improve soil quality, ensure safe agricultural products and a healthy living environment for China’s people. Some key targets and actions are listed below:

- To curb worsening soil pollution by 2020, and control soil pollution risks by 2030, and form a virtuous cycle in the ecosystem by 2050;
- To ensure over 90% of contaminated land can be utilised safely by 2020, and increase this to 95% by 2030;
- By 2017, to set up national-level soil environmental quality monitoring points and monitoring networks;
- By 2020, soil environmental quality monitoring points to cover all the cities and counties; and
- By 2020, to establish soil pollution prevention & control related laws and regulation system.

Source: Soil Pollution Control and Prevention Action Plan, State Council, 1st June 2016

Rare earths impacted as Soil Ten Plan targets “non-ferrous metals”

Rare earths will be impacted by the Soil Ten Plan, which details special supervision of eight industries, including non-ferrous metal extraction & processing and non-ferrous metal smelting. In China, rare earths are categorised under non-ferrous metals¹⁰⁴.

Also, rare earth mining & processing provinces will face special discharge limits

Additionally, from 2017, major rare earth mining and processing provinces including Inner Mongolia, Jiangxi, Hunan, Guangdong, Guangxi, Sichuan, Gansu, Xinjiang, amongst others with concentrated mineral resource development activities, are required to follow the “special discharge limits on key pollutants”, which is normally the most stringent discharge limits in all environmental regulations¹⁰⁵.

Must rein in pollution before impending demand growth from a domestic & international green future

With more stringent laws, policies and enforcement, prices should be going up, but so is demand. Green energy is high on the global agenda with extreme weather events and impacts from climate change becoming more evident, plus of course, the world’s path to a low-carbon economy as decided at COP21 in 2015.

5.2 Growing demand: COP21, green energy & an even smarter future

Targets set by countries at COP21 will drive demand in the next 5-10 years

In addition to China's own new industrial mix push, the next 5-10 years are crucial to achieve the de-carbonization target set by countries at COP21. This translates to aggressive investment in renewables, particularly in wind power; energy efficiency; electronic/hybrid cars and so on. Most of these technology solutions require rare earths for superior performance.

Wind turbines need the less supplied MHREEs....

For example, the requirement of Neodymium (Nd) and Dysprosium (Dy) in the manufacture of wind turbines as highlighted in our report last year, *"Towards A Water & Energy Secure China"*¹⁰⁶. According to scientists from the Massachusetts Institute of Technology an average of 171 kg of rare earth elements are required per megawatt of built wind capacity¹⁰⁷. NdFeB (neodymium iron boron) magnet is the main component containing rare earth elements - mainly Neodymium (Nd), but also Dysprosium (Dy) and Praseodymium (Pr).

China was the biggest driver of wind power in 2015....

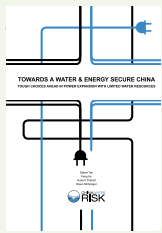
China was the biggest growth driver of global wind power in 2015 by far, accounting for almost half the additional installed capacity¹⁰⁸. China's maximum wind expansion scenario could reach 2TW by 2050. The implications of China's wind power expansion across various scenarios are set out in the following two-page insert. Whereas the impact of rare earth mining and REE extraction on the environment is covered in **Chapter 4: Rare Earth Kingdom's cost to the environment**.

...and it still has plans for big expansion...

...will there be enough for everyone?

Currently, nearly 190 countries around the world submitted Intended Nationally Determined Contribution (INDCs) by 2030 to the secretariat of United Nations Framework Convention of Climate Change (UNFCCC)¹⁰⁹. As the world's largest carbon emitter, China has committed reach carbon discharges peak value before 2030, and promised to do so as early as possible. As of 22 April 2016, 175 countries signed the "Paris Agreement" at United Nations Headquarters in New York¹¹⁰.

The road to a low-carbon future will pave the demand for rare earths, in particular the already scarce MHREEs. It appears that China will likely not be able to supply these to the rest of the world given its own rising urgent demand. Is it China's responsibility or should other nations and end-users manage demand and use in a more responsible manner?



This two page insert is from the report “Towards A Water & Energy Secure China”, published by China Water Risk in April 2015.

Updates to the insert are marked by an asterisk*. Data from the National Energy Administration regarding China’s installed wind capacity now supersedes that in the report. The update data was sourced from the National Energy Administration “2015 wind power industry development” document.

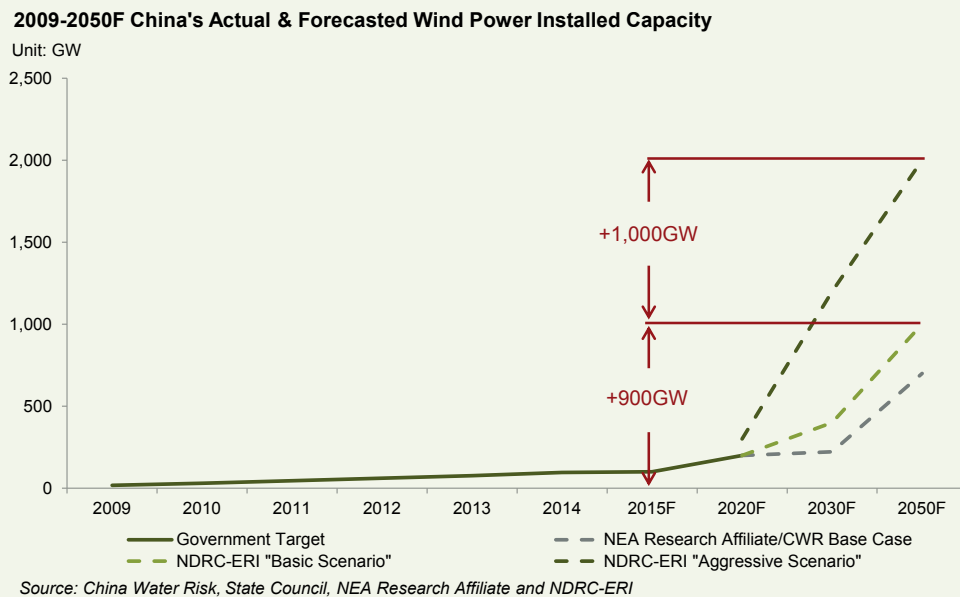
BIG WIND AMBITIONS: 2050F WIND INSTALLED CAPACITY BASE SCENARIOS RANGE FROM 700GW TO 1TW

Wind power not only cuts GHG emissions from power generation but also avoids water consumption and withdrawal for cooling in thermal power plants. Given the double benefits for water and climate, China has welcomed expansive growth of wind power with many large-scale wind farms

In 2014, China’s on-grid wind installed capacity reached 96GW and a further 78GW is under construction. By 2015 China had already surpassed its 2020 target of 200GW with 129GW of on-ground wind and 87GW under construction, totalling 216 GW*.

The future of big wind can be as much as 2TW

Various government affiliated research bodies have forecasted the future development of wind energy from 2020 to 2050. These forecasts are set out in the chart below:



If China follows the “Aggressive Scenario”, it will add +1.9TW of wind capacity between 2015 and 2050; even with the “Basic Scenario”, the 2050 figure is still +900GW more than 2015 target. Regardless of differences, all forecasts indicate big wind ambitions.

Caution! A big wind future could pollute watersheds with acidic water & radioactive waste

As discussed earlier in this chapter, the power generation process of wind power basically does not require any water. Thus, it is a top energy choice in terms of withdrawal/consumption and GHG emissions.

However, if we extend our examination to the production of wind turbines, hidden water risks are revealed. For some types of wind turbines, the production of permanent magnets requires use of rare earth metals (mainly neodymium which is LREE, and dysprosium which is HREE). Moreover, the manufacturing of wind turbines requires a significant amount of steel and carbon fibres.

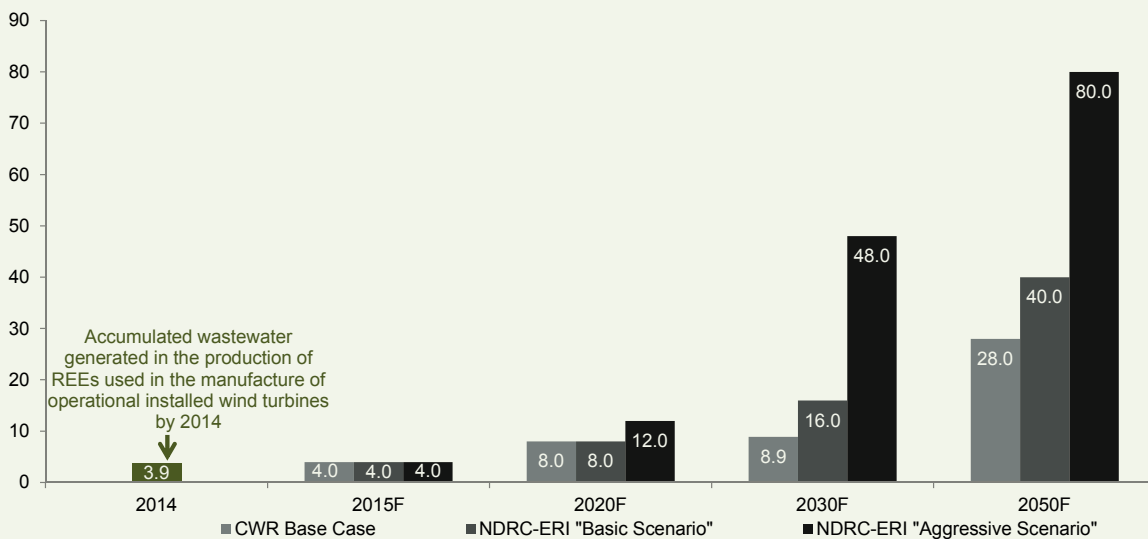
Wind dirty secret: Rare earth demand from forecasted wind power expansion and associated wastewater discharge

Studies have shown that a typical 2MW wind turbine contains about 341-363kg of neodymium and about 59kg of dysprosium. This means to produce 96GW of wind turbines that were installed and put into operation by 2014, China would have consumed about 16,431-17,491 tonnes of neodymium and 2,843 tonnes of dysprosium. To add +100GW wind power from 2015 to 2020, it will require additionally about 17,050-18,150 tonnes of neodymium and 2,950 tonnes of dysprosium. Note that this does not include rare earth demand resulting from the ongoing maintenance of the wind turbines.

As discussed in “China’s Rare Earth Resources & Toxic Impact on Watersheds”, these rare earths are primarily supplied by China. The mining of rare earths has caused negative environmental impacts including water pollution. One tonne of REE can produce 200m³ of acid-containing wastewater. Therefore, to add +100GW wind power from 2015 to 2020 could lead to approximately 4.0-4.2 million m³ of acidic wastewater; and depending on the expansion scenario, wastewater discharged could either double or triple by 2020 or increase 7x to 20x by 2050. The below chart illustrates the accumulated amount of wastewater discharge from REE production due to forecasted wind power expansion under three different scenarios: CWR Base Case, NDRC-ERI “Basic Scenario” and NDRC-ERI “Aggressive Scenario”:

2014-2050F Accumulative REE Wastewater Generated from Manufacture of Wind Turbines

Unit: mn m³



Source: China Water Risk, State Council, NDRC, NEA Research Affiliate, NDRC-ERI, China National Renewable Energy Centre

Note: the figures represent accumulated wastewater generated from the production of REEs, which are used in the manufacture of wind turbines with the forecasted installed capacity by the indicated year. Only operational capacity are considered.

It is clear from the above chart that across the three scenarios, the wastewater discharge will either double or triple between 2014 and 2020. Whereas from 2013 to 2030, wastewater discharge could face a twelve-fold exponential growth if NDRC-ERI’s ‘Aggressive Scenario’ was to be adopted.

Clearly, before embarking to tap China’s massive wind power potential, toxic and radioactive water risks to China’s watersheds need to be prioritised. As mentioned before, without strong regulation of the rare earth industry, future increase in REO mining and REE production driven by the wind industry could be disastrous for China watersheds in both the North and the South. Given the current forecasts, there is a ten-year window to achieve this.

5.3 Think twice before investing or going into rare earth production

In 2014 there were 429 rare earth exploration projects across 37 countries...

According to Technology Metals Research, in 2014 there were 429 rare earth exploration projects – mixture of initial & advanced stages - being conducted by 261 companies across 37 countries and regions. By November 2015, only 53 advanced rare earth projects were still active.

...by Nov 2015 only 53 advanced projects remained; likely due to WTO ruling against China

Between these two points in time, the WTO had ruled against China and its export quotas had been lifted. Not surprisingly many overseas exploration projects shut down following the ruling.

But don't dive in investors....

However, China's domestic rare earth market faces increasing scrutiny, more stringent environmental standards and unfavourable market mechanisms, prices will likely go up. But setting up business operations in other countries is not that simple as historic cases show.

...it's a volatile market as Molycorp Inc shows

A notable case is Molycorp Inc (an American mining corporation), which owned the Mountain Pass rare earth mine in California. Mountain Pass once supplied the majority of the world's rare earths¹¹¹. The mine mothballed due to a shift in production in China among other reasons and was only reopened during the China supply scare. However, by June 2015 Molycorp filed for bankruptcy protection, reaching an agreement with creditors to restructure its USD1.7 billion in debt¹¹². The company's stock price peaked at USD77.5 on 3 May 2011 and dropped as low as USD1 on 28 November 2014¹¹³.

Molycorp's share price went from USD77.5 in May 2011 to USD1 on Nov 2014

Global rare earth supply and demand patterns changed dramatically in Molycorp Inc's five years of operations. China's cancellation of its rare earth export quota system, combined with a series of restructuring of China's resource taxes resulted in China's rare earth prices dropping at least 15-25%, which undercut Molycorp's prices. On top of this, China is either the sole or dominant producer of the less supplied HREEs whilst Molycorp produced LREEs, which are oversupplied.

Molycorp's roller coaster ride shows price & market failure

The global black market must be tackled and China's significant environmental costs factored in if we are to open up a commercially viable supply alternate to China.

Molycorp's roller-coaster experience shows the failure in rare earth pricing and the market. Current prices are low, or "cabbage prices". The market is not including any of the associated costs of rare earths, neither compliance with environmental standards, technological requirements, nor the resources' strategic value or health impacts.

It makes sense to work with China so that we can ensure our clean & smart future that is also sustainable

China's dominance in the global rare earth market has shrunk but remains high. With the challenges of the market and price failure discussed above, it's unlikely that this status quo will change. China's recently restructured rare earth industry of six SOEs will be providing the majority of rare earths for our smartphones, wind turbines, speakers and so much of our lives.

China is taking action to reduce the impacts of its rare earth industry and the black market but it can't do it alone. With these challenges, it makes sense to work with China to get things right, to stop pollution from transferring to other countries so that we can ensure our clean and smart future that is also sustainable.

5.4 China can't clean up or crackdown alone; countries & businesses need to step-up

China proposed a rare earth traceability system in 2015...

In December 2015, China's State Council proposed building a rare earth traceability system¹¹⁴. This was to improve supply chain ownership and crackdown on the black market. There have yet to be any detailed updates to the proposal.

...but to be successful downstream countries & businesses need to be involved

However, to implement such a system and ultimately shift the global rare earth industry into a sustainable one, downstream countries and businesses need to be involved too. Germany by 2014 had installed 24,867 wind turbines¹¹⁵, how much of the rare earths in those turbines was supplied by the black market? Brands like Toyota are benefitting from a 'green' image with electric cars like the Prius, but are rare earths used in their production legally sourced? Was there environmental damage and lives impacted in China as a result of these products?

There are too many shades of grey in the current situation. Action is being taken by the IT industry on "conflict minerals", so why can't there be action too on rare earths?

Leading IT brands sign commitment to weed out "conflict minerals" from Africa...

On 22 August 2012, the US Securities and Exchange Commission (SEC) announced it will adopt conflict minerals rules pursuant to Section 1502 of the "*Dodd- Frank Wall Street Reform and Consumer Protection Act*"¹¹⁶. This means that companies now have to disclose the use of minerals (columbite, tantalite, cassiterite & wolframite), sourced from conflict areas in the Congo Basin and beyond¹¹⁷.

...but ignore "cancer villages" in Inner Mongolia from rare earth mining

The above mentioned minerals are widely used in common electronic products, aircrafts, cars, lighting and others. Apple, Intel and other international brands have signed the "*Commitment to Conflict-Free Minerals*", to rid their supply chains of these conflict minerals¹¹⁸.

The success with conflict minerals came after years of lobbying and after a clear link between electronic products and conflict minerals had been demonstrated. What about the already established link between China's 'cancer villages' and the Baotou rare earth mine in Inner Mongolia? Why does this not receive more coverage?

Corporates using rare earths have a big role to play, as do governments but so too the public. We need to realise what rare earths really mean – pollution, health impacts & black markets. If we are going to continue to use rare earths, as the foreseeable future shows, then we need to 1) change the way we use them and 2) reduce demand by developing a recycling system.

5.5 Less than 1% recycled despite limited supply

Products using rare earths are growing & life cycles of smart tech is shortening = more e-waste

Not only is the list of products demanding rare earths growing but the replacement rate of high tech products increasing. Built-in-obsolence ultimately means more e-waste (waste of electrical and electronic equipment).

In 2011, China already produced around 2 million tonnes of e-waste annually¹¹⁹. Studies estimate that the EU alone would have produced more than 12.3 million tonnes of e-waste by 2020¹²⁰. Although e-waste contains large amounts of metal materials, including rare earths, lithium, aluminium and tin, the recovery rates for these materials are very low¹²¹.

Less than 1% of REEs contained in e-waste is recycled in 2011

Less than 1% of REEs contained in end-of-life products were recycled in 2011, according to UNEP¹²². In a 2013 study, the EU Raw Materials Initiative also suggested a global recycling rate of around 1%; basically the contribution of rare earth resources extracted from waste products from 2010 to 2012 was negligible when compared with global supply. Only Australia and the US reported higher recycling rates - Australia recycled around 1% of HREEs and 3% of LREEs, while the US recycled 7% of LREEs¹²³.

If REEs can be recycled it will ease demand & reduce toxic e-waste

If rare earth elements can be recycled from discarded electronic products, engines, batteries and fluorescent lamps, this will not only ease demand but also reduce e-waste's toxic impacts on the environment.

But small use amounts & low prices means low margins for recycling...

However, scholars who have been engaged in rare earth resources development research and e-waste recycling technology indicate that the "industrial vitamin" feature (small quantities) of REEs make the recovery of these elements extremely difficult. In addition to the small quantities, the "cabbage price" of rare earths, means recycling has either very slim or no profit margins. The lack of policy support for recycling has naturally not helped.

...lack of policy hasn't helped either

80mt of illegal e-waste (valued at USD3 bn) is being sent to China/year

Domestically waste issues are compounded by massive amounts of e-waste illegally being sent to China from other countries like Japan, South Korea, the US and EU so that they don't have to deal with it. The UNDOC estimated that each year about 8 million tonnes of e-waste, valued at USD3 billion, is smuggled in to China, accounting for around 80% of the illicit market in East Asia. The e-waste tends to enter through China's southeast coast or some remote towns and villages in inland provinces. The most notable one is the Guiyu village in Shantou City, Guangdong.

The end of life for many smartphones/tablets/etc. is a dirty & toxic one in a small village in China

Here, phones, iPods, tablets and other smart devices that when new symbolised technological and social advancement lay now as waste. The last leg of their life is a dirty and toxic one. The disposal or "recycling" processes used in rural China, where many of these waste items end-up, are basic - e.g. plastic materials are dealt with by incineration, which releases carcinogenic compounds. People (including children) dismantle the waste items bare-handed. Sometimes, this requires the use of hazardous chemicals. All of this is exacerbated by the black market, which breeds low prices.

We need to completely rethink the use of rare earths & our lifestyles

For the foreseeable future, without any drastic change, one can assume that the black market will continue and recycling rates will remain low. Given this, we need to ensure action at all stages of the rare earth life cycle. This includes going to the start of the demand process and reduce or even eliminate demand by rethinking and redesigning the products that use rare earths.

5.6 Rethinking rare earths – design, demand & lifestyles

Demand for rare earths will increase with our clean energy and ever smarter lives. Renewable energy is high on global agendas following the ratification of the COP21 climate agreement. Electric cars are becoming more and more popular, who doesn't see at least one Prius or Tesla a day? What about smartphones, who doesn't hanker after the latest smartphone model? All of this means we need a big rethink on rare earths and our lifestyles if we want to achieve a truly clean and smart future that is also sustainable.

But as our deep dive into the "vitamins of industry" has shown, there significant yet overlooked problems; environmental damage, water pollution, impact to livelihoods, cabbage prices, toxic e-waste and more.

Though China is the dominant global supplier with 85% of the market it is not for China to act alone. With rare earths in our smartphones, tablets, clean tech (wind turbines) defence & military applications, it is everyone's responsibility to act; both governments and corporates of the world. There is no space for double standards.

This is even more the case with a rampant black market, which means a smartphone in the US or Europe could easily contain illegally mined rare earths.

Accountability & traceability should run throughout rare earth value chain

Businesses and governments buying and using rare earths need to be accountable for their purchases and products with rare earths. They must push for accountability and traceability along the supply chain. Not only should sourcing information of rare earths be recorded but also the amounts used in products and ideally the amount recycled. Governments and businesses should also encourage and support – with policy & funds – the innovation of products with less or no rare earths. This will encourage designers.

We need products with less or no rare earths that don't compromise energy efficiency...

Designers need to find ways to develop clean energy and smart technology with less rare earth requirements or better yet, without rare earths completely but can we do this without compromising performance and energy efficiency? For products with rare earths, is it possible to incorporate easy recycling features for when it reaches the end of its life? Also, built-in-obsolence must go.

...built-in-obsolence must go!

Consumers should think twice before upgrading their smartphones, tablets etc. With little or no recycling of e-waste where do you think your still working but "old" smartphone goes when you upgrade? A lot of the time it ends up in rural villages in China where the hazardous components leach into the water, soil and hands of the villagers.

Consumers think twice before upgrading

We all have a role in debunking the grey shades of rare earths

There is a role for everyone if we are to lead clean and smart lives that do not cost the earth. We need to clampdown on the black market and debunk the grey shades of rare earths.

ABBREVIATIONS

13FYP	13 th Five Year Plan (2016-2020)
AQSIA	State Administration of Quality Supervision, Inspection and Quarantine
China CDC	Chinese Centre for Disease Control and Prevention
EIA	Environmental Impact Assessment
EPA	Environmental Protection Administration
GACC	General Administration of Customs of China
GIS	Geographic Information System
HREEs	Heavy Rare Earth Elements
INDC	Intended Nationally Determined Contributions
INTERPOL	International Police Organisation
LREEs	Light Rare Earth Elements
MEP	Ministry of Environmental Protection of China
MHREEs	Medium & Heavy Rare Earth Elements
MIIT	Ministry of Industry and Information Technology of China
MLR	Ministry of Land and Resources of China
MoF	Ministry of Finance of China
MOFCOM	Ministry of Commerce of China
NSA	Nation Standard Administration of China
REEs	Rare Earth Elements
REO	Rare Earth Oxides
SEC	Securities and Exchange Commission
SOE	State-Owned Enterprise
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UNFCC	United Nations Framework on Climate Change
UNODC	United Nations Office on Drugs and Crime
USGS	United States Geological Survey
VAT	Value Added Tax
WTO	World Trade Organisation

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