

Analysis of Processing Rare Earth Elements from Monazite as Tin by Product Mineral

Budi Nur Rochmadi

Institute Transportation and Logistics Trisakti Jakarta
brochmadi@gmail.com

ABSTRACT

This paper focuses on industry attractiveness of processing monazite into Rare Earth Elements (REE). The analysis is using Porter's Five Forces (PFF). PFF is a framework for the industry analysis and business strategy development developed by Michael E. Porter. In addition, we took four of the six Politics Economic Social Technology Environment and Legal (PESTEL) analyzes to see if there is an impact of these four factors in deriving the conclusion. With combined factors of increasing demand on China's domestic and the soaring world consumption of growing-demand products have impacted to shortfall of supply. The total demand for selected REE in 2040 is projected to increase around 300% compared to 2010. With current supply unless new Rare Earth Oxides (REO) production is developed, the shortage will become even wider. Based on PFF analysis the Rare Earth (RE) Processing Industry is currently attractive. It indicates that the existing players are enjoying healthy margin. Three factors are showing weak, they are: threat of entrance, rivalry amongst existing player and threat of substitution. The bargaining Power of supplier and bargaining power of buyers are both classified as moderate. In general, the industry outlook is promising as it is predicted the demand still outstrip the supply for the next 5-10 years.

Keywords : Rare Earth Element, Porter's Five Forces, PESTEL

A. Introduction

The initial purpose of writing this paper was to provide an alternative business strategy for PT Koba Tin (PTKT) in exploring and processing Monazite into Rare Earth Elements (REE). This is in line with the expiration of the Contract of Work (CoW) in 2013 and approaching the IUP (Mining Business Permit) from 2013 to 2023 (KobaTin, n.d.). Under IUP, the mining area will be limited to 25,000 ha or the equivalent of 40% down from the previous CoW. Therefore, this decline is expected to have an impact on its financial performance in the future. In 2013, unfortunately the PKTK was unable to renew the contract. However, with the increasing demand for high technology and environmentally friendly technology, this will increase the demand for RE in the future. A study for this industry might provide a clear perspective on how this RE

Processing industry shapes business as a whole in general.

Out of several major mineral associated on Tin Ore processing; Monazite is chosen as the prime product to be explored. The derivative product of Monazite as REE is potentially very promising as its application caters for so many different industries and its trend is increasing in term of value and demand. This paper focuses on industry attractiveness of processing Monazite into REE as by product mineral from tin mining.

B. Literature Review

From the mining research there are at least 26 minerals found and associated with Tin. Nevertheless, not all the minerals are found in one place, some minerals are predominantly occupied the associated tin minerals and some others are considered

insignificant. It occurs because the way it was formed centuries ago, some minerals are associated each other due to holding similar or common characters such as hardness level, specific weight, magnetic attractiveness, etc. Such common characters have created strong bound to attract each other.

In general, some of minerals that have dominant position are: Ilmenite, Monazite, Rutile, Xenotime and Zircon. The name monazite comes from the Greek μονάζειν (to be solitary), in allusion to its isolated crystals. There are five different most common "kinds" (actually separate species) of monazite, depending on relative elemental composition of the minerals. Monazite can be isolated as a nearly pure concentrate by the use of gravity, magnetic and electrostatic separation. In the tin mining industry, those processes are usually done at Amang Plant. Monazite is radioactive – because of Thorium content in monazite, sometimes highly radioactive, and specimens are often metamict.

The term “rare earth” is the English translation of French terre rare (terre refers to an oxide). The rare earth minerals are not called rare because they are truly rare. They are called rare because it is very difficult to isolate these elements individually and it takes a lot of skill to do that. REE (with the exception of the radioactive promethium) are relatively plentiful in the earth's crust. As defined by IUPAC (International Union of Pure and Applied Chemistry), rare earth elements (REE) are a collection of 17 chemical elements in the periodic table. (Merz, 2011). REE are acknowledged by the U.S. Geological Survey (Hurst, 2010a) as being critical to many high technology and environmental applications. They are essential in emerging technologies such as hybrid cars, wind turbines, and phosphors utilized in flat screen display panels, amongst many other applications. Below is a list of the main uses:

- a. REE Applications in Wind Turbines Industry:

Wind Turbine uses natural wind energy to generate green zero emission electricity with magnets moving past stationery coils of wire. Permanent rare earth magnets enable generators of wind turbines to increased reliability and efficiency; reduces expensive breakdowns and maintenance expenditures; and also, as critical element for 3MW+ and off-shore turbine segments.

- b. REE Applications in Auto Catalyst Industries

An automotive catalytic converter (auto cat) used to filter & reduce harmful car exhaust emissions from entering the atmosphere. REE plays an important role in chemical reactions in auto catalyst and allows to run at high temperatures, extending durability and also reducing the amount of platinum and other precious metals required thereby lowering costs.

- c. REE Applications in Hybrid Vehicle Industries

Hybrid vehicle cuts fuel use by combining gasoline engine, battery-powered electric motors and brakes that capture energy from stopping. For every 1 Hybrid Car is estimated to contain 0.5-1.9 kg of Nd (Merz, 2011).

In summary Neodymium is majorly used in magnets application, Lanthanum is majorly used for batteries and fluid cracking catalysts (FCC), while Cerium is majorly used for auto catalysts, polishing powder, and glass additives. The data is showed in the following table.

Table 1. Percentage Usage of Rare Earth Elements in Each Application

Application	La	Ce	Nd	Pr	Sm	Eu	Gd	Tb	Dy	Y	Other
Magnets			69	23			2	0	5		
Battery Alloy	50	33	10	3.3	3.3						
Auto catalysts	5	90	3	2							
FCC	90	10									
Polishing Powder	32	65		3.5							
Glass Additives	24	66	3	1						2	4
Phosphors	8.5	11				5	2	5		69	
Ceramics	17	12	12	6						53	
Others	19	39	15	4	2		1			19	

Source: (Lynas Corporation, 2010)

Compared to others, the growth of magnets is estimated to be the highest, although the occurrence could be larger than expected. Growth of rare earth usage in glass industry is estimated remain the same as previous years. It is negligible due to rapidly falling off of glass usage in television and computer screens, replaced by plasma displays and LCDs. Adamas Intelligence reports that permanent magnets and catalysts were collectively responsible for over 60% of global TREO (tons rare earth oxide) consumption in volume and 90 % in value in 2018 (Castilloux, 2019).

The green technologies that currently use rare earths are: magnets (hybrid and electric vehicles, wind turbines), automotive catalysts, energy efficient lighting (CFL, LFL and LED), batteries for hybrid vehicles and industry catalysts. Of these applications, the highest growth rates are projected for permanent magnets, particularly for wind turbines, hybrid/electric vehicles and hard disks.

The principal sources of REE are the minerals bastnasite, monazite, xenotime, loparite, and the lateric ion adsorption clays. The relative abundance of REE within and among deposits is highly variable. USGS reported that at least 44% of world REE production is a by-product (Long et al., 2012). Despite their high relative abundance, rare earth minerals are more difficult to mine and extract than equivalent sources of

transition metals, due in part to their similar chemical properties; making the REE relatively expensive.

USGS (2020) estimates the global reserves of the sum of all rare earth oxides (REO) to be at 120.000.000 metric tons REO. Global mine production was estimated to have increased to 240,000 tons of REO equivalent; a 10% increase compared with that of 2019. Hereby, the reserve is defined by USGS as “the part of the reserve base which could be economically extracted or produced at the time of determination”.

Over 10 years the global reserve has increased 10 million tons REO after some projects both outside and inside China have operated and produced. In outside China, main reserves occur in Australia, Brazil, India, Russia and Vietnam. There are a number of countries where larger deposits are known. Among them are United States, Canada, Greenland, South Africa and Madagascar. Total world reserves outside China are 76,000,000 metric tons REO, contribute 63% of total estimation of world reserves.

During the past 10 years, though China has dominantly supplied the world's RE as concentrates, intermediate products, and chemicals however the percentage is decreasing along with the latest mining operation and production open outside China.

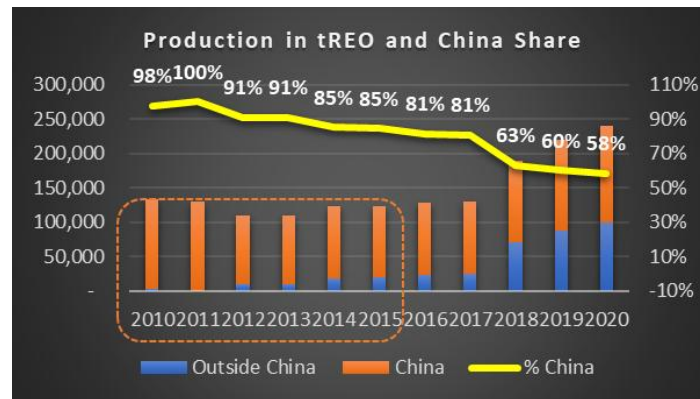


Figure 1. Production REO China and Outside China

Source: Created by author data taken from USGS, MCS – Rare Earth from 2011-2021(USGS, 2021b)

The export ban imposed by China during 2010-2015, somehow brought blessings in disguise where other countries began exploring and producing REE. This shows in the figure 1 that the portion “Outside China” is getting bigger starting in 2016. By 2020, production outside China almost catch up with China production volumes.

RE minerals give beneficial to the industry through their ability in reducing the weight, emissions and energy consumption thus, allowing industries to have greater efficiency performance, miniaturization, higher speed, durability and thermal stability.

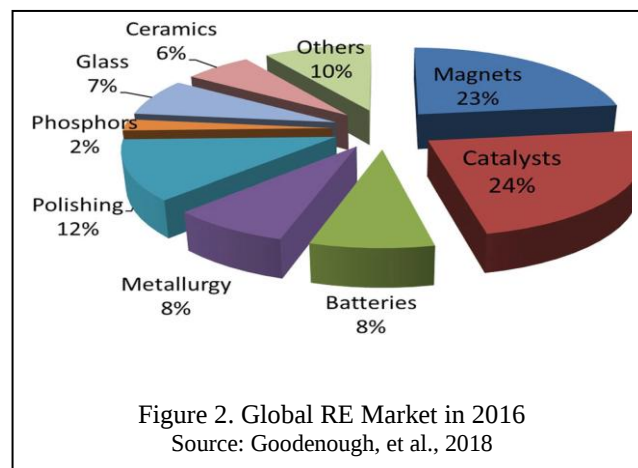


Figure 2. Global RE Market in 2016

Source: Goodenough, et al., 2018

The figure 2 is showing data of estimated global rare earth consumption and market in 2016 by applications as reported by (Goodenough et al., 2018).

The chart clearly mentioned that the rare earth elements used in the magnet and catalyst industry are the highest usage by volume percentage, around 23% and 24%, respectively.

The total demand for rare earths in 2040 is projected to exceed 300,000 tons of

REO, an increase of 200,000 tons of REO compared to 2010, or an increase of around 300%. With significant wind and EV growth, the increases were even dramatic. In 2040 it is projected that the demand will reach above 500,000 tons REO.

The following figure is showing the changes in market demand from 2010 to 2040, compared between organic growth and

quantum expansion of Wind and EV industry.

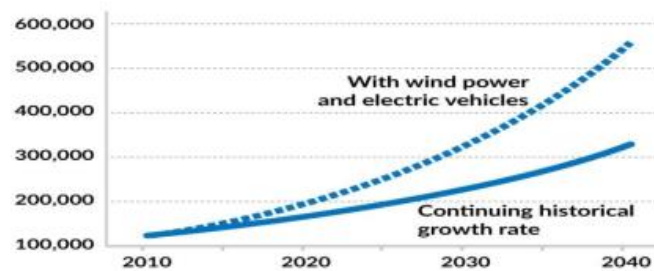


Figure 3. REE: Demand–Supply Balance and Projections to 2040 (metric tons)
Source: Geopolitical Intelligence Service (GIS), 2018 in (Umbach, 2020)

The future supply depends on some key factors such as development of total China REO production, progress of China export quota, and development of production outside China. Back in the period 2007–2015, China exercised control tight export. The policy to reduce exports quota was taken by China government due to their increasing concerns about environment risk of radioactive waste. In addition to setting export quotas, the Chinese Government has encouraged the export of high-value downstream products and discouraged the export of raw material. In 2007, the Government introduced an export duty on rare-earth products to restrict the export of products that consume large amounts of energy to produce in order to protect the domestic supply of strategic minerals. The tax amounts are range between 15 – 25% (Tse, 2011).

Argusmedia, (2021) forecasts that the demand for most REE will increase in line with the increasing application of clean technology. Cerium (Ce) and Lanthanum (La) will be the dominant element since those two elements are applied in most applications. Due to increasing demand of neo-magnets in industry and scarcity of

neodymium elements in rare earth, neodymium balance is projected to be minus over 7000 metric tons of oxides in 2030 (Castilloux, 2019).

For summary, as forecasted by Adamas Intelligence (Castilloux, 2019), and Argusmedia, (2020), rare earth supply will be continuously tight for some elements due to increasing demand and scarcity of supplies. China demand will not be covered only its own supply but it will need to be filled up by importing from other countries like Myanmar and US. Meanwhile, rest of the world should start to consider in fulfilling their demand through mining or production, or even recycling.

The figure 4. shows the moderate price development up to the end of 2010 and the steep increase due to the increased global demand and the reduction of China's exports. This steep price increase was not only affecting REE for which supply shortages are forecasted but also less scarce REE such as cerium and Neodymium. After China loosen the export quota, price is back into normal. In the year 2020, due to pandemic the demand of REE experience contraction but the price is maintained the same as previous years.

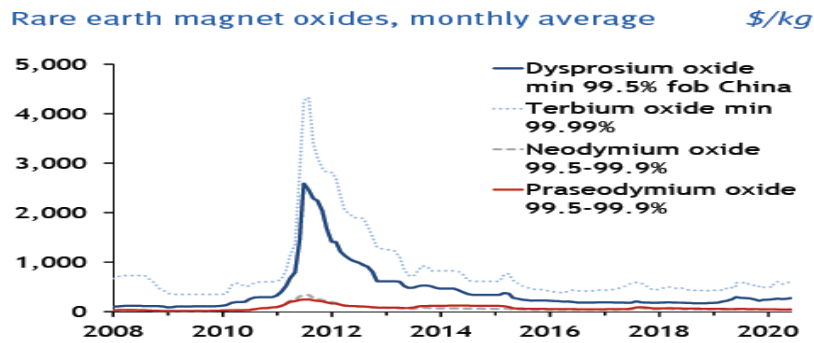


Figure 4. Price Development of REE
Source: (Argusmedia, 2020)

C. Research Methods

Our methodology is constructed from combinations of several approaches or strategic frameworks namely.



Porter's five forces is a framework for the industry analysis and business strategy development developed by Michael E. Porter of HBS in 1979 (Porter, 1980). It draws upon Industrial Organization (IO) economics to derive five forces that determine the competitive intensity and therefore attractiveness of a market (Porter, 2008). This analysis will provide insight of what forces work on RE Processing Industry and thus give us hints to do for the next step on which direction that we should focus on.

The PESTEL (Political, Economy, Social, Technology, Environment, Legal) framework is designed to provide an analytical tool to identify different macro-environmental factors (Sammur-Bonnici & Galea, 2015) that may affect business strategies, and to assess how different environmental factors may influence business performance now and in the future. To minimize very complex analysis, Porter uses PESTEL as the extended forces to see how the macro-environmental factors affect to the existing Five Forces so to emphasize the study on the existing Five Forces. Many factors may have an effect on business success which key drivers of change will potentially have strategic and competitive consequences.

Only 4 out of 6 factors will be analyzed on this study namely Political, Economy, Technology, and Environmental factors. Those factors are considered to have significant impact on the REE processing industry. In brief, PESTEL comprises of following factors:

Table 4. PESTEL Analysis

Factors to be analyzed	
Political factors - Stability of government - Trade regulations and Tax policies - Entry mode regulations	Technological factors - New Technologies - Pace of technological innovations and advances - Pace of technological obsolescence
Economic factors - Demand Fluctuation - Interest rates and Inflation	Environmental factors - Environmental protection laws - Waste disposal laws - Energy consumption regulation
Factors not to be analyzed	
Social Factors - Population demographics - Distribution of Wealth - Educational levels	Legal factors - Competitive regulations - Health and safety regulations - Product regulations

Data are collected through company annual report, existing player report, industry report, internet browsing, industry annual circular or publication, and several readings from various sources.

D. Result and Discussions

The Rare Earth industry can be divided into four major value chain companies

- a. Rare Earth Mining and processing are the companies that greatly engaged in activities of mining, separating, purifying and extracting the ore until it turns into RE Oxide, compound (Nitrate, Carbonate, etc.) or some even can process up to alloy or metal.

- b. Manufacture of RE Technology Intermediate and components are the next value chain companies that processed the input from RE processing companies for specific or general usage, e.g., magnetic bearing, capacitor, etc.
- c. OEMs are the companies that assemble part of RE component or intermediate's part for end-use product, e.g., fluorescent lamp, hard-disk, hybrid engine, etc.
- d. End use product manufacturer are companies that operate in manufacturing final product which using part or component that made of REE.



Figure 5. RE Value Chain
Source: (Research Greater China, 2001)

Our analysis focuses on RE Processing Industry that deals with extracting high purity ore turning it into oxide, compound or metal and alloy as the first part of value chain.

By using PFF Analysis we can map out most of the major forces influencing the competition intensity on particular industry. The competition intensity is referring more

on the overall profitability, as such the higher the profitability the more attractive the industry is. It works in the opposite direction too; the unattractive industry shows that the combination of forces acts to push down the overall profitability.

The major forces that highly connected to this industry can be mapped through following scheme.

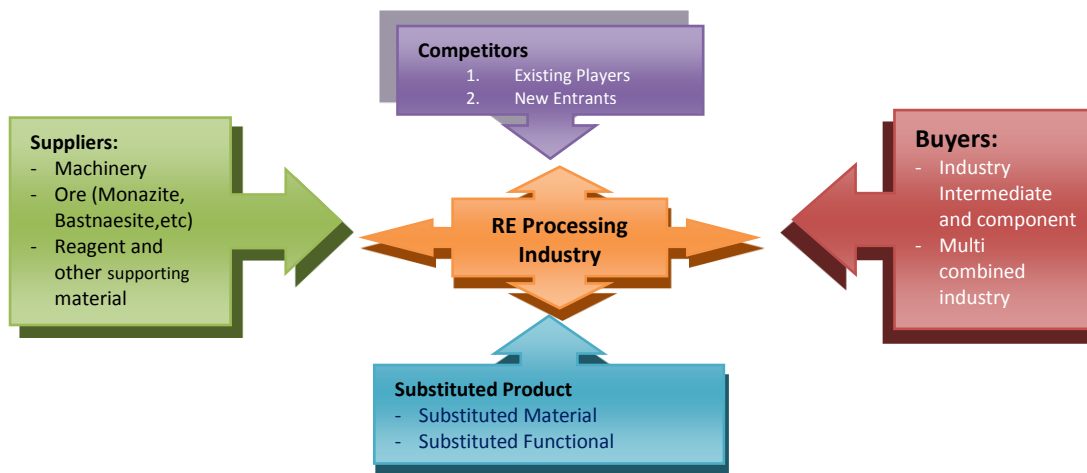


Figure 6. Industry Analysis Scheme (Five Forces)

The existing industry players can be divided into two major group players: China Group and Outside China Group. China group are state-owned companies that heavily controlled by government. Today, China dominates almost all steps of the rare earth supply chain, from mining to the manufacturing of permanent magnet used in high tech applications. In 2010, China holds

97 % of REO producers and supplies almost 100% of rare earth refining capacity. The percentage gradually decreases and reach into 85% of REO Producers and 90% of REE refining capacity by 2020.

To easily control production, China has consolidated the production area into several districts as shown on table 2.

Table 2. List of Existing Players in China

Name	Location	Reserve	Production	Remark
Baogang Rare Earth	Bayan Obo, Inner Mongolia China (Northern district)	56,392,000 – Bastnaesite & Monazite	55,000 tREO	By product of iron ore, mine. Focused on LREE.
Various	Southwest district: Shandong	4 million tons - Bastnaesite		Production - Focused on LREE.
Various	Sichuan	1.5 million tons Bastnaesite	10,000 tREO	Production – Focused on LREE.

Various	Seven Southern Provinces	1.5 million tons – ion adsorption deposit	40 – 50,000 tREO	Production – Focused on HREE.
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Source: (Merz, 2011), <http://www.businessinsider.com/rare-earths-map#ixzz1H1EaWs3o> ; (Insider, n.d.)

The second group belongs to Outside China Group. The group comprise of various countries but with share production of less than 42 % of REO production worldwide (USGS, 2021a).

Table 3. Existing Players Outside-China

Name	Location	Reserve	Production	Remark
Molycorp Minerals, LLC	Mt. Pass (USA)	Proven: 40,000t Probable: 960,000t REO in 13.8 mt ore (avg grade 8.2%)	Current 2,000 – 3,000 Production of REOs at the rate of 19,090tpy	Previously processing ore from stockpile, main : mixed REO for FCC catalyst. MP Materials bought California's Mountain Pass mine and other Molycorp assets in 2017.
Lovozerky Mining Company	Kamasurt Kola Peninsula Russia	1,150,000Loparite, processed to yield RE carbonate	4,400, shipped to Estonia, Austria Kazakhstan, China	High level of radioactivity in some zones of the mine Target cap in 2015 = 15,000 tREO pa
Indian RE Limited	Tamil Nadu & Kerala	Monazite	25 – 100 tpa	Expansion. Target capacity in 2015 = 10,000 tREO pa
Lynas Corp.	Mt. Weld (Australia / Malaysia)	17.49Mt at 8.1% REO (equivalent to 1.42Mt REO)	10,500t REO pa in 2011. Increase to 21,000t REO in 2013	Construction - Started operations in late 2011, full production in 2012.
Steenkampskraal Holdings Ltd	Steenkampskraal Mine in South Africa Hoidas Lake	799,700 Mt	Steenkampskraal: 2,500 tpa Hoidas: 3-5,000 tpa REO. Start-up 2014	Advanced exploration. Some preliminary test work completed. Market Capitalization: CAD\$78 million
Alkane Resources	Dubbo, NSW, Australia	73Mt @ 0.9% REO, 0.65Mt REO (a proven reserve)	1,200-1,400tpa REO in 2013/14. REOs (rich in Y)	by-products to zirconium chemical and niobium production.
Avalon Rare Metals Inc	NWT, Canada	HREE → Low ore grade overall (176Mt-1.43% REO)	Production 10,000tpy REO	Capital costs up to US\$890M for mine, mill and metallurgical plant – including US\$346M for separation plant
RE Resources Ltd	Bear Lodge, Wyoming, USA	9 Mt @ 4.1% REO 0.4 Mt REO (inferred)	Unknown	Resource engineering study underway. Process development commenced. Market Cap: CAD\$233 million
Other	Vietnam, Thailand, Malaysia	Monazite	1,800 - 2,000	Target capacity in 2015 = > 2,000 tREO pa

Source: (Chegwidden & Kingsnorth, 2010) updated by author from various sources

Threat of Entrant (Entry Barrier): Weak Factors Affecting Industry Attractiveness

Industry specific knowledge base and high capital investment are major entrance barriers for new entrants. Kingsnorth, (2010) depicts his finding that projects to be costly for shipping low grade concentrate over 100s km and it needs capital more than USD

40,000/t annual capacity to invest in developing a rare earth mine and processing plant. The industry knowledge-based is part of long learning curve and will face extremely difficult for new entrant to fit into current quality standard.

The existing industrial players (RE Processing) are also benefiting from patented

technology, access to raw materials and locations. Upper-stream rare earth business in general is highly controlled by government. The combined of those factors have resulted to the low of operating cost thus enabling the existing players to spend on R&D for refining or differentiating their products.

The development time of individual RE Project is relatively long, in average it takes 10-15 years from confirming proven resource until production start. (Kingsnorth, 2012)

Environmental Cost: Environmental cost as result of radioactive waste is very costly and requires government permission in handling and storing. China government forced producers to spend USD 182.5/ton product to protect their environment. (Hurst, 2010b)

Economic scale also plays major role. The main aim is to consolidate the production scale, maintain business sustainability and prevent from further environment deterioration.

Factors Affecting Industry Unattractiveness

Back in 2010-2014, the only factor that posed of affecting the unattractiveness of this industry is skyrocketing commodity price. It would stimulate new players to enter irrespective of high barrier entrance. Price had climbed up more than 500% as result of supply dropped below demand, a wide opportunity for new firm to start RE project. Lately, prices are no longer in a high position because China has lifted the export restriction and also new mines outside China have been operating. These factors have created an equilibrium situation where supply has narrowed the gap with the increased demand. In summary, the entire combined factors have **weakened the threat of entrants**.

Bargaining Power of Supplier: Moderate Factor Affecting Industry Attractiveness

Plenty suppliers of machinery and reagent with high quality product. Sources of

machinery and reagent suppliers are abundant. Data is easily accessed at website.

RE industry is important to the suppliers (miner) especially to those who want to concentrate on mining activities only. USGS (2010) (Long et al., 2012) reported that at least 44% of world REE production is a by-product. Ore mineral supplier view by product mineral as least profit generator.

Factor Affecting Industry Unattractiveness

Ore Mineral is not available everywhere, thus only several geographical areas could have economical reserve and potential to supply it. Outside China, mineral reserve account 50% but scattered to various countries. Only some are considered feasible to be commercially explored. Mining is subject to Government approval. Only few miners are granted resulting to concentrated mineral suppliers. Government permission and support are highly needed due to radioactive content in basic mineral sources such as monazite, etc. Overall, the threat of supplier is turning into **Moderate** due to the big influence of bargaining power of ore supplier, while it is weakened by machinery and supporting material supplier.

Bargaining Power of Buyer: Moderate Factors Affecting Industry Attractiveness

RE end-user Industries are growing thus stimulating the demand for RE intermediate product (REO, RE Carbonate, RE Alloy, etc.). Umbach, (2020) reveals his fact findings:

- a Forecasted growth of RE demand in 2030 will be over 300.000 tons organic growth and over 500.000 tons if wind turbine and EV growth as expected.
- b Magnet industry is the highest growth, Adamas Intelligence (Castilloux, 2019) depicts the incremental growth for Nd Oxide demand and by 2030 the supply may not be able to cater the existing demand.

Environmental awareness is increasing and driving demand for RE. Development

auto catalysts, light bulbs, wind turbines and magnetic coolers are some examples of the energy savings of RE products. Automatic catalysts are used to filter & reduce harmful car exhaust emissions from entering the atmosphere, fluorescent light bulbs provide 10x longer durability and require only ¼ power compared to conventional light bulbs, wind turbines are an environmentally friendly energy source and rely on Nd Magnet and magnetic cooling provides 50-60% energy savings compared to traditional cooling systems.

Factors Affecting Industry Unattractiveness

REO high price is weakening the purchasing power, especially for high-demand element. The soaring end use product price will reduce demand. Thereby End-use manufacturer will attempt to decrease the RE content in the end use products either by finding substitute or recycling the element.

Low switching cost. End-use manufacturers possible to switch to other supplier to guarantee supply continuity. Nevertheless, during supply scarcity period, it would be hard to do so. Potential backward integration by buyers. To secure RE supply buyers initiate to setup JV for producing REO. Japanese giant company Sumitomo, Toyota and Mitsubishi has signed agreement with various local RE supplier to produce high grade REO and other intermediate product. Narrow supply and demand gap: Balance supply and demand when the macro economy improves but supply increases. The gap between supply and demand has widened from 2010 when China restricted its exports and only after the WTO resolution, which caused China to lift its export quotas in 2015 (Wikipedia, 2021c). With the combined operation of new mines and China being added to the supply side, the gap is getting closer.

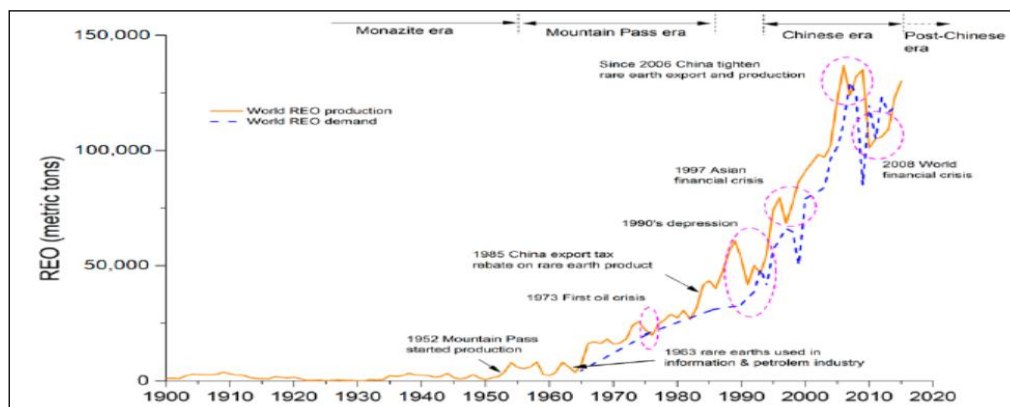


Figure 7. Global REE supply and demand

Source: (Zhou et al., 2017)

At time of reporting, the buyer position is moderate in dealing with REO producers, due to the narrowing of the supply and demand gap allowing buyers to choose REO producers, but it is also weakened by the fact that the number of suppliers may not be as high as in the past due to production costs and environmental burdens. Thus, the threat of bargaining power of buyer is considered moderate.

Rivalry (Industrial Competition): Weak Factors Affecting Industry Attractiveness

Few players while market pie is still big enough to everyone. World total production is only 0.2% of reserves, with China control 58% of the supply (USGS, 2021a). Price is controlled by market as the consequences of supply and demand gap. Supply dropped for high-demand elements as the production unable to meet the increased demand, it leaves big hole of demand side to

be filled in. In the same time demand tend to increase creating further big gap. REs are not commodity product but customer specific. Producing REO will require adjusting into client specification. Hence existing players can serve their own segments without having tight competition with others. Price is not the only factor for choosing REO supplier but other factors like physical properties of the rare earth products, consistent quality in large volumes and a long-term relationship are also playing big part.

Factors Affecting Industry Unattractiveness

Prior to 2015, there were more than 200 projects to build a new REE Processing plant (Chegwidden & Kingsnorth, 2010). However, after China lifted its export ban, some projects were no longer viable. Currently, there are several projects that are in the pipeline process. The following are two prospective projects that are ready to produce REO in the next 3-5 years, namely the Yangibana and Nolan projects. Therefore, they will increase the number of players in the short term.

Table 5. The Prospective Project after 2020

Name	Location	Reserve	Production	Remark
Hasting Tech Metal Limited	Yangibana, Australia	12.3 MT	TREO 8.500Tpa NdPr 3.400Tpa	Commissioning date 2023
Arafura Resources (ASX: ARU)	Nolans, Northern T, Australia	30Mt @ 2.8% REO 848.400 tREO	20,000 tpa REO NdPr Oxide 4.325 tpa	Bankable feasibility study 2019 Investment 2020

Source: Hasting Terchnology Metal Limited, Investor Presentation 202012 (Hastings Limited, 2020).; Arafura Resource Limited, Nolan Project 2020, (Arafura Resources Limited, 2020)

In 2023 onwards, it is expected that there will be over 7,500 tons of NdPr and 28,500 tons of REO per year to add to the general market. But most specifically, this project will fill the underserved segment of NdPr due to lack of production. However, the existence of a supply and demand gap, especially for the high demand elements that still exist and the overall magnetic demand which is still high, will provide sufficient space for each player to enjoy the pie. To conclude, rivalry amongst existing firm is **weak**.

Threat of Substitution: Weak Factors Affecting Industry Attractiveness

At present, no significant substitute in material and functional. According to Merz, (2011): substitution of REE in material is rare and it will need deeper research. In some cases, substitution requires totally new product design to enable its product working in an expected performance. It is

strengthened by USGS on its report that substitutes are available for many applications but generally are less effective (USGS, 2021a). Substituted in functional has been tried on hybrid electric vehicles. The design is practically available but it requires R&D for higher performance.

Factors Affecting Industry Unattractiveness

With the increasing price and shortening supply final manufacturer will force to invest R&D to find substitution of RE either by another material or reduce the consumption of RE on its final product. It clearly shows that the threat of substitute of RE both in functional and material is insignificant or weak.

Characteristics of the Rare Earth industry

- a High capital
- b Raw Material supplies dependent

- c Market growth highly dependent on Economic growth
- d Demand surpasses supply for specific elements
- e High Environmental Risk
- f Sophisticated and patented technology

Overall assessment result: The industry at present is **attractive**. The profit margin is healthy enough for the existing player to grow.

PESTEL (Extended Forces)

Following are 4 out of six factors of extended forces that have major impact in the industry:

Political (P)

Mining concession is subject to government approval. Cited from USGS (2010)(Long et al., 2012), the report shows the overview of time required for the approval procedure and construction work since the discovery of the deposit will vary significantly from 5 - 50 years. It is further stressed by Umbach, (2020) that company at least spend 10 years for from successful exploration to political and industrial consent at all levels, and another 10 years to build the infrastructure for the mine to be operational. Since 2009, China has started a comprehensive series of regulations and standards in the aim to protect rare earth resource and develop in sustainable way. By May 2010, China formulates Access Conditions of Rare Earth Industry. This regulation stipulates the minimum limitation of production scales, operation and technological equipment, the minimum capital ratio of fixed assets, thresholds and requirement for environment protection. (Merz, 2011). Future rule may create favorable or unfavorable to the industry. As it is explained on previous paragraph, any new regulation issued by government may impact to the business sustainability.

Economical (E). macro/micro

Economic boom will increase demand on its RE application. Goodenough et al.,

(2018) predicted that sales for hybrid and electric vehicles production of HEVs and EVs are expected to increase from 2.3 million units in 2016 to more than 10.1 million units in 2026. The result will drag the demand for neodymium-iron-boron (NdFeB) magnets to nearly 140,000 tpa (2026) from more than 120,000 tpa as demand in 2020. The increasing production will still not be able to catch the demand. The projected demand for wind turbines also shows an increase, from 2020-2026 the demand for wind turbines will increase by 175%. The consumption of Nd magnets will reach 13% CAGR (Argusmedia, 2021).

Technology (T).

Limited or even patented technolog. List of patented on RE products (Constantinides, 2010); Hitachi patent(s): Key Hitachi US 5,645,651 ('651) patent expires in July 2014; Hundreds of additional Hitachi patents; Hitachi has refused to license additional manufacturers. Magnequench patent(s) USD 5,411,608 patent expires May 2012, directed generally to neo alloys containing cobalt. In term of technology of separation and smelting, China owns internationally advanced RE technology. It is the only country in the world that can provide rare earth product of all grades and specification (Castilloux, 2019).

Environmental (E).

Mining and processing REEs present environmental risks. According to an article published by the Chinese Society of REs, "Every ton of rare earth produced generates approximately 8.5 kilograms (18.7 lbs) of fluorine and 13 kilograms (28.7 lbs) of dust; 9,600 to 12,000 cubic meters of waste gas containing dust concentrate, approximately 75 cubic meters of acidic wastewater plus about one ton of radioactive waste residue (containing water)." (Kalanztakos, 2017). Cost for fulfilling environmental standard. Though such rigid environmental standard is still questionable to be fully implemented in China, but in general the cost of fulfilling the

environmental standard has been endorsed. There would be an additional cost for environmental protection efforts for every ton of product. Hurst, (2010) stated such cost would be an average USD182.5 per ton of product. Accrual Cost for claim in case any environmental damage. There will be no distinctive cost to accrue on potential environmental damage nevertheless with the pressure of high safety standard there would be some cost to be accrued in case the environmental risk is occurred.

E. Conclusion

Monazite as by product of tin mining process, has economic potentiality to be processed further as Rare Earth Elements (REE) especially Cerium (Ce), Lanthanum (La) and Neodymium (Nd). REEs are high critical sources for some industries such as wind turbines, auto catalysts, hybrid and electric vehicles, fluid cracking catalyst (FCC) and Light Emitting Diode Lamp (LED), etc. All of those industries are projected will still be in positive growth in the future, it infers that REE usages are steadily growing. China is currently accounted as biggest REE producer in the world. Though China only has 37% proven reserves compare to total world reserves, but it can contribute 58% of total world production 240,000 tons REO or around 140,000 tons REO in 2020. Remaining 100,000 tons REO is the productions of other various countries. REE demand is basically driven by intermediate-end industries with potential exciting growth rate in the future such as magnets (23%, use Nd and Pr), polishing (12 %, use La and Ce), metal alloys for batteries (8 %, uses La, Ce and Nd), phosphors (2% use Y, La, Ce), ceramics (6% use Y, La, Ce, Nd, Pr) and catalyst (24%, use La and Ce). The total demand for rare earths in 2040 is projected to exceed 300,000 tons of REO, an increase of 200,000 tons of REO compared to 2010, or an increase of around 300%. With the significant growth of wind turbines and EVs, an even dramatic increase in 2040 it is

projected that demand will reach above 500,000 tons REO.

With few prospective mining to operate in 2023 onward and the quota regime exercised by China, the projected demand will definitely outstrip the world supply. China has reduced its export quotas gradually since 2007, although after the dispute was resolved at the WTO and production returned to normal in 2015, the supply and demand gap is projected to remain wide. Thus, it sparks the incentive to other countries to start their own projects to fill the demand. It is projected that in 2025, supply-demand balance of Neodymium (Nd) will be minus over 7.000 tons REO. This situation had also impact to the steep increase of REO price, making the industry being slightly attractive.

Based on PFF industry analysis developed by Michael E. Porter, the rare earth industry is currently **attractive**. The summary of five forces analysis is:

- a Threat of Entrant (Entry Barrier): Weak
- b Bargaining Power of Supplier: Moderate
- c Bargaining Power of Buyer: Moderate
- d Rivalry amongst existing players: Weak
- e Threat of Substitution: Weak

Other aspects that are considered in analyzing this industry are political, economics, technology and environment. From the political side, the industry is subject to government approval, thus future rule may create favorable or unfavorable to the industry. From an economic point of view, the industry depends on the economic boom as it will increase the demand for its RE applications. From a technological aspect, some manufacturers enjoy the existence of limitations and even technology patents for their products. In term of technology of separation and smelting, China owns internationally advanced RE technology, making China as the only country that can produce all grade of rare earth. In the environment aspects, producers

should consider the environment risks from REE mining and processing especially the water pollutants and radioactive waste.

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