China’s Path towards Global Green Governance on Rare Earth Elements: Challenges and Opportunities

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Abstract
In light of surging demands for critical minerals and its rising profile as a global provider, China can no longer dismiss the negative ecological externalities resulting from its unregulated, near-monopoly production of rare earth elements (REE) since the 1970s. REE, consisting of 17 elements with naturally enhanced chemical properties, is critical for manufacturing future green infrastructures and technologies. However, the extraction and refining processes are resource-intensive and toxic to the immediate environment, further exacerbated by improper radioactive waste management, underfunded land restoration, and illegal mining. By extension, China’s supply supremacy came at the cost of socio-ecological deprivation disproportionately experienced by the local community compared to the beneficiary beyond borders. This study aims to assess the challenges and opportunities for China as they seek global leadership in green governance through its post-reform sustainable development model guided by Ecological Civilization (EC) principle. Using narrative analysis methods, we seek to assess the intersection among three threads: the historical account of China’s REE global dominance, their elite-based approach to governance, and the unmitigated socio-ecological impacts on the local community; regarding EC and its derivatives. While domestic consolidation is strategically integral to China’s EC-guided development agenda, it poses dormant risks of supply volatility for international markets, and innovative secondary production becomes the new source of competitive edge for supply diversification and norm-making power.

Keywords: China; green governance; rare earth elements; ecological civilization

Abstrak
Pesatnya kenaikan angka permintaan untuk mineral unggul dan statusnya sebagai negara penyedia mendorong Republik Rakyat Tiongkok (RRT) untuk mengatasi dampak negatif eksternalitas ekologis yang bersumber dari praktik hampir-monopoli dan lemahnya regulasi industri unsur tanah jarang (UTJ) sejak 1970-an. UTJ terdiri dari 17 unsur kimia dengan kandungan sifat-sifat alamiah yang unggul guna memproduksi infrastruktur dan teknologi hijau di masa depan. Namun, proses ekstraksi dan penyulingannya boros sumber daya dan beracun bagi ekosistem sekitar; kian diperumit dengan buruknya manajemen limbah radioaktif, lemahnya pendanaan restorasi lahan, dan penambangan ilegal. Dampaknya, supremasi UTJ diperoleh Tiongkok dengan mengorbankan kesejahteraan hidup komunitas lokalnya; kerugian yang tidak ditanggung secara proporsional jika melihat kebermanfaatan UTJ secara universal. Penelitian ini bertujuan untuk meninjau faktor-faktor yang menjadi tantangan dan kesempatan bagi RRT dalam mewujudkan aspirasi kepemimpinan hijau secara global lewat model pembangunan berkelanjutan pasca-reformasi yang berbasis prinsip Peradaban Ekologis (PE). Dengan menggunakan metode naratif, kami hendak memeriksa irisan-irisan di antara tiga narasi: latar belakang historis dominasi Tiongkok pada industri UTJ, retoriaka hijau elit Tiongkok, dan lemahnya penanganan dampak sosio-ekologis secara lokal; dengan prinsip PE beserta turunannya sebagai titik referensi. Kami menyimpulkan bahwa meskipun konsolidasi domestik penting secara strategis bagi kesuksesan agenda pembangunan Tiongkok berbasis PE, ia berpotensi menimbulkan krisis suplai bagi pasar internasional, dan terobosan inovatif pada sektor...
produksi alternatif menjadi sumber daya saing baru untuk mencapai kemandirian suplai dan mempengaruhi pembentukan standarisasi.

Kata kunci: Republik Rakyat Tiongkok; pemerintahan hijau; unsur tanah jarang; peradaban ekologis

**Introduction**

Rare earth elements (REE) or minerals and metals—hereafter used interchangeably—are the fabric of a low-carbon, energy-efficient, hence, “green” future. Their unique physicochemical, magnetic, and luminous properties enable and enhance the production of technologies with greater efficiency, durability, and thermal stability (Balaram, 2019). Combined with other critical minerals, such as lithium and cobalt, varying proportions of REE make up the basic technology that enables a wide variety of products whose utility has already pervaded our modern life. For example, cerium is essential to LED screen and optical glass polishing, lanthanum to the petroleum refining, and neodymium to permanent magnets, enabling efficient power generation of wind turbines and electric vehicles (EV). As much as 600 kg aggregate amount of dysprosium, neodymium, and praseodymium is needed to operate a single wind turbine while manufacturing each EV battery needs one kg of cerium and lanthanum—both still largely irreplaceable nonetheless (China Power Team, 2021; FP Analytics, 2019; Adamas Intelligence, 2019a).

International Energy Agency (2022) estimates a 40% increase in REE’s share of global total demand over the next two decades, alongside other critical minerals: nickel and cobalt (70%), copper (40%), and lithium (90%). This trend reflects an international commitment to transition away from high greenhouse gas (GHG) emissions and hydrocarbon-fuelled economies in light of ever-intensifying ecological disasters.

As of 2021, China accounts for approximately 54-60% share of global REE mining production, a steady drop since 2010 (97%) in light of the REE supply crisis (Wubbeke, 2013; Shen et al., 2020; Mitchell, 2022). However, far from declining, China’s stranglehold over the minerals has only been increasing afterward; by capturing the majority of higher value-added downstream sectors in oxides (85%), metals, alloys, and magnets (90% each) (Adamas Intelligence, 2019a). In terms of consumption, China absorbed at least 80% of domestic production in 2015 and 70% of world production in 2021 and is expected to grow 25% by 2030 (Shen et al., 2020; Williams, 2021). By carefully planning the long-term project of the REE industry since the 1970s, China has successfully converted its natural endowment to serve its political, economic, and environmental ends.

Despite their green dimension, REEs are nonrenewable resources that still leave behind a material and carbon footprint, albeit at a fractional rate to hydrocarbons, which damages the surrounding ecological system (Hund et al., 2020). The extraction and refining process is water-intensive and toxic, caused by chemical substances needed to remove the topsoil, leaving behind radioactively-contaminated residue that could end up bioaccumulating in humans, livestock, and crops. Several documented pieces of evidence revealed that mining activity in Baotou contributed to the emergence of “cancer villages” and livestock teeth deformity, which enforced community displacement. In Bayan-Obo, the tailing pond
leak posed a risk of contaminating the Yellow River as a key drinking source which spurred acts of civil resistance in Zhongshan and Yulin, which were met with detention (Nayar, 2021; Kaiman, 2014).

On the other hand, since his early presidency, Xi Jinping has repeatedly mentioned the concept of “ecological civilization” (EC) as a Chinese way to reframe the proverbial economic development-environmental complex during his keynote speech at several top-level environmental conferences. Outwardly, this is manifested in China’s increasing presence in multilateral agreements, such as adopting Paris Agreement in 2016 and the UN 2030 Agenda for Sustainable Development Goals (SDGs), facilitating major environmental conferences, such as the COP15 biodiversity summit in 2021 (Greenfield & Ni, 2021). The decision of the Trump-led United States, as its Western counterpart, to pull out of the former convention has also added an extra layer of importance for China as a provider of common goods. Since the 12th Five-Year Plan (FYP) to the latest 14th iteration, EC as a guiding principle has been adopted to the document. Moreover, the targets listed under the “Green Ecology” category in the 14th FYP, which includes water and soil pollution prevention and hazardous waste disposal, are valued as binding—although REE-related issues are not explicitly mentioned in the official document. Recent trends saw China’s shift toward an environmentally conscious development.

This research assesses the intersection among these three intertwining phenomena: China’s REE prime stakeholder status, its green rhetoric, and the inadequate mitigation of the socio-ecological impact at home. Those will be filtered through China’s approach to global green governance under the EC guiding principles to assess the challenges and opportunities, primarily for China’s leadership in the REE industry and, additionally, for Chinese nationals and foreign actors. This research aims to explain the nuances of the complex situation of China’s REE industry and hopefully inform the readers about what to expect as the REE industry progresses within the grander, concerted effort to combat climate change.

**Literature Review**

Generally, two types of literature discuss China’s REE industry and policymaking: natural science and social science—including the overlap between them. Biological science-based research mostly assesses the impact of either suboptimal or irresponsible mining on the surrounding environment and humans by systematically measuring and quantifying the adverse and the concurrent beneficial factors to formulate an informed policy recommendation. Bai et al. (2022) evaluated the resource and environmental carrying capacity, “the number of lives that can be sustained without destroying the ecosystem, emphasizing the goal of not destroying the ecosystem to achieve sustainable development”, of the selected 8 mining areas in China. They use the combination of the Analytic Hierarchy Process (AHP) and entropy methods to evaluate the “support capacity” and “pressure capacity” of a given area. Some notable results are in the “pressure capacity”. The weight of ecological damage losses is the largest, while social pressure is the lowest. In the “support capacity”. The weight of ecological damage losses is the largest, while social pressure is the lowest. In the “support capacity”, the favorable climatic condition is the largest, while the economic development scores the most poorly. Shin et al. (2019) and Pagano et al. (2018) assessed occupational REE exposures. They found that e-waste recycling...
workers are exposed to a higher risk of skin irritation and respiratory, nervous, and liver toxicities. In contrast, bioaccumulation of REE is found in scalp hair and urine of in-site mine workers.

Social science-based research generally differs in the theoretical or conceptual framework or the research subject. Shen et al. (2020) chronicled the historical account of China’s public policies on REE from 1975-2018. Teng & Wang (2021) reviewed the three decades of evolution of China’s climate governance system driven by the state’s quest for performance legitimacy. Martin & Iles (2020) proposed the dual concept of environmental justice and intergenerational justice to provide an ethical framework useful to mitigate the present and future impact of REE mining. Packey & Kingsnorth (2016) assessed the impact of unregulated ionic clay type, which result in rampant illegal mining practices within China, which drive out competitors due to depressed market price. Kostka & Zhang (2018) analyzed the impact of introducing a new environmental actor constellation within China’s internal government and big data analytics under Xi’s administration. Dong (2020) proposed the internationalization of China’s idea of a community of a shared future for humanity (CSFH) as a guiding principle in multilateral cooperation in a new type of international relations featuring win-win cooperation, Belt and Road Initiative (BRI), and South-South relations.

Our standing position is to explain the influence of ideology deeply embedded in Chinese culture, simultaneously a catalyst and compromising factor, in navigating their REE industry’s development path between economic growth and ecological accountability. Instead of introducing novelty in the analytic method or theoretical framework, this research builds on the established evidence extracted from secondary literature. It attempts to recontextualize the REE industry’s development path as a proxy of the Chinese approach to green governance. Ecological civilization will serve as the frame of reference through which the development narratives are understood and discussed. This research contributes twofold: 1) By providing a storied and nuanced description of the situation surrounding China’s REE industry and 2) By bringing forward the ideological aspect of China’s approach to governance on REE to the discussion.

**Conceptual Framework**

In a broad sense, ecological civilization is a set of values and development concepts enshrined in the Constitution of the People’s Republic of China (PRC), which emphasizes safeguarding ecological services and natural resource protection and improvement (Hanson, 2019; Pan, 2018). It also alludes to socialism. The term was first coined in an agricultural discussion between the Soviet Union and China in 1980, and indigenous cultural origin, Taoist belief in a harmonious relationship between nature and humans (Hanson, 2019). The concept has been given a new life through its incorporation into official documents, such as the constitution as a part of Xi Jinping Thought and the FYP from the 12th edition (2011-2015) until the 14th (2021-2025). Furthermore, the contemporary reinterpretation introduces the “5-in-1 approach,” which adds the elements of politics and culture to the existing sustainable development triangle of environmental, economic, and social—making it sustainable development with Chinese characteristics. Politics element
implies central authority and planning to nurture the development, while the culture implies a differentiated and culture-specific approach to governance. Hanson (2019) noted that this approach should be considered a “balancing effort that at times genuinely will provide for a filtering that places nature first”. EC will also remain relevant for the coming years as the guiding principle to achieve the 2035 target of a “Modern PRC” and fully develop into a prosperous “Beautiful PRC” by 2050.

Bear in mind that while EC is not necessarily useful to evaluate policy implementation forensically, we argue that it is an instructive tool as it reflects not only the general trend pursued by the authority but also the procedure of policymaking within their internal bureaucracy. Due to its looseness as a “guiding principle”, inconsistent, not least contradictory, policy among subnational government bodies is inevitable, therefore a careful reading on the added context and what is spelled out and omitted—also what is quantified and mentioned—in the official documents should be underlined. In the subchapter on China’s green rhetoric, we will further elaborate on the roots of EC in the characteristically Chinese approach to governance and its derivatives in achieving sustainable development.

**Methodology**

This qualitative-based research used a narrative method of analysis in which “events are perceived as important, selected, organized, connected, and evaluated as meaningful” (Given, 2008). Therefore, we recontextualized existing evidence by placing it within three narrative threads to assess the challenges and opportunities that arose from it regarding the ecological civilization principle. We gathered the data from open-access websites that provide books, journals, working papers, official documents, issue briefs, and articles. The data types were mostly secondary literature and a few publicly available official documents.

**Result**

*China’s Unparalleled Global Dominance on REE: From Mining to Market*

China has cemented its position as the prime stakeholder in the global REE industry in virtually all respects, firstly, as a result of a decades-long head start, bypassing NRC (Nuclear Regulatory Commission)/ IAEA (International Atomic Energy Agency) regulation on radioactive thorium in 1980, of which, unlike the US and other compliant members, China was only an observer (Kennedy, 2019). After that, a large proportion of REE production capacity was effectively transferred from the US to China and by 1995, China’s total output had surpassed the rest of the world (RoW) combined. Two years later, China overtook the US in total cumulative patents issued, thanks to the ring-fencing strategy—the first US patent was in 1950, while China was in 1983 (Balaram, 2019; Kennedy, 2019).

Moreover, China has capitalized on that early momentum through careful, long-term, and strategically coherent CPC-guided industrial planning. Shen et al. (2020) defined five stages of evolving China’s REE public policy from 1975-2018. In the initial stage (1975-1990), upstream, low-value-added production for export, in the form of ores and concentrates, was prioritized. Low production costs and lax administrative regulation made the upstream sector profitable. At this point, the central government has already recognized the adverse impact of rampant
illegal mining on price fluctuation and ecological damage but chose not to do away with it in favor of economic growth. Export tax rebate was introduced, doubling the growth of mixed ores and oxides from 1985-1990; Japan and the U.S. were the major importers. The second stage (1991-1998) saw the fastest mineral production growth at an overall 22% annual growth rate and global market share from 33% to 85%. Issuing legal mining licenses and foreign investment restrictions to the upstream sector were introduced; meanwhile, illegal mining and smuggling of state-protected ion-adsorption clays deposits persisted. The third stage was the introduction of export quotas and taxes, production quotas, and further foreign investment restrictions on upstream products (1999-2009). The objectives are to encourage domestic high-value-added downstream sectors by granting domestic firms cheaper upstream products and driving foreign firms to move their processing operation to China.

The fourth stage (2010-2015) was the most eventful. With the grim prospect of resource depletion and long-overdue ecological damage, China doubled the REE production and export quotas in 2010, about 25% and 37% decrease, respectively. This move culminated in the infamous WTO dispute after China decided to embargo Japan over a territorial dispute in 2010, which resulted in a speculative bubble as the REE metals and oxides price shot up by 850% in the same year and peaked at no less than 1,000% a full year onward; not until 2016 it returned to pre-crisis level. However, Wubbeke (2013) and Shen et al. (2020) argued that the export quota cut would still be announced regardless of the embargo. They went on to justify the cut as part of the long-term strategy of consolidating domestic industry to combat illegal mining and internalize the environmental cost—both highly correlated. China’s market share drop ensued—from 97% in 2010 to 83% in 2016—as several importers diversified the REE supply by restarting domestic mining, increasing production, or substituting material and end-product. During the same period, China also seriously began investigating and shutting down illegal mining as it had continued to not only get away with polluting soil and water but also increasingly put a substantial dent in the legal firm’s profitability. While the estimated size of illegal production varied from one independent report to another, all of which agreed that illegal miners reap the most benefit—by extracting and smuggling high-grade reserves only—without bearing the cost—tax-free and environmental responsibility-free. By the end of this period, China’s domestic share of global REE consumption rose to 70%, and their market absorbed 80% of domestic production.

In the latest stage (2016-present), the revocation of the export quota after China lost the appeal to the case in WTO accelerated the industry consolidation in terms of institutional merger and regulatory reform. The former was achieved by selecting six state-owned enterprises (SOEs) owned by central or local government, to which production quotas were split accordingly. Recently, three will merge and be listed under China Rare Earth Group, accounting for 70% of China’s MHREE production quotas in 2021 (Chang, 2022; Daly, 2021). The latter was achieved by introducing the Environmental Protection Tax; meant to internalize environmental cost instead of a fee mechanism; and an experimental product tracing system; meant to monitor the movement of goods to improve accountability extensively. As of 2021, China hit the lowest share of global mine production in the last decade at 60% but still maintains
dominance in overall processing capacity at 84%, thus reflecting a continuous trend of securing high value-added, downstream activity (US Geological Survey, 2022; Thompson, 2022).

**China’s Approach to Green Governance: Rhetoric and Practice**

This part will explain the dynamics between China’s green rhetoric and practice in shaping the Party’s image and legitimacy inside and outside the border. While explicitly mentioning exclusive REE governance is rare, China’s approach to green governance—or climate governance—should shed some light on what to expect, given their propensity.

Beyond the border, China has made its commitment to climate responsibility clear. Rather surprisingly, in September 2020, Xi announced the dual carbon pledge to reach peak emission by 2030 and carbon neutrality by 2060. The pledge was eventually added to the 14th FYP articles alongside points recognizing the “role of the United Nations (UN) as the core of the international system” as well as putting forward more “Chinese initiatives and plans” in a multilateral framework (UNDP, 2021). In reality, tasked with kickstarting the post-pandemic economy, China fell back on the all-too-familiar stimulus of heavy industry and building new coal plants at an outpacing rate compared to closing the older, inefficient plants (Ng, 2022). This hasty decision to backtrack marred and even negated the broader movement to achieve carbon neutrality envisioned in Paris Agreement and Xi’s dual pledge.

Domestically, ecological civilization serves as one of the overarching principles, from which are derived supporting rhetoric under Xi, notably: the two-mountain theory and dual circular economy. State-run media, Xinhua (2021), still in the spirit of the virtual Leader’s Summit on Climate, covers an anecdote about an ordeal endured by Yucun people who ultimately succeeded in transforming their fortune from mining to eco-tourism, in which Xi was depicted as a prophet-like figure, auspiciously delivering a moral lesson: green mountains are themselves gold mountains. The two-mountain theory reinforced a harmonious relationship between economic development and environmental conservation. Its importance lies less in its nominative theoretical status, which is scientifically rigorous, than in a “rhetorical heritage”; that is culturally meaningful (Young, 2022). Interestingly, Xi alluded himself, consciously or not, to founding father Mao Zedong and socialist doctrine, such as Xi’s “unity is strength” speech in Xibaipo (Wang, 2021) and the incorporation of “Xi Jinping Thought” into the constitution (BBC, 2017).

A dual circular economy is an experimental project aimed at reducing input and waste while reusing and recycling as many products as possible (Holzmann & Grunberg, 2021) with an added dimension of incentive-based participation called reverse recycling. This project was introduced in China in the early 2010s by deploying a reverse vending machine to collect waste materials in exchange for rewards (RTGE, 2014). While the idea was mentioned in the 14th FYP, the implementation remains to be seen. In light of growing REE demand and its end product’s short life cycle, we expect this mechanism to be applied to the e-waste recycling industry, in which China captures more than 90% global market share (Thompson, 2022).

Besides rhetoric, pseudo-reform also defines the characteristics of China’s green
governance. Pseudo-reform relates to how China’s central government incrementally, as opposed to fundamentally, deals with weak institutions and regulations. Kostka (2016) defined the structure of Chinese climate governance as “a two-tier system of setting targets and allocating responsibility”: in the first tier, the central committee of the Party sets targets, and the central government lays out the plan; the same process is repeated down the line to the lowest level of the local entity. The relationship between tiers is called “upward accountability,” which means “the objective of the lower level is to fulfill the tasks assigned by the higher level” (Teng & Wang, 2021). Another ingrained feature is performance-based compensation and promotion, mainly divided into individual and jurisdiction performance. A combination of performance-based evaluations without strong monitoring from the superior led to collusion and false reporting from below. Before the massive crackdown campaign, which ended in 2017, local governments played a key role as the main enabler of illegal mining. Typically mining activities took place in less-developed regions. Therefore, whether legal or not, it became the main source of local GDP, which, combined with how performance evaluation works in China, highly contributes to the local official’s chance of promotion (Shen et al., 2020). To tackle collusion and internalize environmental costs, the central government introduced the Environmental Protection Tax (EPT) to replace the fee-based revenue system in 2017. However, with limited success since it did not fully address the uncertainty problem of compliance rate.

Additionally, in measuring some targets in the 14th FYP, China avoided the use of the ‘absolute’ indicator; setting new goals directly by referring to the same indicator from the previous performance record, but instead favoring the ‘relative’ indicator; setting new goals indirectly by referring to another relevant indicator that tends to obscure progress. For example, instead of building directly on the GHG emission performance record from the previous period, the 14th FYP uses GHG emission per unit of GDP as a relative indicator to achieve the emission reduction goal (UNDP, 2021). This move, in turn, afforded so much leeway for government executives to implement policy and measure its success.

Socio-Ecological Impact of REE Mining and Beyond

Contrary to the name suggests, REEs are abundant in the earth’s crust but rarely concentrated in an economically justifiable amount to be mined (Adamas Intelligence, 2019b). REEs are divided into two main groups based on their electron configurations, viz. light REE (LREE) and medium to heavy REE (MHREE)—barring sudden innovation, to date, MHREE possesses higher value owing to advanced end-use applications. However, while they are essential to our clean, smart, low-carbon, and climate-resilient future, they come with a pollution price tag (China Water Risk (CWR), 2016). While the REE is not toxic, the polluting agent comes from the chemical substance in the extraction process. There are two methods: 1.) Heap leaching and pool leaching involve removing topsoil layers and transporting them to a leaching pond where the initial beneficiation process begins, 2.) In-situ leaching was done by drilling holes into hills, inserting PVC pipes and rubber hoses, and flushing the earth using water and chemicals. This mix was then pumped into the leaching ponds for beneficiation (Standaert, 2019). Bai et al. (2022) note that heap and pool leaching
methods are more likely to cause greater ecological damage than in-situ leaching. They also found that dry, plain northern RRE mines; which predominantly extract LREE, are dominated by atmospheric and radioactive contamination, whereas hilly southern RRE mines; which predominantly extract MHREE, are dominated by pollution of water and agricultural soil due to ammonia nitrogen wastewater. Abandoned mining left behind plastic waste, such as PVCs and hoses, and unattended, exposed tailing ponds, reported as “one landslide or barrier failure away from a spill into waterways” (Standaert, 2019).

REE poses many occupational health risks across the supply chain. In the upstream sector, for example, 3 out of 7 Bayan-Obo mine workers are exposed to thorium-containing airborne dust, putting them at risk of developing cancer (Balaram, 2019). In the downstream sector, movie operators are at risk of contracting pneumoconiosis during cerium aerosol exposure, e-waste recycling worker during plasma markers exposure, mechanics during catalytic additive exposure, and permanent magnets factory worker during exposure to static magnetic fields (Pagano et al., 2018). Shin et al. (2019) argued that recycling workers’ lack of health and safety procedures has put them at greater risk of skin irritation and toxicity for respiratory, nervous, cardiovascular, and liver systems through inhalation, ingestion, and skin contact.

The mining project has also triggered the enforced displacement of the community nearby. For instance, the enforced displacement of the already-disillusioned Baotou “cancer village” community in 2009 to build the belated waste management facility (Kaiman, 2014). Withering crops, dying livestock, and sulfuric air and water were enough for the people of Zhongshan and Yulin to start boycotting in 2015 and 2018, respectively. The civil resistance was unsurprisingly met with police arrest: some have been released, while others spent years in detention (Nayar, 2021). In the south—which has a higher risk of soil and water pollution compared to its northern counterpart—two rivers near mining sites: Dongjiang and Ganjiang Rivers, threaten to contaminate Hong Kong’s major source of freshwater (CWR, 2016).

Discussion

Challenges

This section features three key themes defining the challenges: governance, utilization, and standardization. The governance theme pertains to China’s rigid chain of top-down commands and embedded culture of reverence, which informs their unique decision-making structure. This condition is shown firstly in the principal-agent problem inherent in the two-tier climate or green governance system, resulting in a gap of empowerment between goal-setting and implementation apparatus, feeding into behavioral problems of unreliable reporting and collusion in the local government (Teng & Wang, 2021). Secondly, China’s domestic REE supply consolidation into the hands of powerful six—while in further progress to only four—state-owned enterprises (SOEs) would deny internal competition and deter external competitors on certain minerals and therefore inviting the possibility of another round of global supply crisis and price volatility (Chang, 2022; Daly, 2021).

The theme of resource utilization is best exemplified in the balance problem, a supply-demand mismatch of given REE minerals that favors high-value elements and, in effect, entails the overproduction of the low-demand,
low-value counterparts. This problem occurs because REE deposits concurrently contain several types of elements, rendering selective mining of any single type of ore impossible. The major implication is price fluctuation since the profit margin from the high-demand mineral has to consider the overproduction cost incurred by the low-demand. This problem has persisted since the onset of mining, along with changing demand for certain elements, and as of late, cerium and lanthanum have already experienced overproduction with the price implication on neodymium, which is expected to climb unless newfound uses of the former are discovered (Adamas Intelligence, 2019b; Binnemans & Jones, 2015). Another implication is the MHREE scarcity risk in the Ganzhou mining area, which had already reached a production reserve ratio 87 in 2009. It would have taken 87 years to fully deplete the resources if the production rate remained unchanged (CWR, 2016). Alarmingly, the projection did not consider the increasing rate of production per year, which was inevitable considering the need to build more wind and solar farms in place of traditional power plants.

The third theme pertains to insufficient standardization of acceptable limits for REE contamination and human toxicity assessment in drinking water resources by international health and research organizations (Balaram, 2019). Also, occupational health and safety standards from the mining to the recycling stage are largely underexplored, putting workers at various unidentified risks and uninformed treatments. (Pagano et al., 2018; Shin et al., 2019).

Opportunities

Conversely, opportunities are presented through increased competition for innovation and reforming the rule of law. Though limited at the moment, supply diversification and sub-technology material substitution are the steps in the right direction to promote innovation in general and reduce supply dependency in particular. Supply diversification and material substitution for cerium and lanthanum have already succeeded in countries outside China, such as the EU and South Korea (Adamas Intelligence, 2019a; CSIS, 2020). Moreover, China, already capturing 90% market share of secondary production from recycling, is at the forefront of exerting its influence on recycling norm-making and internationalization of dual circular economy practices (Thompson, 2022). The next competition stage will likely be in the recycling sector since mining is not environmentally sustainable, and manufacturers are forced to use existing materials and by-products. A recent study that found the ratio between the growth of green energy production and the growth of GHG emission at almost 1:1 has shown us the unsustainable side of relying solely on production in the long run (Golroudbary et al., 2022). Also, heavy REE importer countries are the most incentivized to innovate to break the supply dependency from China.

Secondly, a considerable improvement in civil law has been made by increasing the capacity of environmental NGOs and public prosecutors to file lawsuits against polluters under Xi’s administration (Lubman, 2017). A case of the government’s engagement in the Kunming oil refinery case (Wang, 2018) has shown that public participation is possible, despite being heavily mediated by the national agenda. Institutional and regulatory reforms within executive governmental bodies have progressed in recent years. The establishment of the Ministry of Ecology and Environment (MEE) in 2018 and the consequent reshuffle of the Climate Change Department (CCD)
from NDRC (National Development and Reform Commission) to MEE were designed to improve efficiency by avoiding policy overlap and coordination (Teng & Wang, 2021). The introduction of EPT and product tracing in 2017 attempted to internalize the environmental cost of REE production, combat illegal mining, and increase the profitability of state-sponsored mining companies (Shen et al., 2020).

Conclusion and Future Research Recommendation

The assessment of challenges and opportunities is not as clear cut: some events are overlapped, some are co-beneficial, some represent shared challenges, and some cancel out each other’s impact. For instance, REE firm merger and consolidation into six—currently going on four—major SOEs was meant to suppress illegal mining, but in doing so, has given China massive pricing power, rendering domestic and foreign private competitors vulnerable to disruption.

Secondly, the shift of developmental priority from economic growth to ecological protection benefits China’s government, REE industry stakeholder, and their people—in the present and future. Third, illegal mining and smuggling harm everyone except themselves, their collaborator, and their immediate buyer. Finally, the balance problem can be compromised directly by innovation, such as e-waste recycling—albeit ingredient and product dependent—and, indirectly, domestic environmental protection as long as environmental costs are internalized, providing funding for innovation.

China’s approach to green governance under the banner of “ecological civilization”, which is deeply rooted in their authoritarian governance, is characterized by elite-based consensus, more of “guiding and emphasizing” and goal-setting at the top while the task of creating concrete and tangible policies are passed onto local governments. At times, this loose coordination is, by design, not necessarily a weakness since it could provide leeway for policymakers to adjust accordingly. Regarding establishing REE global governance, considering long lead times to create an independent supply chain and ever-growing demand for high-grade REE, China will continue to assume leadership in trade in the foreseeable future. While China has the potential to influence the norm-making of the REE industry on the global stage due to its sheer dominance and domestic success, any attempt at internationalizing, or duplicating, the uniquely Chinese approach to green governance is unlikely to succeed because of its distinct political and ideological root and development path. However, better practices at each stage, from exploration to recycling, must be improved as China seeks to offshore its production capacity, especially LREE upstream activity. It remains to be seen whether REE offshore policymaking will develop other critical minerals, which China has already secured, such as cobalt in the Democratic Republic of the Congo and lithium in Chile, Argentina, and Australia (CSIS, 2020). Future research on the implication of offshoring is required regarding technology and know-how and whether China’s authoritarian style of green governance will translate to especially underdeveloped but resource-rich countries.

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