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ABANDONED OIL WELLS FUTURE GOLD MINES

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THE ENERGY FORUM

ABANDONED OIL WELLS – FUTURE GOLD MINES

Humanity's incredible journey is truly inspiring! It all began with the discovery of fire, a transformative element that sparked imagination and creativity in our ancestors. Picture them huddled around a flickering flame, amazed at the warm glow that not only lit up their surroundings but also allowed them to cook delicious meals! This remarkable discovery laid the groundwork for everything that followed.

As time passed, we evolved as a civilization, and the domestication of animals led to even more significant advancements. Oxen, horses, and donkeys became our trusted allies, helping us traverse landscapes, cultivate crops, and tackle numerous tasks. Then came the groundbreaking inventions of the water wheel and windmill! These ingenious devices harnessed the natural power of flowing water and gentle breezes to grind grain and pump water. Just imagine communities thriving, powered by the very elements of nature.

The emergence of coal was a true game changer, bringing about a revolution in how energy was produced. With coal-fueled steam engines, industries made a significant leap forward, spurring mass production and transforming transportation networks. The growth of cities soared as people flocked to urban centres filled with opportunity and innovation. Then, the discovery of oil ushered in the modern era! Oil-powered machines, vehicles, and entire industries reshaped economies and lifestyles globally, creating a web of interconnectedness that continues to grow.

As we progressed into the 20th century, there was an extraordinary increase in the consumption of non-renewable energy sources, such as coal, oil, and natural gas. These fuels fueled rapid economic growth, urbanization, and incredible technological advancements. However, as we basked in these achievements, the realization of our dependence on these finite resources also dawned on us. Concerns surrounding sustainability, climate change, and environmental protection began to surface, creating an urgent call to action.

This is where we stand today—at a pivotal moment in our shared narrative, where humanity is actively working to meet energy needs while respecting and protecting our planet. It is an exciting time to engage in conversations about shifting towards renewable energy sources and reducing our reliance on non-renewable fuels.

…critical minerals and rare earth elements (REEs) have emerged as essential players in the energy transition…energy technologies and cutting-edge energy storage systems.

As we embark on this journey of transformation, critical minerals and rare earth elements (REEs) have emerged as essential players in the energy transition. These minerals are the unsung heroes behind the development and deployment of renewable energy technologies and cutting-edge energy storage systems. Although often used interchangeably, it is essential to understand that REEs and critical minerals have distinct characteristics.

Rare earth elements refer to a specific group of 17 elements located near the bottom of the Periodic Table (Fig. 1). While they may seem rare, their occurrence worldwide is more widespread than one might think. The complexity lies in the fact that mining and separating these elements can be challenging, sometimes requiring over 100 processing steps and significant amounts of powerful acids. But the exceptional properties of these elements make the effort worthwhile.

Figure 1

This remarkable group consists of lanthanides, which have atomic numbers from 57 to 71, (Fig. 2) along with two special elements: Scandium (Sc) and Yttrium (Y). Interestingly, REEs are often found together in Nature, making them fascinating yet challenging to isolate from one another. Whether referred to as rare-earth metals or rare-earth oxides, these elements are essential to modern technology.

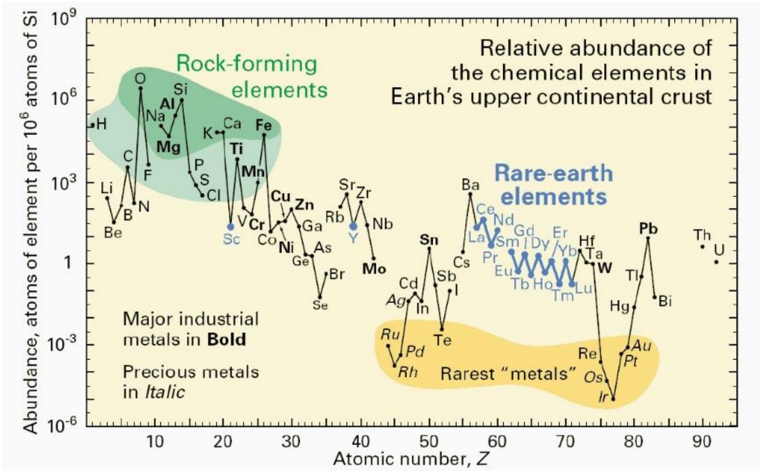

Figure 2

The fascinating story of REEs (Fig. 3) began back in 1787 when Lieutenant Carl Axel Arrhenius first discovered them within gadolinite. However, it was not until 1891 that their potential began to be recognized in the industry. By around 1930, knowledge of their applications had spread, and as time progressed, so did our understanding and technology for separating these elements. Since the 1950s, our consumption of rare earth elements has increased significantly, underscoring their growing importance.

SEVENTEEN RARE EARTH ELEMENTS

Rare earth name	Discovery year	Atomic name & number	Light/heavy REE	Critical/ Uncritical
Yttrium	1788	Y-39	Heavy	Critical
Cerium	1803	Ce-58	Light	Excessive
Lanthanum	1839	La-57	Light	Uncritical
Erbium	1842	Er-68	Heavy	Critical
Terbium	1843	Tb-65	Heavy	Critical
Ytterbium	1878	Yb-70	Heavy	Excessive
Holmium	1878	Ho-67	Heavy	Excessive
Scandium	1879	Sc-21	Heavy	Critical
Samarium	1879	Sm-62	Light	Uncritical
Thulium	1879	Tm-69	Heavy	Excessive
Praseodymium	1885	Pr-59	Light	Uncritical
Neodymium	1885	Nd-60	Light	Critical
Dysprosium	1886	Dy-66	Heavy	Critical
Europium	1886	Eu-63	Heavy	Critical
Gadolinium	1886	Gd-64	Heavy	Uncritical
Lutetium	1907	Lu-71	Heavy	Excessive
Promethium	1947	Pm-61		

Source: Author

The Print

Figure 3

REEs can be classified into two groups: light rare earth elements (LREE) and heavy rare-earth elements (HREE). LREEs, including lanthanum and cerium, are more abundant, while HREEs like dysprosium and yttrium are rarer and even more critical due to their high demand. Neodymium, among the LREEs, stands out for its extensive use in mobile phones, medical equipment, and electric vehicles, making it a cornerstone of today's technology.

Furthermore, HREEs play a vital role in clean energy technologies, underscoring their importance as we transition to more sustainable energy solutions. With their unique magnetic, electrical, and optical properties, REEs are indispensable in various high-technology applications, ranging from electronics to renewable energy systems. Just think of the smartphone in our pockets, the wind turbines generating power, and the solar panels harnessing sunlight—all made possible by these special elements.

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China plays a dominant role, accounting for over 90 per cent of global REE production. They extract around 70 per cent of the world's rare earths, with Myanmar, Australia, and the United States contributing to the remainder. China is at the forefront of supplying rare earth elements, meeting 72 per cent of the annual demand, with Malaysia contributing 11 per cent and Japan 6 per cent. This strong position can be traced to Deng Xiaoping's insightful remark in 1992 during a visit to Inner Mongolia: "While there is oil in the Middle East, China has rare earths." Thanks to a thriving research community and an innovative environment, China has established five National Rare Earth Laboratories, all of which are supported by strategic policies. With 39 universities dedicated to training professionals in mining and REEs, the future looks promising. The China University of Mining and Technology is the world's leader in mining technology. Is it not inspiring to see such a commitment to excellence? This dynamic highlights the interconnectedness of our global efforts as we seek to secure a sustainable energy future.

China is a powerhouse in the rare earth elements (REEs) market, particularly for seven key components: dysprosium, gadolinium, lutetium, samarium, scandium, terbium, and yttrium. Since early April, China has significantly reduced its exports of these essential materials, which are primarily mined in China and Myanmar. It is a challenge to separate these elements chemically. Still, China's refineries excel in this area, producing up to 99.9 per cent of the global supply of heavy rare earths (Fig. 4), particularly dysprosium and terbium, which are used in heat-resistant magnets.

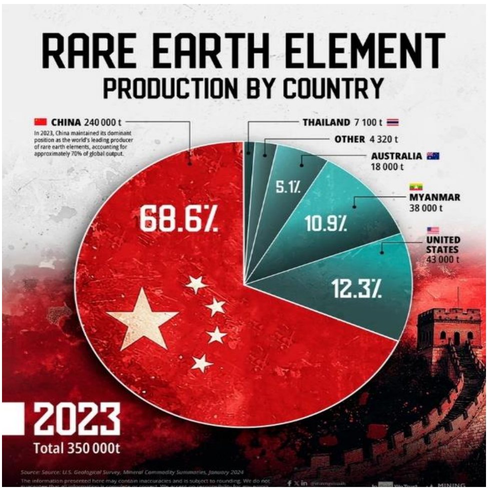

Figure 4

Let us explore the differences between rare earth elements and critical minerals.

1. Scope: Rare earth elements refer to a specific group of 17 elements, while critical minerals include a broader spectrum that contributes to economic and national security.
2. Definition: REEs are distinct due to their unique characteristics, while critical minerals are defined by their importance in various sectors.
3. Supply Chain: The REE market is dominated by China, whereas critical minerals have more varied and intricate global supply chains.

…REEs and critical minerals share some commonalities, they exhibit distinct characteristics, applications, and supply chain dynamics. The role of rare earth elements is vital in advancing renewable energy technologies.

In summary, while REEs and critical minerals share some commonalities, they exhibit distinct characteristics, applications, and supply chain dynamics. The role of rare earth elements is vital in advancing renewable energy technologies.

Let us take a closer look at the applications (Fig. 5) of some key REEs:

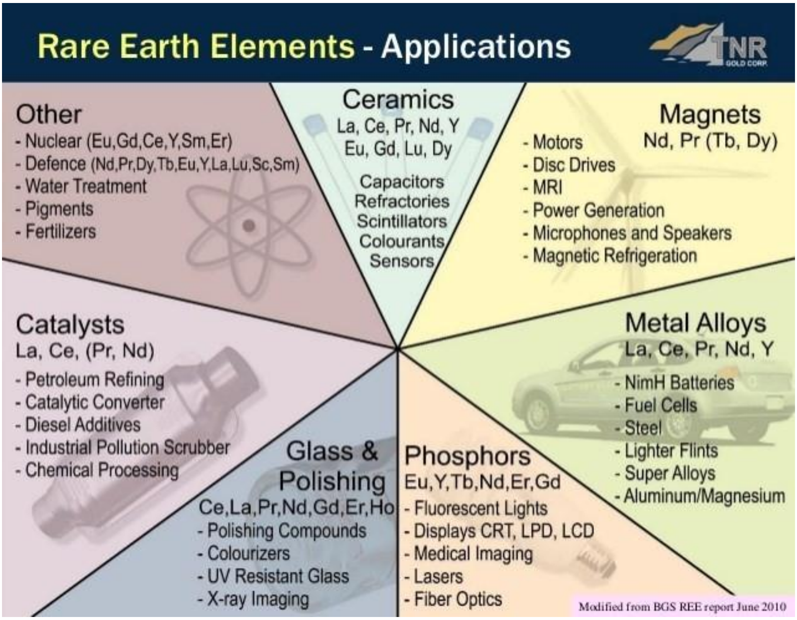

Figure 5

Dysprosium, gadolinium, lutetium, samarium, scandium, terbium, and yttrium are crucial in the manufacturing of heat-resistant magnets, particularly in the automotive industry. Neodymium, praseodymium, dysprosium, and terbium are used to create high-strength permanent magnets for wind turbines, optimizing energy efficiency and reliability. Moreover, Neodymium-Iron-Boron (NdFeB) magnets power electric vehicle (EV) motors, significantly contributing to their performance and efficiency, as they are up to 15 times stronger than traditional iron magnets of similar weight.

These rare-earth magnets are found in various small electric motors throughout modern vehicles. For example, a luxury car seat might use up to 12 rare earth magnets for its adjustment system. Electric cars require even more magnets for effective motor operation. A shortage of these crucial components can lead to significant production setbacks, potentially halting entire assembly lines and affecting thousands of jobs.

Interestingly, most rare earth magnets are derived from two lighter rare earth elements: neodymium and praseodymium. While China continues to export these, they can also be sourced in smaller quantities from Australia and the United States. However, due to their sensitivity to heat and strong electrical fields, manufacturers often add small amounts of heavier rare-earth elements, such as dysprosium or terbium, during production to optimise performance. With many modern engines generating substantial heat, the auto industry primarily opts for magnets containing these specialized elements.

The global magnet industry produces nearly 200,000 tons of rare earth magnets with dysprosium or terbium annually. Another 80,000 tons are generated without these metals for applications such as purse clasps, further highlighting the versatility of rare earth elements. Impressively, China produces around 90 per cent of the world's rare earth magnets.

Dysprosium and cerium also play crucial roles in enhancing the efficiency of solar panels, particularly in thin-film solar cells. Additionally, lanthanum and cerium are essential components in lithium-ion batteries, helping to improve energy density, lifespan, and safety. Yttrium plays a crucial role in manufacturing catalytic converters, which significantly reduce emissions from combustion engines. Moreover, REEs like neodymium, dysprosium, and praseodymium are becoming increasingly vital in hydrogen production through electrolyzers, enhancing efficiency and energy consumption.

India, too, has notable reserves of rare earth minerals, boasting approximately 6 per cent of the world's total supply. Among these minerals is monazite–rich in light rare earth elements such as lanthanum and cerium–found mainly in Kerala. Other valuable minerals, such as ilmenite, rutile, zircon, garnet, and sillimanite, are also present in coastal regions like Odisha.

Although India has significant reserves, its refining capacity for rare earth elements is relatively limited, producing less than 2 per cent of the global total despite holding around 6 per cent of the world's rare earth reserves. In comparison, China holds a commanding position in the realm of rare earth refining, accounting for an impressive 85-95 per cent of global production. This dominance stems from China's early strategic approach to developing its rare earth industry and its comprehensive supply chain management.

Other nations, including the United States, Australia, and Japan, are recognized players in the rare earth market, each contributing to a more diverse global landscape. The future of rare earth elements and critical minerals is bright, holding tremendous potential for innovation in technology and sustainability. By understanding and exploring these resources, we can pave the way for a greener and more efficient future. The recent developments in Japan have sparked an exciting transformation in its approach to diversifying rare earth supply chains, demonstrating just how resilient and adaptable its industry can be. This is an exciting time for innovation and collaboration. Japan has actively taken steps to reduce its reliance on Chinese imports, managing to cut its dependence on China for Rare Earth Elements (REE) from a staggering 90 per cent to approximately 60 per cent.

To enhance its supply chain, Japan is forming valuable partnerships with countries such as Australia and Vietnam, opening doors to new opportunities. The Japan Oil, Gas and Metals National Corporation (JOGMEC) is also playing a vital role by supporting projects geared towards mineral resource development.

In a truly groundbreaking achievement, Japan has recently uncovered a vast reserve of rare earth minerals valued at an impressive $26 billion near Minami-Tori-Shima Island. This discovery is more than just a find; it has the potential to dramatically reduce Japan's reliance on imports and establish a self-sufficient supply chain.

With a commitment to environment friendly practices, the Japanese government has outlined comprehensive plans to commence operations by 2025 utilising overseas mining vessels. This newfound treasure is poised not only to reshape Japan's economy but also to transform global supply chain dynamics for essential materials.

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While Japan currently imports rare earth ore and processes it for export, it stands as a leader in the manufacturing of advanced technologies through its focus on innovation and quality. Since China notably restricted exports of these vital metals back in 2010, Japan recognized the need for diversification and acted decisively.

This conversation also highlights that India is making commendable strides in enhancing its rare earth refining capabilities. Companies such as Indian Rare Earths Limited (IREL) are establishing facilities to extract and separate these valuable elements. Despite holding 6 per cent of the global REE reserves, there remains untapped potential that can be harnessed for significant advancements with the right strategic reforms and increased involvement from the private sector.

By utilizing oil well water and geothermal resources, we can tap into critical minerals and rare earth elements.

Taking a cue from the innovative spirit seen in Japan, India can also explore creative solutions for resource extraction. By utilizing oil well water and geothermal resources, we can tap into critical minerals and rare earth elements. Imagine gathering Lithium, Strontium, and other REEs like neodymium and dysprosium, which could fundamentally change the game for our mineral resources.

The exciting reality is that critical and rare earth elements can even be extracted from brine water found in oil wells—a process known as unconventional REE extraction. This presents a promising opportunity for India to focus on extracting minerals such as lithium from abandoned or high-water-cut oil and gas wells.

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India needs to invest time and resources into developing technologies that support alternative methods for lithium extraction, particularly by collaborating with national oil companies. With the increasing demand for lithium, especially for electric vehicle (EV) batteries, the time is ripe for investment in this space. With India's EV estimates reaching 10 million by 2030, the potential for investments in this sector could rise to around ₹ 20 lakh crores.

It is essential to remember that while the spotlight is on EVs, lithium—often referred to as the lifeblood of EV batteries—needs our attention. Earlier this year, a discovery of a deposit containing 5.9 million metric tonnes of high-quality lithium reserves in the Salal-Haimana area of Jammu and Kashmir has ignited excitement about what lies ahead.

This promising finding marks the beginning of what could be a transformative journey for India's position in the global market for critical minerals. Engaging in discussions, fostering collaborations, and encouraging innovative strategies will empower India to shine in this ever-evolving industry.

As we stand on the brink of exciting technological advancements, the potential of geothermal and oil well brines is becoming increasingly evident. Energy and mining companies, along with proactive governments, are enthusiastically funding research initiatives aimed at discovering the most effective techniques for extracting lithium from these valuable resources. This represents a significant step forward in our pursuit of sustainable energy solutions.

...harnessing lithium from geothermal and abandoned oil well brines is particularly fascinating—abandoned oil wells could very well transform into future gold mines.

The idea of harnessing lithium from geothermal and abandoned oil well brines is particularly fascinating—abandoned oil wells could very well transform into future gold mines. When petroleum and gas wells reach a point where they are deemed economically unfeasible, they are often abandoned, thus becoming a legacy challenge for the companies that drilled them. These wells not only serve as a reminder of resource depletion but also pose potential environmental risks if not decommissioned properly.

A 2020 Report from the Ministry of Petroleum and Natural Gas indicated that out of 20,562 oil wells, approximately 13,348 have been abandoned. This presents us with an opportunity; in developing countries, a substantial portion—approximately 80 per cent—of abandoned oil and gas wells are nonproducing, yet they continue to produce water. This water can be channeled towards extracting lithium, highlighting the immense potential for utilizing oil well brine in geothermal energy production. Much like the exploration for new energy sources, there is a treasure trove of possibilities waiting to be unlocked.

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Globally, it is estimated that oil wells yield around 39.5 million cubic metres of water per day. To give a clearer picture, in 2020, this translated to approximately 28 billion cubic meters per year—an amount projected to soar to 54 billion cubic meters by 2030. Maximizing the use of brine is essential for enhancing the profitability of oil field operations, making the push for "beneficial use"—such as lithium extraction—a compelling narrative in the green energy movement. Interestingly, brines containing 80 to 300 parts per million (ppm) of lithium can be commercially viable.

The co-production of lithium alongside medium-temperature geothermal energy projects in sedimentary basins is proving to be an attractive proposition. India is home to seven petroliferous basins, with four of them showing promising reservoir temperatures for this purpose:

1. Cambay Basin: Bottom Hole Temperature around 175 ± 25 degrees Celsius
2. Krishna-Godavari Basin: Bottom Hole Temperature around 205 degrees Celsius
3. Cauvery Basin: Average Bottom Hole Temperature between 90 and 120 degrees Celsius
4. Assam-Arakan Basin: Bottom Hole Temperature ranging from 48 to 214 degrees Celsius

These high-temperature oilfield-produced waters can not only be used for geothermal energy production but can also be repurposed in direct lithium extraction processes. The beauty of this scenario is that it can all occur without relying on fossil fuels, a significant step towards a more sustainable future.

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However, it is essential to note that decommissioning oil and gas wells can be a costly endeavour. If these abandoned wells are not handled with care, they risk contaminating the surrounding environment. Integrating heat exchangers into these wells for geothermal energy extraction is a good way to address this issue. By testing the previously produced water for lithium content, we can make substantial advances in both geothermal energy and lithium extraction.

Utilising already-drilled wells could significantly enhance energy efficiency by tapping into the high-temperature environments found at depths of 3,000 to 3,500 metres beneath the Earth's surface. Considering the drilling costs, which can account for an impressive 42 to 95 per cent of total expenses related to enhanced geothermal power plants and lithium extraction, it is clear that leveraging these pre-drilled, extendable abandoned wells is a clever, resourceful approach.

The geothermal fluid temperature is heavily reliant on subsurface conditions, making abandoned oil and gas wells a valuable asset for geothermal applications. By incorporating these wells into our energy strategy, we could economically invigorate projects, reduce land disruption caused by drilling, and increase our renewable energy footprint. With four hydrocarbon provinces in India boasting a favourable temperature gradient, the potential for geothermal energy exploration using these abandoned wells is genuinely promising.

Geothermal Deposits

Geothermal brines account for approximately 3 per cent of known global lithium resources. These enriching solutions come into play as hot, concentrated saline water circulates through crustal rocks in regions with exceptionally high heat flow.

Elements such as lithium, boron, and potassium become concentrated, making geothermal deposits a curious intersection of nature's chemistry and our technological aspirations.

The synthesis of paleo-seawater and the leaching of evaporated rocks are pivotal elements in determining lithium concentrations in geothermal waters, which can be traced to bedrock reservoirs. Therefore, exploring these opportunities is not just beneficial; it is an exciting venture into the future of sustainable energy.

Lithium in Petroleum Brine Deposits

The world of energy is evolving, and we are beginning to discover fascinating potential sources of lithium within petroleum source rocks, particularly shale formations. Traditionally viewed solely as sources of oil and gas, these shales are now recognized for their ability to yield lithium concentrations ranging from 80 to 300 ppm in the water produced from these reservoirs. This shift in perspective could have significant implications for our energy landscape.

Moreover, deep oil reservoirs are emerging as another intriguing source of lithium brine deposits, accounting for approximately 3 per cent of the known global lithium resources. The oilfield brines are characterized by unusually high levels of lithium,

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along with valuable elements such as magnesium, bromine, and potassium. It is fascinating to think that this lithium might originate from interactions with saline solutions within phyllosilicate-rich geological layers.

Furthermore, exciting leads are pointing to other sources of lithium, such as ancient metamorphic brines and organic compounds. One particularly noteworthy example is the Neuquen Basin in Argentina, which boasts ideal conditions for lithium enrichment. This region features a closed basin, an arid climate, adequate source rocks for lithium, geothermal activity, and sufficient time to allow brine concentration— all key factors that culminate in high lithium yields.

Typically overlooked, the water brine produced during oil extraction might serve as a valuable resource rather than waste. Often, these brines are injected back into wells to mitigate pollution risks. However, it is inspiring to see studies revealing elevated lithium concentrations within these brines; for instance, a depth of 1,800 to 4,800 metres below the surface in Arkansas has yielded lithium concentrations as high as 500 ppm.

This discovery opens the door for innovative mining projects that extract lithium from former oil wells, potentially creating new pathways for sourcing this essential mineral. The Gulf Coast of the United States is estimated to hold approximately 4.335 million tons of lithium carbonate equivalent.

Geothermal Waste Deposits

Turning our attention to geothermal sources, we find yet another promising avenue for lithium extraction. The chemical composition and volume of geothermal fluids in regions such as the United States, Indonesia, the Philippines, Iceland, and New Zealand presents great potential for lithium recovery. After the use of thermal waters in geothermal power plants for generating carbon-free electricity, the resulting geothermal waste could contain significant amounts of lithium in whitish, soup-like brine.

By integrating lithium extraction with geothermal energy production, we can unlock the dual benefit of harnessing clean energy while simultaneously recovering valuable minerals. This synergy could reduce the operating costs associated with geothermal power, enhancing the overall profitability of the plants.

For example, in the Salton Sea region of the US, companies are making strides in developing joint geothermal-lithium facilities. They utilize the steam generated from hot brine to produce clean energy while also extracting lithium through advanced ion exchange technology. Similarly, New Zealand has noted the advantageous composition of its geothermal fluids. It is exploring commercial opportunities for lithium extraction, as well as other valuable elements such as silica and precious metals.

It is inspiring to think that even countries like India are beginning to explore the potential for lithium within their geothermal plants.

The future looks bright for geothermal technologies and mineral extraction.

Understanding Lithium Presence

Before diving into extraction methods, it is crucial first to confirm the presence of lithium in oil well brine or geothermal waste. Traditional oil well testing can pose challenges in accurately estimating lithium concentrations. However, advanced techniques like Inductively Coupled Plasma Mass Spectrometry (ICP-MS) have proven invaluable since their adoption in the 1980s.

The sophisticated ICP-MS/MS method excels in determining lithium levels free from interference. This precision is particularly vital when addressing polyatomic interferences from elements like sodium and sulfur, which can complicate measurements. By employing reaction gases such as nitrous oxide and ammonia during the analysis, we can achieve precise results, especially when testing trace impurities in products like pure lithium carbonate.

How does ICP-MS/MS work? Initially, a sample—either liquid or gas—is introduced into the instrument. Here, it undergoes ionization in inductively coupled plasma, which generates the high-temperature energy necessary to break down the sample into its elemental components. The resulting ions are then analysed by a mass spectrometer, which sorts them based on their mass-to-charge ratio. The innovation of conducting a second round of analysis enhances sensitivity and selectivity, allowing for the identification of trace elements even at remarkably low concentrations.

With facilities like the National Geophysical Research Institute (NGRI) equipped with this cutting-edge technology, we are on the brink of discovering unparalleled opportunities for oil companies to explore and implement effective lithium extraction strategies.

Standard Lithium Limited and Lanxess Corporation have recently entered into an exciting joint development agreement with Koch Technology Solutions. This collaboration aims to pool resources and knowledge to innovate and commercialize integrated lithium brine processing flow sheets. With an ambitious target set for an annual output of 30,000 tonnes of battery-grade lithium hydroxide, this partnership is paving the way for significant advancements in lithium extraction. Notably, companies such as E3 Lithium Limited, MGX Minerals, Empire Metals Corporation, and Prism Diversified are already making strides in this field, focusing on innovative methods for rapid lithium extraction from oilfield brines. Additionally, Rec3

ion Technologies has introduced a groundbreaking technique for extracting lithium from both geothermal and oilfield brines, highlighting the diverse potential in this space. Interestingly, Ukraine has also identified oilfield brines as a promising source of lithium, contributing to a global exploration of new resources.

When it comes to recovering lithium from geothermal and oilfield brines, the similarities lead to intriguing questions about which material might be more promising and which extraction technology may yield better returns. The reality is that there is no one-size-fits-all answer. The profitability of lithium recovery plants from both sources can be high, but this success hinges on a variety of factors. These include the plant's location, brine composition, production capacity, and existing infrastructure. The ability to extract lithium domestically is a game changer, reducing our dependence on sources from South America and Chinese refining processes.

India's Path to Reducing Rare Earth Mineral Dependency

India is embarking on a remarkable journey within the energy sector. With approximately 4.6 billion barrels of proven oil reserves, our nation ranks as the 22nd largest oil producer globally, accounting for around 0.3 per cent of the world's total reserves. Additionally, we possess significant coal reserves, accounting for approximately 9.45 per cent of global totals, making us the fifth-largest among coal-rich nations, with around 107,727 million tonnes at our disposal. Moreover, in the realm of rare earth elements (REEs), India is fifth worldwide, with about 6.9 million metric tons of reserves. Although our current production stands at a modest 2,900 metric tonnes projected for 2024 the potential for growth in this sector is vast and filled with opportunities.

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Acknowledging the challenges ahead, the Government of India government is taking bold steps to strengthen its REE supply chain, setting the stage for a resilient and dynamic system. With a visionary approach backed by an investment of ₹ 3,500-5,000 crores, the Government is committed to reducing our reliance on imports and fostering domestic self-sufficiency in REE production. This comprehensive initiative emphasizes essential exploration and beneficiation activities, which are crucial for sustainable development.

To ensure the success of this ambitious project, we are establishing a strong foundation built on five key pillars:

1. Developing Technologies: Investing in cutting-edge technologies and equipment is essential for progress.

2. Exploring Alternative Materials: Innovating ways to utilize alternative materials broadens our prospects and enhances sustainability efforts.

3. Promoting Recycling: Encouraging investment in recycling facilities and advancing recycling technologies will enhance our rare earth resource base.

4. Expanding Global Partnerships: Actively developing mines and securing equity interests in rare earth projects worldwide will strengthen our resource portfolio. With Government-supported organizations powering loan guarantees and equity investments, our approach is more robust than ever.

5. Strategic Stockpiling: Establishing forte reserves of critical minerals is vital for our long-term strategy.

As we navigate this multifaceted landscape, the National Critical Minerals Mission (NCMM) emerges as a crucial, timely policy initiative. It fosters private sector participation in the exploration and mining of essential minerals, streamlines mine licensing, incentivizes the recycling of rare earth elements, and promotes collaboration among public, private, and academic organizations. In doing so, it mitigates vulnerabilities and bolsters our domestic research and refining capacities. By leveraging our strategic geopolitical position, India stands to play a key role in resilient and trustworthy critical mineral supply chains with allies such as the Quadrilateral Security Dialogue (QUAD), which plays a significant role in promoting cooperation and collaboration on Rare Earth Elements (REE).

An auspicious opportunity exists in establishing a dedicated technical institution focused on REEs and critical minerals. The Government is unwavering in its commitment to providing substantial financial resources and policy support for research and development within this pivotal sector, fostering innovation and advancing innovative REE applications. Our vision embraces a comprehensive production system that encompasses everything from exploration and mining to the creative utilization of over 400 distinct REE products.

We are wholeheartedly dedicated to elevating our position in the REE sector, viewing the development of our rare earth industry as integral to energizing low-carbon and high-technology manufacturing. This strategic vision encompasses robust Government support for research, the development of specialized technologies, and the establishment of a comprehensive domestic supply chain to meet our growing needs effectively.

Currently, India invests approximately 0.64 per cent of its GDP in research and development. While this figure is behind that of leading economies like China (2.4 per cent) and Germany (3.1 per cent), there is tremendous opportunity for growth. By encouraging investments in the Rare Earth Elements (REE) sector from both public and private entities, we can tap into beneficial income tax rebates, paving the way for innovation. Collaborating with top regional universities will allow us to monitor our progress effectively, ensuring we stay on track. Together, we can embark on an inspiring journey towards a sustainable and innovative future.

While recycling presents a promising and sustainable approach to sourcing REEs and critical minerals, it is crucial to view it as a complement to, rather than a substitute for, traditional mining. Recycling does have its challenges, including substantial investment needs and longer lead times. According to the International Energy Agency, the recycled shares of copper and nickel have declined by 4 per cent from 2015 to 2023, and the recycling rates for cobalt and lithium remain below 10 per cent.

Implementing any diversification strategy will require patience, ongoing technological advancements, and an innovative approach to global relations. While a complete disengagement from China is not practical or feasible in the short term, developing alternative capacities to reduce our dependency will take concerted effort over many years. This ambitious vision demands a coordinated national commitment and strong international collaborations.

We must acknowledge that China's prominence in the rare-earth sector stems from well-planned, deliberate strategies. With robust Government support, cutting-edge processing technologies, exceptional educational institutions, and a readiness to embrace transformative measures, India is poised to tap into the potential for a prosperous future in rare earth minerals.

Action Plan for the Current Scenario

Our first step will be to investigate the different formations of water across various petroliferous basins to confirm lithium's presence. Once we establish its existence, we can then pivot towards executing Direct Lithium Extraction (DLE) from the brine.

In the realm of oil exploration, the strategies we are discussing reflect standard practices among oil companies; however, we have an opportunity to take it further. Alongside oil testing, we should embrace simultaneous water testing to explore the presence of lithium. Our first step will be to investigate the different formations of water across various petroliferous basins to confirm lithium's presence. Once we establish its existence, we can then pivot towards executing Direct Lithium Extraction (DLE) from the brine. Numerous innovative startups are already pioneering this technology, and we are eager to engage in discussions with them.

Determining whether commercially viable lithium is available within oil-brine is indeed a significant challenge, but it is one we are ready to take on. For India to join the ranks of lithium-producing nations, we need a wholehearted commitment to extracting this valuable resource from oil well brine. Given India's abundant resources, we have a unique opportunity to lead in this energy race. With proactive measures and a collaborative spirit, India's future in the energy landscape appears promising. Our dedication to innovation and growth in this sector reflects a bold, positive vision for a sustainable energy future.

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In conclusion, the exploration of lithium in petroleum and geothermal sources presents an optimistic pathway towards a sustainable future. The potential for innovative mining and energy solutions could be pivotal in meeting our future energy needs while also driving economic growth.

Mr. Sunit Roy graduated in Geology from Jadavpur University and completed his post-graduation in Exploration Geophysics from the prestigious Indian Institute of Technology, Kharagpur. He has spent an impressive 35 years in the oil industry. Mr. Roy retired as Group General Manager from ONGC and is currently applying his vast knowledge as a Domain Expert at Oil India Limited. Mr. Roy has significantly contributed to both national and international journals, showcasing his research at numerous conferences.

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