

MATERIAL CRITICALITY: FOR ENRICHMENTS OF NATIVE PRODUCTS AND TECHNOLOGY

Abstract

Material criticality refers to the assessment of the importance and vulnerability of certain materials within various industries. This abstract explores the concept by examining factors such as scarcity, economic significance, and geopolitical considerations. Understanding material criticality is crucial for sustainable resource management and the development of resilient supply chains, particularly in the context of evolving technologies and global demand patterns. The abstract delves into methodologies for assessing material criticality and highlights the implications for decision-makers in both public and private sectors, emphasizing the need for strategic planning to mitigate risks associated with the potential scarcity of critical materials.

Keywords: Material criticality, Environmental and Social Concerns, Future Advancement.

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I. INTRODUCTION

Material criticality refers to the importance and vulnerability of certain materials in the framework of a nation's economy, industry, and national security. It arises from the reliance on specific materials that are vital for the production of various goods and technologies, but their supply might be limited, uncertain, or susceptible to geopolitical risks. In previous years advancements in technology and industrialization have led to an increased demand for certain raw materials. These materials play a crucial role in manufacturing products such as electronics, renewable energy technologies, aerospace components, and defense systems. Several aspects subsidize to material criticality:

- 1. Supply Concentration:** Some materials are principally sourced from a limited number of countries or regions, making their supply susceptible to political instability, trade disputes, or supply chain disruptions.
- 2. Limited Reserves:** Certain materials are rare, and their natural reserves may be limited, making it challenging to meet the growing demand.
- 3. Complex Production Process:** Some materials require intricate and resource-intensive extraction or refining processes, leading to supply bottlenecks or high production costs.
- 4. Substitution Challenges:** In some cases, there are no direct substitutes for critical materials, making it difficult to find alternative solutions in case of supply disruptions.
- 5. Rapidly Growing Demand:** The increasing adoption of new technologies and applications can lead to a sudden surge in demand for specific materials, straining their availability.
- 6. Environmental and Social Concerns:** The extraction and processing of critical materials may have significant environmental impacts and raise ethical issues related to labor practices.

1. Focussed strategies to address material criticality:

- **Diversification of Supply:** Reducing reliance on a few sources by diversifying the supply chain and establishing trade partnerships with multiple countries.
- **Recycling and Circular Economy:** Promoting recycling and reusing of materials to reduce the demand for primary sources and lower environmental impacts.
- **Substitution and Innovation:** Investing in research and development to find suitable substitutes for critical materials or developing new technologies that require fewer critical resources.
- **Stockpiling:** Creating strategic reserves of critical materials to mitigate supply disruptions and ensure availability during crises.
- **Responsible Sourcing:** Encouraging responsible mining and sourcing practices, which consider environmental sustainability and ethical labour standards.

Material criticality is a multidimensional challenge that requires collaboration between governments, industries, and research institutions to ensure stable and sustainable access to essential resources while minimizing potential risks.

2. Supply concentration: is a crucial aspect of material criticality. It refers to the situation where a significant portion of the global supply of a particular material comes from a limited number of countries or regions. When a material is heavily concentrated in a few locations, it can lead to heightened risks and vulnerabilities in the supply chain. Several factors contribute to supply concentration:

- **Geographic Distribution:** Some materials are naturally abundant in specific geographical regions, resulting in a concentration of production and reserves in those areas. For example, rare earth elements are primarily found in China, while lithium resources are concentrated in countries like Chile, Argentina, and Australia.
- **Resource Monopolies:** In certain cases, a single country may dominate the production and export of a critical material, effectively creating a monopoly. This can give that country significant leverage in global trade and create dependency issues for other nations.
- **Political and Geopolitical Factors:** Political stability and diplomatic relations play a significant role in determining the continuity of material supply. Trade disputes, sanctions, or geopolitical tensions can disrupt the flow of critical materials.
- **Trade Agreements and Alliances:** Some countries may form trade agreements or alliances that prioritize the exchange of specific materials. While this can promote economic cooperation, it can also lead to a higher concentration of supply sources.
- **Mining and Production Capabilities:** Countries with advanced mining and processing capabilities may dominate the supply chain due to their ability to efficiently extract and refine the material.

3. Limited Reserves: are another critical aspect of material criticality. It refers to the finite nature of certain natural resources that are essential for various industrial processes, technological applications, and economic activities. When the reserves of a particular material are limited, it can lead to concerns about long-term availability and sustainability. Several factors contribute to limited reserves:

- **Natural Abundance:** Some materials occur naturally in low concentrations in the Earth's crust, making their extraction and accumulation challenging and economically unviable.
- **Slow Formation Processes:** The geological processes involved in the formation of certain critical materials are slow, taking millions of years to create deposits, making them non-renewable on a human time scale.
- **Resource Depletion:** Continuous extraction and consumption of these materials without proper conservation or recycling can lead to depletion, reducing the available reserves over time.
- **Geopolitical Access:** Limited reserves might be accessible only in politically sensitive or remote regions, leading to challenges in their extraction and transportation.
- **Technological Constraints:** Some materials might be difficult to extract due to technological limitations or high costs involved in their processing.

4. The complexity of the production process: is another significant aspect of material criticality. It refers to the intricate and resource-intensive steps involved in extracting, refining, and manufacturing certain materials. When a material requires a complex production process, it can create challenges and vulnerabilities in the supply chain, impacting industries and economies that rely on these materials. Several factors contribute to the complexity of production processes:

- **Extraction Challenges:** Some materials are embedded in complex geological formations, making their extraction technically difficult and financially costly.
- **Chemical and Metallurgical Processes:** The refining and processing of certain materials require sophisticated chemical and metallurgical processes, involving multiple stages and specialized equipment.
- **Supply Chain Interdependencies:** The production process of critical materials often involves multiple interconnected stages, making the entire supply chain vulnerable to disruptions at any point.
- **Energy and Resource Intensity:** Certain materials demand a significant amount of energy, water, and other resources during their production, impacting both cost and environmental sustainability.
- **Waste Generation:** Complex production processes may generate substantial amounts of waste and by-products, necessitating proper waste management and disposal measures.
- **Expertise and Technology:** Access to specialized knowledge, skilled labor, and advanced technologies is crucial for efficiently and effectively producing certain critical materials.
- **Supply Chain Vulnerability:** The intricate and interdependent nature of production processes can create vulnerabilities, as any disruption in one part of the supply chain can cascade and affect the entire system.
- **Limited Production Capacity:** The complexity of production processes might limit the rate at which critical materials can be produced, hindering the ability to meet rapidly growing demand.

5. Rapidly growing demand: is a crucial aspect of material criticality. It refers to the escalating need for specific materials driven by industrialization, technological advancements, and changes in consumer behavior. When the demand for critical materials outpaces their supply, it can lead to concerns about shortages, price volatility, and potential disruptions in various industries and applications. Several factors contribute to rapidly growing demand:

- **Technological Advancements:** The development and adoption of new technologies, such as electric vehicles, renewable energy systems, and advanced electronics, can significantly increase the demand for critical materials required in their production.
- **Population Growth:** The world's population continues to grow, leading to higher consumption rates and increased demand for products that rely on critical materials.
- **Urbanization:** The ongoing trend of urbanization results in greater infrastructure development and the need for materials in construction, transportation, and energy systems.

- **Consumer Electronics:** The proliferation of smartphones, tablets, laptops, and other electronic devices contributes to the rising demand for materials like lithium, cobalt, and rare earth elements.
 - **Sustainable Practices:** The shift towards sustainable practices and clean energy solutions may require more materials, such as those used in renewable energy technologies.
 - **Global Economic Growth:** As economies grow, the demand for goods and services increases, further driving the need for critical materials.
 - **Supply Shortages:** If the supply of critical materials does not keep up with demand, shortages can occur, affecting industries and hindering the production of essential technologies and products.
- 6. Environmental and social concerns:** are significant aspects of material criticality. The extraction, production, and use of certain critical materials can have considerable impacts on the environment, local communities, and workers involved in the supply chain. Addressing these concerns is essential for promoting sustainable practices and ensuring the responsible management of critical resources. Some of the key environmental and social concerns in material criticality include:
- **Environmental Degradation:** The extraction and processing of critical materials can lead to habitat destruction, soil and water pollution, deforestation, and loss of biodiversity, impacting ecosystems and natural resources.
 - **Carbon Emissions:** Some production processes, especially in the mining and refining sectors, contribute to greenhouse gas emissions, exacerbating climate change.
 - **Water Scarcity:** Material extraction and processing can be water-intensive, putting pressure on local water resources and potentially exacerbating water scarcity in already vulnerable regions.
 - **Human Rights and Labor Practices:** The supply chain for critical materials may involve unethical labor practices, including child labor, hazardous working conditions, and low wages in some regions.
 - **Land Rights and Indigenous Communities:** Material extraction can encroach on lands traditionally owned or used by indigenous communities, leading to land rights disputes and cultural disruption.
 - **Conflict Minerals:** In certain regions, the extraction and trade of critical minerals may fuel armed conflicts and human rights abuses.
 - **E-Waste:** The disposal of electronic waste containing critical materials can lead to environmental contamination if not managed properly.
 - **Sustainable Sourcing:** Promoting responsible sourcing practices that consider environmental impacts, human rights, and social welfare throughout the supply chain.
 - **Environmental Regulations:** Implementing and enforcing strict environmental regulations to minimize the ecological footprint of material extraction and processing.
 - **Certification and Standards:** Supporting and recognizing certifications and standards that ensure ethical and environmentally sustainable practices in material production.
 - **Circular Economy:** Encouraging the adoption of a circular economy model to reduce waste, promote recycling, and extend the lifespan of critical materials.

II. EXAMPLES OF MATERIAL CRITICALITY

Certainly! Material criticality refers to the significance and vulnerability of certain materials in the context of a nation's economy, industry, and national security. These materials are essential for the production of various goods and technologies, but their supply might be limited, uncertain, or subject to geopolitical risks. Here are some examples of materials that are considered critical:

- 1. Rare Earth Elements (REEs):** REEs are a group of 17 elements, including neodymium, dysprosium, and europium, which are crucial for manufacturing high-tech products like smartphones, electric vehicle batteries, wind turbines, and defense systems.
- 2. Lithium:** A critical material used in lithium-ion batteries for electric vehicles, renewable energy storage systems, and portable electronic devices.
- 3. Cobalt:** An essential component in lithium-ion batteries, aerospace alloys, and other high-temperature applications.
- 4. Platinum Group Metals (PGMs):** Metals like platinum, palladium, and rhodium are crucial for catalytic converters in vehicles, fuel cells, and various industrial processes.
- 5. Indium:** Used in flat-panel displays, touchscreens, solar cells, and other electronics.
- 6. Tantalum:** An important material for electronic components, capacitors, and medical implants.
- 7. Gallium:** Used in semiconductors, LEDs, and photovoltaic applications.
- 8. Titanium:** Critical for aerospace applications, medical implants, and high-performance sporting goods.
- 9. Bismuth:** Used in pharmaceuticals, cosmetics, and electronics.
- 10. Antimony:** Used in flame retardants, batteries, and semiconductors.
- 11. Helium:** Although helium is abundant in the universe, it is relatively scarce on Earth. It is essential for various scientific and industrial applications, including cooling superconducting magnets in MRI machines, semiconductor manufacturing, and aerospace industries.
- 12. Phosphorus:** Phosphorus is a critical element used in fertilizers, which are essential for global food production. However, its supply is limited, and excessive use can lead to environmental pollution and depletion of phosphorus reserves.
- 13. Potassium:** Potassium is a crucial nutrient for plant growth and is commonly used in fertilizers to enhance agricultural productivity.

- 14. Nitrogen:** Nitrogen is a key component of fertilizers and is essential for plant growth. However, the extraction of nitrogen from the atmosphere for use in fertilizers requires a resource-intensive process.
- 15. Palladium:** Palladium is a platinum group metal used in catalytic converters for automobiles and various chemical processes. Its limited supply and high demand make it critical in certain industries.
- 16. Cobalt:** Besides its use in lithium-ion batteries, cobalt is also utilized in various chemical processes, such as catalysts in the production of synthetic rubber and petrochemicals.
- 17. Selenium:** Selenium is used in various chemical applications, including electronics and photovoltaic cells. It is also an essential micronutrient in human and animal nutrition.
- 18. Iodine:** Iodine is an essential element for human health, especially in the production of thyroid hormones. It is also used in various chemical applications, such as in the production of pharmaceuticals and disinfectants.
- 19. Molybdenum:** Molybdenum is used as an alloying element in various materials, including steel and superalloys for high-temperature applications.
- 20. Cobalt Chloride:** Cobalt chloride is used in humidity indicators and catalysts. However, due to environmental and health concerns, there is increasing interest in finding alternatives to this material.
- 21. Ordered, non-periodic materials:** Some structures are known to hold orderliness and non-periodic designs with lack of translational symmetry found to constantly occupy all the obtainable 3D space e.g., like quasi-crystals and ionic crystals.
- 22. Quasi-crystals** are fascinating materials with unique atomic structures that exhibit long-range order but lack translational symmetry. These structures were first discovered in the 1980s and were initially considered “impossible” according to conventional crystallography. Quasicrystals have since become a subject of intense scientific research and have applications in various fields, but they are not typically considered as materials criticality in the same sense as some of the other examples provided earlier.

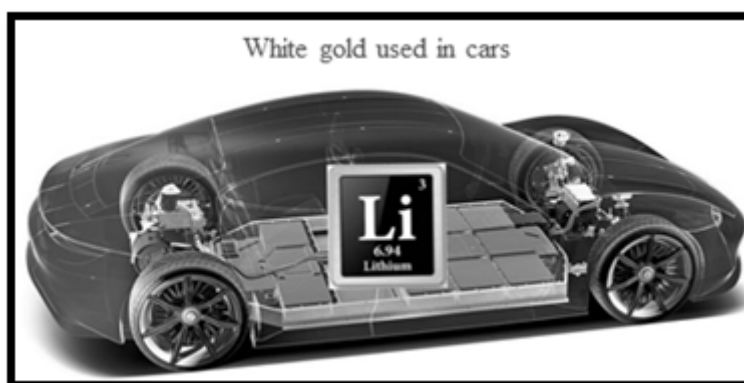
However, quasi-crystals have found some specific niche applications in areas such as coatings, heat insulators, and even potential applications in certain electronic devices. Researchers continue to study their unique properties and explore potential uses, but their criticality in the broader sense is not currently on the same level as other materials like rare earth elements, lithium, or platinum group metals.

It's worth noting that material criticality can change over time as technologies evolve, and the demand for specific materials grows or declines. As scientific advancements and industrial needs progress, it's possible that the status of quasi-crystals and their applications could evolve, potentially leading to increased relevance in specific industries.

23. Ionic-solids, also known as ionic compounds or salts, are chemical compounds composed of positively charged ions (cations) and negatively charged ions (anions) held together by electrostatic forces. Examples of ionic solids include sodium chloride (table salt), calcium carbonate (calcite), and magnesium sulfate (Epsom salt). Material criticality usually refers to materials that are crucial for various industries, technologies, and economic activities, but their supply might be limited, uncertain, or subject to geopolitical risks. Ionic solids are abundant and can often be found in various geological formations, seawater, and naturally occurring mineral deposits.

III. CASE STUDY

Lithium is used in Toyota and Ford cars' electric car batteries. Lithium is an energy critical element (ECE) and a non-renewable resource. About 100 times more lithium is necessary in an electric car battery as in a standard laptop battery. As society tries to lessen fossil fuel usage through the use of electric vehicles, lithium will be subjected to increased demand.



At the corporate level, lithium must be evaluated in terms of its importance to the company and can be replaced in the company's products. Both Ford and Toyota's current and most used batteries in electric cars are lithium-ion batteries. According to Toyota's environmental technology corporate strategy, "As Toyota anticipates the widespread use of electric vehicles in the future, research in developing next-generation secondary batteries with performance that greatly exceeds that of lithium-ion batteries."

At the national level, lithium-producing countries must consider their national lithium policies. The major lithium-producing countries include Bolivia, Chile, Argentina, Afghanistan, and Tibet. The high demand for lithium could bring large revenues into these resource-rich nations: a ton of lithium can sell for anywhere between \$4500 and \$5200, and the purer lithium that is used in batteries sells at the upper end of that interval. Bolivia's current reserve is estimated to be around 100 million tons. By comparison, the current market value of a ton of zinc is roughly \$2670.

Finally, at the global level, highly developed countries are the ones extracting resources and bringing industry into poorer countries. In terms of the population utilizing lithium, there are relatively large number of people using lithium, with technology encompassing a large percent of interactions and activities in the world. With some villages

in Africa operating more cell phones than bathrooms, it is reasonable to estimate a large percent of the world uses lithium, and to predict that the material usage will increase as industrialization and technological dependency grows. In terms of Toyota and Ford's lithium usage, it is important to note that as of 2005, global zinc air production could produce enough zinc-air batteries to power 1 billion electric vehicles, and lithium reserves could only power ten million lithium-ion powered vehicles.

The Geological Survey of India has found India's second Lithium reserves in Rajasthan. Lithium is quite a demanding metal which is used in making mobiles, laptops and all battery-operated devices. So far with the absence of any reserves of Lithium in India, it was China's monopoly over the supply of the metal.



On February 9, the first Lithium discovery was made in the Reasi district of Jammu and Kashmir where it is reported to have a stash of 5.9 million tones valued at \$410 billion. It is said that further studies are required to confirm if the area is feasible for mining.

In Degana it was found recently and after research, it was confirmed to be Lithium. A senior geologist in Rajasthan told the media, "Exploration was completed in March in a couple of blocks. But testing and analysis to ascertain the lithium content to determine whether it will make mining financially viable."

Reportedly this reserve is at the pre-mining stage and only after more exploration will the officials are able to confirm about the quantity of Lithium available in the reserve. If this area is confirmed for mining then the two existing reserves can meet 80% of India's Lithium demand, as per reports. Rajasthan could also become a richer state consequently.

IV. MATERIAL CRITICALITY AND ITS FUTURE ADVANCEMENT

1. Research and innovation: play a crucial role in addressing material criticality challenges. As the demand for certain materials grows and concerns about their limited supply intensify, investing in research and innovation becomes paramount to finding

solutions and ensuring a stable and sustainable supply of essential resources. Here are some ways researches and innovations can contribute to addressing material criticality:

- **Material Substitution:** Research can focus on finding suitable alternatives and substitutes for critical materials in various applications. Identifying new materials with similar or superior properties can reduce dependency on scarce resources.
- **Recycling Technologies:** Innovation in recycling technologies can help recover valuable materials from discarded products and waste streams. Implementing efficient recycling processes can reduce the demand for primary resources and minimize environmental impacts.
- **Efficient Extraction and Processing:** Developing more efficient and environmentally friendly extraction and processing methods for critical materials can help optimize resource utilization and reduce production costs.
- **Resource Exploration:** Research efforts can focus on identifying new sources of critical materials and exploring previously untapped reserves. This can help diversify the supply chain and reduce reliance on a limited number of suppliers.
- **Advanced Manufacturing Techniques:** Innovation in manufacturing processes can lead to the development of materials with improved properties and enhanced performance, potentially reducing the need for certain critical materials.
- **Circular Economy:** Advancements in the circular economy concept can foster the design of products and systems that promote material reuse, remanufacturing, and recycling, reducing waste generation and the demand for virgin resources.
- **Materials Science and Nanotechnology:** Research in materials science and nanotechnology can lead to the discovery of new materials or the enhancement of existing ones, expanding the range of options available for various applications.
- **Policy and Regulation:** Research can inform the development of policies and regulations that promote responsible sourcing, sustainable practices, and ethical standards throughout the supply chain.

2. Diversification of supply: is a crucial strategy in addressing material criticality challenges. It involves reducing reliance on a limited number of suppliers or geographical regions for critical materials and establishing a more balanced and secure supply chain. Diversification can help mitigate the risks associated with supply disruptions, geopolitical tensions, and price fluctuations. Here's how diversification of supply can be achieved in material criticality:

- **Identifying Alternative Sources:** Research efforts can focus on identifying new sources of critical materials in different geographic locations. Exploring previously untapped reserves and evaluating their feasibility for extraction can provide additional supply options.
- **International Trade and Partnerships:** Engaging in international trade and establishing partnerships with multiple countries can diversify the sources of critical materials. This approach can provide access to materials from regions with different geopolitical and economic factors.
- **Development of Secondary Sources:** Investing in technologies for recycling, reusing, and recovering critical materials from discarded products and waste streams can create secondary sources and reduce the dependence on primary resources.

- **Stockpiling and Strategic Reserves:** Creating strategic reserves of critical materials can provide a buffer during supply disruptions, ensuring a more stable supply chain during times of crisis.
 - **Sustainable Mining Practices:** Promoting sustainable and responsible mining practices in different regions can ensure a reliable supply of critical materials while minimizing environmental impacts.
3. **Circular economy:** principles are highly relevant in addressing material criticality. The circular economy aims to reduce waste, promote resource efficiency, and maintain the value of products and materials for as long as possible. In the context of material criticality, adopting circular economy practices can help manage the demand for critical materials, minimize environmental impacts, and ensure their sustainable use. Here's how circular economy principles can be applied in material criticality:
- **Recycling and Recovery:** Implementing efficient recycling technologies can recover valuable materials from discarded products and waste streams. Recycling critical materials can reduce the need for extracting and processing virgin resources, extending their usability and conserving natural reserves.
 - **Design for Durability and Reuse:** Designing products for longevity and easy disassembly can facilitate their repair, refurbishment, and reuse, reducing the consumption of critical materials in manufacturing new products.
 - **Remanufacturing:** Remanufacturing involves restoring used products to their original specifications, significantly extending their life cycle and reducing the demand for new critical materials.
 - **Material Substitution:** Circular economy thinking can encourage the use of alternative materials with less criticality or those that are more easily available and recyclable, reducing dependency on scarce resources.
 - **Waste Reduction and Prevention:** By minimizing waste generation and employing waste prevention measures, less critical materials are used, easing pressure on the supply chain.
4. **International cooperation** is essential in addressing material criticality challenges effectively. Given that critical materials are often sourced from limited geographic locations and their supply can be influenced by geopolitical factors, international collaboration becomes crucial for ensuring a stable and sustainable supply chain. Here's how international cooperation can play a significant role in material criticality:
- **Diversification of Supply:** Collaborating with multiple countries and regions can lead to the identification of alternative sources of critical materials. By sharing knowledge and resources, countries can collectively reduce dependence on a few suppliers and create a more balanced supply chain.
 - **Resource Exploration:** International cooperation can facilitate joint efforts in exploring new sources of critical materials, especially in regions where extraction may require significant investment and expertise.
 - **Knowledge Sharing and Research:** Collaboration between countries can promote the sharing of research findings, technological advancements, and best practices related to critical materials' extraction, processing, and recycling.

- **Strategic Stockpiling:** International cooperation can enable the establishment of strategic stockpiles of critical materials that can be accessed by multiple countries during supply disruptions or emergencies.
5. **Responsible sourcing** is a fundamental approach in addressing material criticality. It involves ensuring that critical materials are extracted, processed, and traded in a manner that meets social, environmental, and ethical standards. By adopting responsible sourcing practices, industries and countries can contribute to sustainable resource management, minimize negative impacts on the environment and communities, and promote a more resilient supply chain for essential resources. Here's how responsible sourcing can be applied in material criticality:
- **Environmental Considerations:** Responsible sourcing involves minimizing the environmental footprint of material extraction and processing. This includes adhering to sustainable mining practices, reducing energy consumption, and mitigating pollution and habitat destruction.
 - **Ethical Labour Standards:** Ensuring fair labour practices, safe working conditions, and compliance with international labour standards in critical material supply chains are crucial components of responsible sourcing.
 - **Transparency and Traceability:** Transparency in the supply chain, from material extraction to the end product, helps ensure that critical materials are sourced responsibly. Traceability measures can verify the origin and conditions of materials, reducing the risk of sourcing from unethical or environmentally harmful practices.
 - **Conflict-Free Minerals:** Responsible sourcing aims to avoid the use of conflict minerals, which are minerals that originate from regions associated with armed conflicts and human rights abuses.
 - **Support for Local Communities:** Engaging with and supporting local communities affected by critical material extraction can help address social issues and build positive relationships with stakeholders.
6. **Long-term planning** is essential in addressing material criticality effectively and preparing for future challenges. Material criticality involves managing the supply, demand, and sustainable use of essential resources over extended periods, considering technological advancements, economic shifts, and environmental factors. Here are key aspects of long-term planning for material criticality:
- **Resource Assessment:** Conduct comprehensive assessments of critical materials, including their availability, reserves, production capacities, and current and projected demands. This data serves as a foundation for developing long-term strategies.
 - **Forecasting and Scenario Analysis:** Use forecasting models and scenario analysis to anticipate future material demands, potential supply risks, and geopolitical factors that may influence critical material availability.
 - **Technology Roadmaps:** Develop technology roadmaps to identify emerging technologies that may impact material demand and to explore potential material substitution options.
 - **Diversification Strategies:** Create diversification strategies to reduce reliance on a limited number of suppliers or regions for critical materials. This includes identifying alternative sources and fostering international collaborations.

- **Circular Economy Integration:** Incorporate circular economy principles into long-term planning to promote material recycling, reuse, and remanufacturing, reducing the overall demand for critical materials.
 - **Responsible Sourcing Guidelines:** Establish and enforce responsible sourcing guidelines and policies to ensure that critical materials are extracted and processed ethically and sustainably.
 - **Strategic Reserves:** Consider the establishment of strategic reserves of critical materials to provide a buffer during supply disruptions or emergencies.
 - **Policy and Regulatory Framework:** Develop and implement a policy and regulatory framework that supports sustainable material management, promotes responsible sourcing, and encourages innovation in material use.
7. **State of the Art:** Material criticality determines its native flow feasibility validated via diversified paths viz; R & D, industry, and economy at global scale being most vital for assorted phenomenon including production and processing. Indeed material criticality evaluation criteria involve three basic extents namely: supply-risk, vulnerability to supply restriction, and environmental implications.

Any adoptable technology at global level seeks mandatory fulfillments of certain such criteria. Critical material so bligate to perform well, in the context of economy are judged by means of certain crucial factors including vigor, bulk, and stability besides recycling, reusability, durability, portability. All these aspects shield a realistic outcomes and relative performance in order to be much economic than the past and current resources. Material criticality is examined through the claimed supply chain being more crucial for any novel technology. The multiplicity of raw materials used in the development of many products are compounded via menace of supply disruptions which arise by means of irregular geological spreading of resourceful assets, besides socio-economic issues such as dimension of production, policy and political uncertainty of natural resource generating nations are much vulnerable to the domain of material criticality.

8. **Summary:** This is an overview of integrated critical assessment of material criticality and its evaluation criteria through the assorted dimensions, based on allied perspectives of short or long-term temporal outlooks. Several polygonal threatened factors arise in global markets, may or may not, be captured in criticality assessments provided are furnished on a material-by-material basis. The prime persuasive of such issues are possibly the close association amid the renewable energy field and ever craving upcoming materials need, with theoretical and applied catastrophic concerns for the universal economy. Human civilization would not have progressed as quickly as it did, nor will it be capable to endure such growth into the future without advancement of materials sciences. Some prime raw materials apt enabler for prevalent technological development. Many materials generally identified as crucial, chiefly produced as biomass/by-products from nature and mere employed in function, notwithstanding high-tech, utilities, are perhaps non-critical.

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