Mineral Supply Chain Visibility: Impact of Disruptive Technology on Critical Raw Materials

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Seminar Structure

13:00: Registration, Luncheon and Networking

14:00: Keynote | Simon Moores, Managing Director, Benchmark Mineral Intelligence

Critical Minerals and Metals: A battery powered tipping point

- Where are critical raw materials used in emerging technology
- A new era for global battery consumption
- Rise of the battery megafactories: Tesla Motors’ Gigafactory, LG Chem and more
- A medium term industry outlook

14:30: Market Brief | Analyst, Benchmark Mineral Intelligence

- Graphite, lithium, vanadium and cobalt analysis
- Supply, demand and prices
- Introducing the guest speakers

15:00 PUBLIC COMPANY SPEAKERS

16:00 Q&A Expert Panel Session

17:00: Networking Drinks

Call for Sponsors

There are opportunities for a limited number of companies to speak and sponsor the event.

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Expected Attendees

- Institutional Investors
- Retail Investors
- Mining Industry Executives

SUPPLY CHAIN 2020

BATTERY RAW MATERIALS
GRAPHITE | LITHIUM | COBALT | VANADIUM

London
New York
Toronto
Vancouver
Tokyo
Hong Kong
Sydney
Melbourne
As we move through 2015, the management of raw material supplies will become of increasing importance to leading companies across the value chain.

With many existing critical mineral mines long established, and in many cases depleted, the importance of bringing new resources to market is becoming paramount.

Emerging markets, led by disruptive technologies such as portable electronics, advanced materials and renewable energy are adding strain to supply chains and challenging the dominance of existing industrial consumers.

As a result of these changing market dynamics, price volatility is increasing, compounding the uncertainty surrounding raw material sourcing for many sectors.

Visibility of upstream industries will therefore become increasingly important throughout the value chain. Knowing not only who supplies your raw materials, but where these products are mined and at what market price, is imperative to managing a modern day business in this field.

Benchmark Mineral Intelligence has been designed to address these issues. Using in-house experts, our global, independent insight provides supply-chain visibility for your business, helping you to improve efficiency and better understand the environment in which you work.

Contact us today to learn more.

Simon Moores,
Managing Director,
Benchmark Mineral Intelligence

Benchmark Mineral Intelligence is a publishing company focused on the collection of market intelligence and data for critical mineral industries.

Situated in London, England, Benchmark is the home of accurate and independent industry insight and analysis for niche raw materials and their supply chains.

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Benchmark Mineral Intelligence

May 2015

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At a time when new technologies are emerging at an ever-increasing rate to meet the needs of a growing global population that is online, interconnected and mobile, the importance of establishing secure and sustainable raw material supply chains has never been greater.

The availability of raw materials has subsequently become a major concern to companies worldwide. In the same way as energy and food markets have been acute in guiding the economic development of previous generations, basic minerals and metals will be critical in the creation of new technology economies.

Now more than ever, the importance of the basic raw materials that supply today’s economies is being brought into question. This has seen increasing concerns at a government level about the availability of minerals and metals that are crucial in fuelling sectors such as renewable energy, portable electronics and defence technology.

Subsequent policy initiatives have seen a selection of minerals labelled critical, with the European Commission beginning a regular evaluation of the supply security and economic importance of raw materials such as graphite, lithium, rare earths, cobalt and vanadium. In the three years following the commission’s first analysis of non-energy/non-food materials in 2010, the number of minerals deemed critical has risen from 14 to 20, illustrating the fragility of today’s global supply chains.

Moving forward, there will be a growing need for firms to identify and effectively manage their raw material supply chains as a fundamental part of their business plans in order to combat this fragility.

In this report, Benchmark Mineral Intelligence examines the trends that are driving insecurity in these critical mineral industries and shows the growing importance of supply chain visibility, as downstream users seek to develop and sustain industries crucial to economic advancement.

![EU Criticality Assessments for Minerals and Metals in 2013](image-url)
Benchmark | Membership is your portal to a wealth of information. Covering a range of critical minerals & metals, our members receive a quarterly magazine, exclusive online content, downloadable graphics and full publishing rights.
The Nature of Minerals

The difference between commodities and specialist products

Critical minerals play a fundamental role in both established markets and the industries we expect to lead us into the future.

As non exchange-traded platforms, these markets tend to operate in a private manner, far removed from traditional commodity industries.

In fact, critical minerals such as graphite, lithium and cobalt are often far from what most would term ‘commodities’ both in terms of the way they are produced and the ways in which their markets operate.

Diverse and specialised specifications dictate that these materials remain niche in the eyes of many today, with each user requiring different properties for their product.

An emerging set of new markets threaten to disrupt the industry balance, however, and transform the make-up of these markets.

As new uses for these raw materials emerge, producers will be forced to evolve their product offerings to cater to new customer bases. Spending on new processing capacity for these emerging markets has begun in some areas but investment risk is holding back serious changes.

Today, with access to finance dwindling, it will be the responsibility of producers to adopt a longer-term approach to prepare for these new markets. It will also become the necessity of new consumers to acquire greater understanding and appreciation of the raw materials that will drive their technologies.

Unlike commodities, the markets for critical minerals are low-volume and, as a result, perform in a traditional manner of privately negotiated contracts.

Although this is unlikely to change in the short term, the intrusion of new hi-tech demand in markets previously dominated by industrial consumers has sparked industry volatility over the last decade. This situation is only intensifying.

It is now time for these emerging dynamics to modernise a previously neglected sector. This will only happen if the disconnect between buyer and supplier is bridged.

MAJOR COMMODITIES

1.7bn

tonnes of iron ore produced globally in 2014

$63

the average price per tonne of Australian iron ore in 2015

NICHE MINERALS

375,000

tonnes of flake graphite were produced globally in 2014

$900

the average price per tonne for medium flake graphite in 2014
Arguably the most important of all potential new markets for critical minerals is the battery sector and the disruptive technologies it supplies, which are revolutionising how we live our lives.

The use of large scale batteries in electric vehicles (EVs) and stationary storage, alongside existing small-scale smartphone and tablets is having a vast effect on the world of raw materials.

Today, lithium-ion batteries are the technology of choice across most of these markets and as such the graphite, lithium and cobalt used to make its anode and cathode materials are critical in ensuring performance.

The performance of these materials is dependant on the purity, size and the nature of impurities. As battery technologies mature and improve, the demand for higher quality raw materials will increase.

The processing required to achieve these hi-tech grades dictate a premium and as a result many existing producers and exploration-stage companies are seeking to position themselves to capitalise on growth in these sectors.

As with all niche minerals, the ability to process and tailor output is almost as important as the natural properties of the material itself.

In the case of graphite, lithium and cobalt, each has a particular set of characteristics that make them difficult to substitute, or in most cases irreplaceable.

Graphite is the primary anode material in lithium-ion battery technologies. The carbon purity and shape of the particles determine its conductivity.

While synthetic graphite is used by some anode producers, Benchmark Mineral Intelligence estimates that 60% of graphite anodes are derived from natural material.

For application in batteries, the material is processed to a purity of above 99.95% C and spheritised to increase the surface area of the particles. Finally, the material is coated with a layer of carbon to improve conductivity.
Lithium-ion Battery Revolution continued...

**Lithium**

Lithium raw material can start as a brine or a hard rock (spodumene). While the beneficiation techniques are different, the pre-cursor product produced for batteries is either lithium carbonate or lithium hydroxide. These products are then purified to a level of 99.95% Li or greater for use as a battery cathode material.

**Cobalt**

The majority of mainstream lithium-ion cathode materials are based on a lithium-cobalt chemistry. Battery or chemical grade cobalt (cobalt oxide) is sourced from the same raw material as cobalt metal and predominately comes from the Democratic Republic of Congo. In fact, 55% of cobalt raw material is sourced from the central African nation, with the majority of battery-grade refining capacity in China. This imbalance in supply and refining capacity and technology has deemed cobalt one of the most critical of all minerals and metals.
Battery growth outlook: Tesla case study

In March 2014, Tesla Motors announced unprecedented plans to build a $5bn plant that will more than double global battery storage capacity – the Gigafactory. With the primary aim of achieving economies of scale significant enough to overcome the cost barriers associated with EVs, Tesla’s plans promise revolutionise the automotive market. These plans have paved the way for a wave of competing projects, as battery producers look to expand capacities, capitalise on the potential cost reductions and take advantage of a new wave of demand.

Estimates suggest these companies would need to reduce costs from around $250/kWh to between $100-150/kWh to commercialise lithium-ion batteries. For EVs, Tesla believes these cost reductions will allow them to produce a mass-market vehicle for as little as $35,000.

If Tesla meets its target capacity of 35GWh by 2020, it alone could require up to 26,000 tpa of lithium (6% of global supply in 2014), 105,000 tpa of flake graphite (28% of global supply in 2014) and over 7,000 tpa of cobalt (7% of supply in 2014). To meet this demand in little over four years there will have to be fundamental change in the way these upstream markets operate. Tesla is aiming to continue to push EV boundaries with the release of the Model X in mid-2015, followed by the Model III in 2017 – the company’s first mass-market EV. Further to vehicles, the company is also exploring the stationary storage market which is forecast to experience rapid growth as governments seek develop more reliable energy supplies.

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<th>Battery Grade Increases on 2013 (%)</th>
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<td>Flake graphite</td>
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<td>Lithium</td>
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<td>Cobalt</td>
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<th>BATTERY GRADE INCREASES ON 2013 (%)</th>
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<td>160%</td>
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<td>120%</td>
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4.5bn

battery cell demand in 2014

500,000

number of EV batteries the Gigafactory will be capable of producing at capacity

25%

of flake graphite demand is from the battery sector
**Benchmark | Data:** your exclusive, online data and analysis tool. An annual subscription to a database of market prices, production data, and monthly analysis. Graphite and lithium will launch in Q2 2015, soon followed by cobalt and vanadium.
Look out, Ford, General Motors, and Tesla: In a secret facility somewhere in Silicon Valley, Apple is reportedly building an iCar. It makes sense, in an Apple-centric sort of way: If Apple wants all of us to be able to safely use our iPhones while driving, why not just build a compatible car? The entire automotive industry could become an app.

Apple may not be ready to morph into a nation-state, but this is all heady stuff for a company that just powered past the $700 billion market cap mark and is touted by otherwise hard-boiled analysts as the odds-on favorite to be the world’s first trillion-dollar company.

Yet we should marvel at the lack of attention companies such as Apple pay to their Achilles’ heel: The minerals and metals with which make the magic.

The more these companies rule the world, the more fortunes rest on the weakest link in their material supply chains.

Take the typical smart phone. In the screen, you’ll find indium, aluminum, and tin, in addition to 7 of the 17 rare earths. The battery holds lithium, graphite, manganese, and cobalt. For the electronics, you’ll need copper, gold, silver, tantalum, tin, lead, arsenic, antimony, nickel, gallium, and again, a handful of rare earths. Finally, the case includes nickel, bromine, and magnesium.

In all, the average smartphone contains as many as 40 elements on the Periodic Table - nearly half of the 90 elements found in nature. It may be gram-flakes in each phone, but it all adds up: Last year, new smartphones consumed more than $2.5 billion-worth of gold and silver alone.

Apple has made attempts to find out where the metals it uses come from. The company’s newly released Supplier Responsibility Report, with a standalone Conflict Metals SEC filing, shows the efforts Apple take to source conflict-free minerals and metals.

The company discloses a long list of its supply chain smelters and refiners, and it cuts off suppliers that don’t meet conflict-free standards. But the conflict metals legislation tucked away in the 2010 Dodd-Frank omnibus act focuses on just four metals - tantalum, tin, tungsten, and gold - from one country, the Democratic Republic of the Congo.

Apple knows precious little about the remainder of the 40 metals and minerals found in smartphones - how they’re mined and where they come from - and no one else knows much more.

Some of them come from recycled e-waste, which sounds virtuous. After all, Jane Jacobs, the late urban activist, rhapsodized that “cities are the mines of the future” - chock full of metals and minerals we can reclaim to build the next stage of technological progress.
She was right, and even now, innovative companies are showing it is possible to extract rare metals from spent electronics, coal ash, and red mud waste dumps - and to do so by environmentally benign means.

Urban mining may be the wave of the future, but the cities that are the mines of the present should be the ones that concern us.

Take Guiyu, on the South China Sea coast, known as the electronic wastebasket of the world. Children as young as 3 scabble through metal mountains of shattered flip phones, motherboards, and other assorted electronic innards. Sharply increased lead levels make their way into the food supply, and the air, dense with the chemical stew used to tease metals out of trash, literally burns visitors’ nostrils.

While it is illegal to export e-waste, truckloads of it somehow keep rolling into Guiyu. Not far from Guiyu, subsistence farmers trade their health for a family fortune, mucking out heavy rare earths from the local ionic clay using toxic chemicals and plastic buckets.

The supply chain leads through criminal gangs past corrupt Chinese generals - Beijing regularly cracks down on illegal mining, but it persists all the same - onto the docks and ultimately into an unknown number of our smartphones. By some accounts, more than 30,000 metric tons of heavy rare earths are being smuggled out of China each year.

So what do we really know about the metals in our tech gadgets? Okay, they don’t come from the conflict regions of the DRC. But are they “sourced” from the children of Guiyu? Or in pails full of heavy rare earth concentrate from poor Chinese farmers? Is the antimony in our phones fed into the global supply chain via Burmese rebels over the mountains of Myanmar?

We don’t know, because no one is asking. And to some extent, perhaps no one wants to know: Just make sure there’s a new phone out when I’m ready for my upgrade. Our policy amounts to Don’t Ask, Can’t Tell.

It doesn’t have to be this way. Many of the metals we need could come from new mines in the United States, where supply chains could be easily certified, and labor, environmental, and safety practices would be among the most scrutinized in the world.

But the political and regulatory climate in the United States has grown more and more inhospitable for mining over the past two decades, even though the time it takes to permit a new U.S. mine already ranks near the worst in the world.

And little wonder, as many of the very groups that depend on metal-laden tech-gadgets to spread their message and plan their protests are the loudest objectors to new mines of any kind.
How short-termism in public markets has prohibited the development of new mines

Developing a new mine for niche mineral industries can take up to ten years - and that is without any major disruptions.

New sources require a significant capital outlay, which hinges upon the economics of the project. With market prices relatively low, despite greater volatility in recent years, the long-term planning required to develop a project is difficult to achieve and generally proves too risky for many financiers.

Therefore, new sources very rarely come on-stream. For example, graphite has not had a new mine in nearly 30 years, while lithium’s last entrant, prior to March 2015, was in 1996. These are raw materials that are supplying both large, existing traditional industries and emerging hi-tech markets - yet supply availability is still limited.

A lack of understanding and transparency in these markets are major hurdles to the development of new sources. With commodities like iron ore, copper or bauxite, demand is fairly predictable and the required product specifications are well known.

With critical minerals and metals, each buyer may require a different product tailored for their specific needs. Producers would therefore alter each run of the processing plant to fit individual customers – good for a niche producer, but not good for scale.

The size of buyers are also limiting development of new sources. Large volume consumers that would use 30% of output from a lithium mine, for example, do not exist in today’s world.

Therefore, there is no one off-take partner that miners can target to guarantee cash flow when operational, which limits the channels of investment available to exploration-stage companies.

This dynamic could be changing, however. Using the emergence of battery megafactories as an example, Tesla Motors, LG Chem, Foxconn Technology Group, Boston Power and China’s BYD are all building super-plants that will dwarf today’s operations and, in turn, require much larger volumes of raw material at one specification for each plant.

Instead of battery anode producers buying a tailored order of 2,000 tpa of spherical graphite, for example, demand from one buyer could now jump ten-fold to 20,000 tpa.

This potential for huge growth could commoditise parts of these niche industries; increasing volumes, prices and market transparency - making the development of new sources easier in the future.

Life Cycle of a Typical Exploration Stock

Source: Zimtu Capital Corp.
1) EV competition to intensify
The mass market adoption of electric vehicles (EVs) has become a case of not if, but when.

Efforts by companies such as Tesla, BMW and Toyota to overcome the obstacles of adoption are pushing the market from niche to commercial, however the race for market dominance is still on.

This competition will intensify with the rumoured entrance of large technology firms such as Google and Apple into the EV space, leading producers to funnel capital into R&D projects.

As much as this competition will drive the market forward, subsequent efforts to cooperate and collaborate will remain crucial to the evolution of the market.

Tesla has gone some way to promoting this process by opening up its patented technology for the wider industry.

Nevertheless, many hurdles remain for the growing number of companies seeking to position themselves in the EV space.

2) Tough times for exploration finance
The wave of investment into critical mineral markets that began in 2010, will continue to subside in 2015, leaving many junior companies fighting for survival.

As the recovery in end-markets continues, and new consumers emerge, the need for supply chain security will remain providing some hope to development stage-companies.

Tightening finance markets are likely to force some out of the market, however projects with good resources and secure economics are likely to weather the storm with signs of brighter times ahead.

3) A new generation of suppliers
Despite turbulence in capital markets, a number of projects have managed to move ahead of the crowd and will attempt to position themselves as producers over the coming year.

In terms of the graphite market, some projects have already begun produce small quantities, however other critical mineral markets continue to lag behind.

With finance tightening, the exploration community will face a fight to advance their projects in the short-term, but for those on the verge of production a set of new challenges await.

Ten Critical Mineral Trends for 2015
From resource nationalism to price rebounds: The trends impacting critical minerals in 2015
4) Light on the horizon for prices
Three consecutive years of price decreases have left many critical mineral markets at rock bottom.

While signs of an immediate recovery remain scarce, the majority of markets have shown signs of bottoming out.

Although large inventories, following years of over-production, are likely to suppress any significant upturn in the short-term, tightening supply in many sectors alongside a steady recovery in global economic markets is likely to fuel some more positive news for producers approaching the end of the year.

5) Regional the new global?
The importance of supply chain security has become a prominent trend within industrial markets over recent years and this looks likely to spread to peripheral markets in 2015.

While tightening capital flows for many are likely to prevent widespread vertical integration, the importance of supply stability will see greater consumption either domestically or from neighbouring nations.

Being strategically located will subsequently become of growing concern to both exiting and junior projects with consumers willing to pay premiums for consistency and stability of supply.

6) Slow but steady industrial recovery
As the largest consumption sector for critical raw materials today, the performance of industrial markets will continue to drive demand throughout 2015.

Growth in many industrial sectors is set to remain at low levels this year, with steel production growth forecast to stabilise at 2% despite increased industrial activity in developing regions such as Africa, Central and Southern America and the Middle East.

While the outlook for North America and Europe is less bullish, a stable recovery is expected to continue to eat into the surplus of raw material supplies.

With little demand growth expected from the industrial sector, critical mineral producers could be forced to reduce production in the short-term, however hopes of new market emergence will see many upgrade processing capabilities in order to diversify customer bases. This will pose a threat to existing industrial end-users in the longer-term.

7) The Chinese evolution
As China shifts away from its position as a low-cost supplier to international markets, a void will be left in the supply of many critical minerals.

Industries such as rare earths, magnesium and fluor spar have already seen the effect that Chinese government restrictions can have on the balance of the market, and 2015 looks
Ten Critical Mineral Trends for 2015

set to see a continuation of these policies as the country attempts to advance its involvement in downstream sectors.

The natural graphite market came under particular scrutiny during 2014 as a series of consolidation policies came into effect. This process will continue in graphite as well as a number of other critical mineral markets.

Swift policy changes are not uncommon in China, leaving any market which is highly dependant on Chinese supply subject to potential upheaval.

8) Low-cost competitors
As critical mineral markets move towards recovery, China will shift focus to further domestic downstream development, with the higher quantities of raw material being used domestically leaving a potential deficit in export markets.

The race to become the new low-cost suppliers in markets previously dominated by the Chinese is already underway and is likely to intensify in 2015.

From fluor spar in Vietnam, to graphite in Africa, to lithium in Argentina, new low-cost projects are aiming to develop mines capable of replacing China on the world stage.

Expect these efforts to intensify as supply insecurity escalates in many markets.

9) Closures ahead
Following three years of decline across many critical mineral markets, tightening margins are forcing many to reevaluate the economic feasibility of existing projects.

In some markets, this has already forced some existing mines out of production and threatens to spread to other industries as a slow price recovery begins.

At the highest threat of closure will be mines with low quality resources, depleted reserves or those that are not strategically positioned geographically to serve major consumption markets.

This could see mines that have been prominent in the critical minerals space for a generation, forced out of the market in 2015.

10) The push towards energy storage
With demand for more sustainable, reliable and efficient sources of energy booming in recent years, utility storage solutions have become a major industry.

Projects from US states as large as California to islands the size of Bermuda are looking at increasing energy storage capabilities. Today, the world’s energy storage capacity is under 600 MWh, but conservative forecasts expect this to grow to 20 GWh by 2022.

This will see demand for critical minerals in these markets grow by an order of magnitude, over the coming years, with a significant uptick in consumption expected in 2015.
Benchmark | Forecasts: medium and long term supply, demand and price forecasts. These annual reports will give our independent view on the future of critical mineral industries. Graphite will launch in Q2 2015.
Crucial to the development of all disruptive technologies is the ability of producers to reduce prices to a level that makes adoption viable on a commercial scale.

In the case of electric vehicles and energy storage, battery production costs are a major obstacle in achieving this goal.

With market adjustments taking places in battery raw material markets in terms of both supply and demand, a new era of price volatility has emerged, redefining what were previously relatively stable industries.

This threatens to impede the work new end-markets are undertaking to cut production costs and lower prices.

In 2010, potential new demand from the battery sector saw a wave of interest in minerals such as graphite, lithium and cobalt.

In the graphite market this saw prices increase by over 100% in 18 months. Both lithium and cobalt experienced similar price spikes over the same period.

In the preceding three years, the vast majority of these gains have been wiped out, leaving some areas of these markets at historic lows.

Price cycles of this magnitude were previously unheard of in these markets. But it is not only the size of the fluctuations which is important to consumers.

The frequency by which price distortions have occurred has increased significantly over the past decade alone, leading to greater instability for raw material purchasers.

As a result of this uncertainty, deals which were once negotiated annually or bi-annually are now taking place quarterly, monthly or even weekly, changing the fundamental dynamics of the markets.

For industrial consumers this has already seen a growing focus on supply chain security, with offtakes, mergers and more regional trade structures becoming the norm.

The challenge for emerging market consumers will be to match the upstream visibility that other industries possess and position themselves in a manner that will secure raw material prices and allow them to cut production costs.
Addressing supply chain challenges for a new generation of industry

Today, we stand on the precipice of a new era in mineral supply chains. For the first time in a generation, a set of disruptive technologies will intrude on well-established and inflexible raw material industries that have undergone little change for over two decades.

These new end-markets threaten to squeeze supplies to a level many of these industries have never experienced before.

The need for these minerals in new technologies are pressuring upstream markets to change, but if, how and when they evolve is far less clear.

Often niche, rigid and opaque, the majority of these industries are not built to supply major, large-scale sectors. No longer will the ability to produce minerals in small, tailored quantities be sufficient to meet downstream demand, should these new technologies reach their potential.

The criticality of minerals in the development of renewable energies, green transportation, portable technologies and sustainable power solutions is growing and becoming more mainstream.

While existing miners and exploration companies position themselves to serve these growth sectors, the market dynamics of mineral raw materials are expected to experience rapid change.

But it will not only be the supply side which is required to adapt.

Fluctuating supply, demand and price dynamics will force downstream firms to take a bigger interest in upstream developments as the need for supply chain visibility becomes ever-important.

The success or failure of tomorrow’s major companies will hinge upon factors further upstream that have previously been off the radar.

As the importance of minerals and metals increases, so too will the need for greater transparency and information.

If the ideas of today are to become the realities of tomorrow, specialist raw materials will be the building blocks of this growth.

Whether traditional commodities or niche materials, the need for supply chain visibility has never been greater.

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> Forecasting by Benchmark’s in-house analysts
> Based on data collected, first-hand by us
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