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Elon Musk, CEO, Tesla Motors Inc.

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smoores@benchmarkminerals.com
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Beijing accepts defeat in WTO case and will now switch focus to reorganising rare earth export licences and taxes

Orocobre enters lithium market on tightening supply
As the lithium industry welcomes its first new producer in a generation, demand is once again beginning to outpace supply

Uranium set for higher prices
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Critical mineral trends for 2015
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Apple puts batteries at the centre of its EV masterplan
Law suit exposes Apple's electric vehicle ambitions and focus on batteries as Project:Titan begins to emerge from the shadows

EVs at the tipping point, says Deutsche Bank
Independent report says we are at the point of an 'unprecidented shift' in global transport, with electric vehicles and diesel cars set to reach cost parity within five years

Steel supply chain faces new lower equilibrium
Slowing growth in steel output forces further raw material and refractory restructuring 2015

EXCLUSIVE INTERVIEW

Slowing EV's roll
In an exclusive interview with Benchmark Mineral Intelligence, SQM's COO, Patricio de Solminihac discusses lithium's 'spectacular' rise in portable batteries, but issues caution over history repeating itself in electric vehicles

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Tesla Motors, LG Chem, Boston Power and Foxconn are building battery super-plants that will come on-stream in the next three years. The new supply could revolutionise how we source and use energy, creating a once-in-a-century disruptive event.

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A new generation

It is not easy to find a tipping point: that one moment that can signify a definitive and fundamental change. In the past, true change in minerals and metals has happened over a longer period of time through a series of trends.

But where our industry stands today in 2015, these trends are becoming shorter and change is more rapid. During the past 18 months, there have been more tipping points in our industry than in the entire period since the global financial crisis of 2008.

For critical minerals and metals those key moments of change include: the collapse in oil prices, Tesla Motors’ Gigafactory (p46), the subsequent surge of battery megafactories (p38), Apple’s boom in iPhone sales which saw it become the most profitable company in history (p26), and China losing its rare earths WTO case (p14), to name only a few.

Disruptive events are becoming more commonplace in what are fragile and inflexible industries. Disruptive companies, outsiders, are entering these sectors with different rules.

Benchmark Mineral Intelligence occupies a privileged position in this time of change. We are able to independently analyse those supply chains that are becoming increasingly critical. To start with, we have chosen the battery supply chain and the raw materials of graphite, lithium, cobalt and vanadium.

Benchmark has been established with the mission of providing global supply chain visibility, all the way upstream to the mine. We are independent onlookers to the three core market fundamentals of supply, demand and prices.

Our commitment to this cause is demonstrated with our Supply Chain 20/20 seminars hosted as part of the Benchmark | World Tour 2015 (p3). This is an ambitious tour of eight cities across four continents, and has never before been done in our industry. And what’s more, it’s free, for every delegate from London to Hong Kong.

All of our product offerings will be built upon the bedrock of first-hand data collection.

Benchmark’s analysts collect prices and production data from the source by travelling around the world to see the mines and processing plants that create the products we evaluate.

Our own in-house, transparent methodology will ensure the accuracy, reliability and trustworthiness of this data. The expertise of our analysts will ensure relevance, telling you what the data means, why something is happening and where we are heading.

With our world becoming increasingly mobile, the need for better, longer-lasting, lower cost batteries is paramount. We could not have these batteries without the graphite, lithium and cobalt that make up the anode and cathode components.

A host of critical minerals and metals make smartphones and tablet PCs possible, including rare earths, antimony, gallium and tantalum. Meanwhile, the majority of electric vehicles are still reliant on a permanent rare earth magnet, let alone a huge battery.

On the energy side, the US shale boom rests upon a specific grade of sand or engineered mineral products known as proppants. The growing need for cleaner energy sources is driving up demand for uranium feedstock for nuclear power, but it could take up to a decade to finance and build a new mine.

The recent resurgence of solar power is increasing pressure on its most critical of raw materials, silicon, which is derived from a handful of high-purity quartz mines around the world. Meanwhile, wind turbines cannot operate without a neodymium (rare earths again), high-performance magnet.

These renewable energy sources will become increasingly reliant, again, on batteries: this time large stationary units to store the intermittent power generated.

If we rewind the clock five years, knowledge of these critical minerals was not widespread. Few anticipated the importance and scale of the role they would play in future technologies. But these raw materials feed global industries that are on the tipping point of becoming industrial-sized sectors influencing every part of our daily lives.

It is no longer that change is coming, but change is here. We are in a new era for minerals and metals, driven by a new generation.

Simon Moores
Managing Director
Benchmark Mineral Intelligence
@sdmoores @Benchmarkmin
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Daniel McGroarty of Carmot Strategic Group outlines the importance of supply chain visibility in an era of technology superpowers

Geopolitics of mineral supply

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 the magic happen.

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.

Sourcing conflict-free minerals and metals

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 scrabble 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.

Illegal e-waste exports

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 persist spreads 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 Congo. 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, Canada or the EU where supply chains could be easily certified, and labour, environmental, and safety practices would be among the most scrutinized in the world. But the political and regulatory climate in these regions has grown more and more inhospitable for mining over the past two decades, even though the time it takes to permit a new US 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.

Daniel McGroarty, principal of Carmot Strategic Group, an issues management firm in Washington, D.C., served in senior positions in the White House and at the Department of Defense.
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Upstream | News Analysis

Analysing major news developments from mining, processing and global trade of critical minerals and metals

IN THIS SECTION:
- CHINA LOSES RARE EARTHS CASE
- OROCOBRE ENTERS LITHIUM MARKET
- URANIUM SET FOR HIGHER PRICES
- PEAK GRAPHITE IN CHINA?
- CRITICAL MINERAL TRENDS FOR 2015

Source: BHP Billiton
China has lifted export quotas on rare earth elements after admitting defeat in the World Trade Organization (WTO) case from last year.

The country, which supplies 85% of the world’s rare earths, has abolished a long standing quota which capped exports and is set to restructure the way the rare earths taxation system operates.

This has come after the WTO ruled that its rare earths restrictions were “designed to realise industrial policy goals rather than conservation”.

The WTO complaint, which was initially raised in 2012 by the US and saw the EU, Japan and Canada join soon after, claimed that China was deliberately conducting unfair business practices by restricting supply of irreplaceable elements to its competitor nations.

The major focus was the export quota China imposed on rare earth concentrates which capped quantities from as high as 50,145 tonnes in 2009 to 30,611 tonnes in 2014. This news is likely to see other forms of restrictions imposed.

Benchmark Mineral Intelligence believes that fundamentally the game will not change and that China’s preferential treatment of domestic producers will continue by other means.

We expect China to refocus its efforts on restructuring the way it issues export licences to its producers and on simplifying its rare earths tax system.

Without a licence companies are banned from exporting. Beijing still controls this vital bottleneck of the supply chain, therefore whether it caps exports at the port or controls the number of export licences issued, the result is the same: restricted supply of rare earths to the rest of the world.

China has achieved this in many other critical mineral industries and while rare earths is the most extreme of all, the principal is no different in the eyes of the country’s governing bodies.

A major talking point now is whether western joint-venture (JV) companies will be allocated export licences.

The move also offers up a chance for China to simplify its rare earths tax. It will be of great interest to the industry to see what the new taxation will look like and whether it will be different for 100% Chinese owned operations and international JVs.

“The Chinese Ministry of Commerce indicated that [rare earths] are now to be exported through only 9 designated ports,” explained Gareth Hatch of Technology Metals Research.

“Export licenses will be “handled” through a Special Commissioner’s
Office within MOFCOM, on a case-by-case, shipment-by-shipment basis,” he added. All of these factors will create short-term uncertainty as the industry will wait to see how the new scenario plays out.

In the long term China’s stance of redirection of rare earths towards domestic consumption is likely to remain the same, consistent with its plan to create an economy based on value-added products and not raw materials.

Long-term clean up
China’s long-term plan goes beyond rare earths.

The world’s second biggest economy is in the midst of fundamental change to the way it operates. A major overhaul of its mining operations is key to securing a future based on value-added products such as batteries, smartphones and new energy, not just materials upstream at a low cost.

And rare earths is not alone. Graphite, phosphate and fluorspar are examples of other mineral industries that have been subject to consolidation and modernisation.

Therefore, while many countries will want to criticise China for its rare earths stance, the reality is it is entitled to do what it wants with its own resources.

While, for now, it has to obey the WTO membership rules to remain at the negotiating table, the reality is China does not need the revenue from rare earths, it is symbolic and rather than economic.

In terms of supply security for users of the elements, having 85% of total supply reside with one country is an unsustainable environment.

It is a situation that the industry, and end users in particular, only have themselves to blame for after being more than willing to accept lower cost rare earths from China for two decades while not investing in new sources externally.

The only other critical minerals which come close to such a one-sided supply dynamic are graphite (75% from China), silicon (60% from China), cobalt (55-60% from Democratic Republic of Congo), and fluorspar (50-55% from China).

Another surprising fact is that major users have known about this supply imbalance for decades and have felt the price impact as recently as 2010 when China blocked exports to Japan.

With China changing, the question for the rest of the world is: where will significant new supply of rare earth elements come from?

It is the same question that was being asked five years ago and the industry has not really made progress since.

**RARE EARTHS IN NUMBERS**

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Source: Molycorp (left), Dudley Kingsnorth (right)
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.
Orocober enters lithium market on tightening supply

As the lithium industry welcomes its first new producer in a generation, demand is once again beginning to outpace supply

The lithium industry has welcomed its first new supplier in 19 years after Orocober Ltd confirmed the start-up of its Olaroz lithium carbonate plant in Argentina.

The Australia-based company has begun brine operations at the Salar de Olaroz in Argentina’s north and plans to ramp up to full capacity of 17,500 tonnes of lithium carbonate by the end of 2015.

Orocober is targeting the battery industry as its primary customer base, but is not closing itself off to market opportunities elsewhere including the glass, ceramics and industrial lubricants sectors.

“We can produce 100% battery grade material from our feedstock brine but we are not purists, we will do business where it makes sense,” Richard Seville, Managing Director of Orocober explained in an exclusive interview with Benchmark Mineral Intelligence.

The company is the first of a new wave of lithium projects to make it to production, somewhat of a rarity in today’s financial environment.

In what has been one of the worst ever slumps experienced by the exploration mining sector, Orocober has managed to secure $250m funding for Olaroz since 2010 with construction starting in late-2012.

It has still been a seven-year process from registering the company to starting production, but in relative terms that is a rapid start-up for a niche mineral operation and perhaps comes as a stark warning to end users seeking to secure medium term raw material supply that new projects can take the best part of a decade to develop.

Major backers of the project include Japanese joint-venture partner, Toyota Tsusho Corp, in addition to major share holders Acorn Capital Ltd (7.17%), Renaissance Asset Management (4.52%), CIBC Asset Management (4.48%), Invesco Asset Management (3.97%), and Blackrock Investment Management (1.92%).

And for these backers, the timing is looking good with the lithium market bracing itself for a period of tightness as increasing demand meets stagnant supply.

There have been no significant expansions in recent years at any of the major lithium brine producers of SQM, Rockwood Lithium (now Albemarle) or FMC Lithium. In the meantime, demand from lithium-ion batteries used in smartphones, tablets and laptops has been steadily rising and is likely to move the supply/demand balance into deficit by mid-to-late 2015.

“During our time in construction, the market has gone from a perception of an excess in supply to a very, very tight situation. Despite publicly stated plans from existing lithium producers over the last two years, there have been no production expansions at all,” Seville explained.

“If we were negotiating our contracts a year ago we would have been on the back-foot, but now with complete market uncertainty it’s a
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good time to enter the industry,”

“The lithium market is going to get
even tighter this year,” he added.

Orocobre has equipped itself
with the capacity to produce both
technical grade and battery grade
lithium carbonate.

It does not yet have the ability to
produce lithium hydroxide, but the
company explained that it is certainly
considering it as an “integral part” of
its first expansion phase.

Supply of lithium hydroxide,
which is also a key battery cathode
raw material, is tighter than
lithium carbonate at present. It is
a more niche product than lithium
 carbonate, but is also used by
major battery producers that are
competing with the industrial
lubricant industry for the same raw
material.

Lithium hydroxide is subsequently
expected to endure an even tighter
supply situation to its carbonate
counterpart in 2015.

Can lithium be
 commoditised?
The price of technical grade lithium
carbonate has fluctuated since 2004
from $3,000/tonne to an all-time
high of over $6,000/tonne in 2009.
The last five years the price has since
settled back in the mid-$4,000/tonne
region, but is expected to start its
rising trend once again in 2015.

The difference between this price
and that of battery grade material,
which is purified to a minimum
of 99.95% lithium content and
micronized, has always been one
of contention with some producers
claiming the superior grade has a
higher price.

While this may be true of the
sell-side offer price, the buyer, who
negotiates the contract privately and
not via an exchange, can drive this
down to, at times, levels on a par with
the technical grade product.

It has always raised the question of
whether lithium, a specialist product
that is tailored for each customer,
can be commoditised and exchange
traded.

Seville believes that with the
way the market is structured at
present, it is not possible. The talking
point, however, is on whether
the emergence of the battery
megafactories and huge buyers
of raw materials – up to ten times
the size of today’s customers – can
change this.

“I think the market will change a
bit, but I don’t think lithium will ever
become a commodity,” Seville told
Benchmark.

“End users buy a product which
is qualified for quality and consistency
through a rigorous process. Short
term substitution is not possible so it
is not a commodity.

“The only way you can have some
form of standardisation in lithium is
if large buyers get all of it from one
source, with one set of chemical
attributes. Product specs vary
between producers depending on
the source,” he added.

Orocobre is presently negotiating
its first round of contracts and is
expected to reach its full production
rate by the end of this year.
Uranium set for higher prices

With low prices stifling new sources, Japan set for a post-Fukushima demand rebound, and China forced to reduce its coal addition, Peter Epstein analyses how the groundwork for higher uranium prices has been laid

Uranium does not trade on an open market which makes it difficult for many to analyse accurately.

Buyers and sellers negotiate contracts privately and prices are published by independent market consultancies. The opaqueness of the uranium market is more akin to critical minerals like graphite and lithium than exchanged-traded commodities like copper and coal, and is also similar in size with just under 60,000 tonnes of uranium mined each year.

The industry is driven by global electricity consumption, which typically increases in both good times and bad. Since 1980, global electricity consumption has tripled, and major Canada-based uranium producer, Cameco Corp, forecasts it will increase by 70% over the next two decades.

The largest growth is coming from countries with rapidly expanding economies, like China and India. To put it into perspective, of the seven billion people on the planet, there are almost two billion who do not have access to electricity.

Cameco forecasts demand of 240m pounds (108,862 tonnes) and primary supply of just 120m pounds (54,431 tonnes) by 2023. That would equate to a compound annual growth rate (CAGR) of about 4%.

This has left many asking: Where will the supply come from to fill that gap?

The biggest problem facing the industry is the spot price of uranium. It has halved since March 2011 after Japan’s Fukushima disaster which resulted subsequent closure all of its reactors. These reactors are yet to come back online and the low price has all but halted the development of any significant new sources.

Many industry participants talk about the "incentive price" of uranium, i.e. the price at which new large scale projects need to become developed.

This price range is between $65/lb and $85/lb – a far cry from the spot price of just $37.5/lb. However, the vast majority of uranium contracts are long-term, frequently 5-year deals.

Therefore Ux Consulting and Trade Tech provide quotes on both the spot and the long-term price, which stands at $49-$50/lb. Utilities have been especially slow to sign new 5-year contracts because they feel no urgency and long-term contracts signed between 2012 and 2014 were significantly below the norm. This will have change. The question is when?

The utility companies that are presently sitting on the fence are
expected to become more active in H2 2015 and certainly into 2016. If Cameco is largely correct in its forecasting of demand and supply, then the long-term contract price should rise in each of the next few years.

Given the increased compliance, legalities, funding and environmental factors, the timeline to get a new mine up and running has expanded meaningfully. For example, many new, potentially viable projects in the highly prolific Athabasca Basin in Canada are thought to be 10-15 years from initial production.

Just before the Fukushima accident, the long-term and spot price for uranium was in the low $70s/lb. This is important to remember because the next time uranium prices hit their stride, the new normal price might be $80s-90/lb.

This is simply because the cost of mining has not declined along with the uranium price. Of course, virtually no one is forecasting a price above $80/lb anytime soon, but with the incentive price thought to be between $65-$85/lb and longer lead times to get new projects into production, the pieces may be falling into place for a higher price than pundits imagine.

There are two additional factors to consider regarding demand. Firstly, new reactors need to prime the pump with roughly three times the average annual consumption in the first year. If China and India are as active as or even more active than expected, there could be supply shortages in the coming years.

Secondly, given the huge upfront cost of building reactors, it is not surprising that those with design lives of 40 years are being upgraded and approved for operations to be expanded for 10-20 years. With less nuclear power generation capacity coming offline, global demand forecasts could be too conservative.

China’s new reactors

Uranium is very much another commodity tied to China’s growth. According to uranium expert Alex Molyneux of Azarga Uranium, China’s construction of nuclear reactors will be considerably more than expectations. However, unlike some commodities that China can manipulate the price of, it will be difficult to control the price of uranium. The country needs it too much, as does Russia and India.

Both China and India generate a remarkably low percentage of electricity from nuclear power. For example, it produces just 2% to 3% of its electricity from nuclear sources, compared to 20% in the US.

Another reason why China needs uranium is to reduce its reliance on coal generated electricity. Today, it still generates 70% of its electricity from coal which has been a major contributor to serious air pollution in many Chinese cities.

Japan also has a significant role to play. Pundits look to Japan for a uranium price catalyst as it restarts some of its reactors that were closed post-Fukushima. So far, of the 50 estimated operable reactors, zero have been restarted. Experts predict that 2-6 will come back online in 2015. That alone would have a minimal impact. But if Japan restarts 20-30 reactors over the next 2-3 years, then the impact would be significant.

Uranium is a critical commodity with demand expected to grow between 3% and 5% annually for the next two decades.

Importantly, security of supply is a real threat with many of the proposed new mines located in Africa where uranium ore grades are quite low and some of the countries being tough to do business in.

Kazakhstan is by far the largest producer of uranium in the world, accounting for the vast majority of the growth in global supply over the past decade. However, it has already taken advantage of the easier resources to access which fuelled its astonishing rise.

In 2001, the country began mining uranium, but by 2008 it leapfrogged Canada to become the world’s number one producer at about 14,000 tonnes. In 2014, Kazakhstan produced 22,000 tonnes of uranium which equated to 37% of global output.

Production increases out of the central-Asian country has stalled in recent years as demand softened, but many believe that robust supply (at low cost) growth is no longer guaranteed like it was in the mid-2000s.

Kazakhstan is also seeking to build its own reactor and in January 2015 signed a deal with Toshiba to build a $3.7bn, 1GW plant, signalling its intention to also become a consumer of uranium, thereby withdrawing tonnages from the international marketplace.

With the long term outlook for supply hard to pin down, together with the expected steady and constant increase in demand, uranium has a perfect recipe for rising prices in the coming years – a trend which could start in 2015.

Contributor: Peter Epstein, CEO and founder of resources consultancy MockingJay Inc.
Has China reached peak graphite?

China's global share of natural graphite output falls to mid-1990 levels leaving questions over future policy of raw material exports from the world's leading producer

China's share of global natural graphite output has fallen to levels not seen since the mid-1990s when the country started ramping up exports to international markets.

According to data from Benchmark Mineral Intelligence, China has seen output fall to 70% of the world's share from an all-time high of 85% in 2011.

This raises the question: has the world seen peak graphite production from the world's leading supplier?

2014 was notable for the Chinese graphite industry as it consolidated and modernised its flake graphite operations and cut its production of amorphous graphite.

Both forms of natural graphite contributed to the country's significant output levels in recent years, which reached levels of as high as 800,000 tpa. But this figure has now fallen by at least 40% as the country recalibrates its domestic steel industry, modernises its mining operations and focuses its future on higher value manufacturing.

As a result of these trends, Benchmark believes we have seen the height of natural graphite supply from China. However, this will be a steady process which cuts output levels to between 50-60% of global production over the next 3-5 years.

Therefore, China will continue to be the world's number one supplier of both flake and amorphous graphite in the long term.

The country is, however, likely to attempt to significantly slow exports of graphite concentrate in favour of greater domestic consumption and value added products including coated, battery anode materials and graphene.

Existing demand from steel markets is expected to continue with low growth rates of 1-3% a year, therefore the industry will turn to the battery sector for the bulk of new demand which Benchmark expects to be significantly greater than that of refractories.

The main reason for the decline in output since the highs of 2011 is the decline in demand for flake graphite's volume product of medium flake and fines sold into industrial markets, in particular steel and refractories.

The international market for natural graphite began its decline in 2012, while China's demand has only slumped in the last 18 months. If China had not slowed domestically then we would have likely seen a flake graphite output rebound close to previous highs, but China has changed and its hunger for huge volumes of metals and minerals is no longer what it was.

The amorphous market has been hit hardest by the Chinese slowdown. Domestic output has fallen significantly from highs of 400,000 tpa to under 200,000 tpa in 2014. This has somewhat skewed the overall figures for global natural graphite production.

Benchmark believes the decline in flake graphite consumption from 2011-2014 has been in the region of 20%.

If the flake market is viewed in more granular detail by grade then the story becomes more complex with medium flake graphite demand falling the most, while large flake of +80 mesh and +50 mesh has either stabilised or increased in the last two years.

With China seeking to close many of the older, large flake graphite mines in Shandong province, there are likely to be restrictions in the supply of large flake product over the longer term assuming no new supply enters the market.

Considering these supply-side restrictions, and with four battery megafactories slated to come on-stream in the next three years, the question is: will the natural graphite industry be able supply these new projects or will buyers have to turn to its synthetic counterpart?

It also raises the point of where new supply will come from to satisfy existing markets let alone the emergence of a potentially huge market in batteries.

 Regardless of what the future holds, one thing is clear in the present: the days of low cost, abundant graphite from China are over.

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**CHINA'S SHARE OF GLOBAL PRODUCTION (% OF ALL NATURAL GRAPHITE)**

![Graph](https://via.placeholder.com/150)

*Source: Benchmark Mineral Intelligence*
Critical mineral trends for 2015

From more robust pricing to China’s evolution, here Benchmark Mineral Intelligence outlines five trends expected to define upstream markets this year

1. STRONGER 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 these markets have shown signs of bottoming out.
Although large inventories, following years of over-production, are likely to suppress any significant upturn in the near-term, tightening supply in many areas will be met by a steady recovery in the global economy is likely to fuel some more positive news for producers approaching the end of 2015.

2. REGIONAL, THE NEW GLOBAL?
The importance of supply chain security has become a prominent industry trend and this looks likely to increase this year.
While tightening capital availability for the vast majority of companies is likely to prevent wide-spread vertical integration, the importance of supply security of the more scare minerals and metals is rising.
As a result, the willingness of consumers to pay premiums for consistency, stability, and long term security of supply will increase.
For niche minerals, being strategically located will become of growing concern to end users, certainly for the larger manufacturing nations such as the US, Germany and Japan.

3. REPLACING CHINA
As the leading low cost supply base for many niche minerals such as rare earths, graphite, fluorspar, and vanadium, China’s downstream push to produce value-added products will leave less supply available for the rest of the world.
This has opened up a window of opportunity for other nations to become the new low-cost supply in minerals previously dominated by the Chinese.

4. FINANCE FALLING
The wave of investment into critical minerals between 2009 and 2011, will continue to subside for the majority of the exploration sector in 2015, leaving many junior companies fighting for survival.
For Canadian traded juniors especially, it has been one of the toughest and longest investment slumps ever.
As the slow recovery in end-market demand continues, driven by new product innovation, the need for supply chain security will increase.
This will provide some hope to development-stage companies.
Tightening finance markets are likely to force some juniors out of the market, however projects with good resources, secure economics, and/or a unique story to tell are likely to weather the storm.

5. NEW GENERATION OF SUPPLIERS
Despite turbulence in capital markets, a number of mineral and metal projects have managed to move ahead of the crowd and will attempt to position themselves as producers over the coming year.
In the graphite market, for example, some projects have already begun produce small quantities, lithium has welcomed its first new producer in a generation (p.17), while rare earths has seen two new operations come on-stream in the US and Australia.
Meanwhile, other industries have struggled to bring new resources to the market.
The lack of available capital, however, has prevented a glut of new producers coming on-stream.
A new generation of suppliers are slowly filtering into these niche mineral and metal industries, however, and this trend is expected to continue in 2015.

Graphite mining in China has been a case study for consolidation and modernisation in the niche mineral sector of mining
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.
Downstream | News Analysis

Analysing major developments for disruptive technology and, as a consequence, critical mineral and metal demand

IN THIS SECTION:
- APPLE SET FOR EV ENTRY
- DEUTSCHE BANK: EVS AT TIPPING POINT
- STEEL FACES NEW LOWER EQUILIBRIUM

Source: Nissan
Apple puts batteries at the centre of its EV masterplan

Law suit exposes Apple’s electric vehicle ambitions and focus on batteries as Project:Titan begins to emerge from the shadows

The electric vehicle (EV) ambitions of Apple Inc has been brought into the public domain after lithium-ion battery producer, A123 Systems, filed a lawsuit against the California-based company for “systematically” poaching employees to establish a new battery division.

The venture, reportedly named Project:Titan, has already seen Apple recruit “hundreds of employees” according to the Wall Street Journal and is expected to see the world’s most profitable company enter the self-driving, EV industry.

The law suit filed by A123, signifies intensifying competition in the EV market, as firms seek to establish themselves in the industry ahead of what are expected to be significant growth rates over the coming years.

As these project developments expose a shortage of skilled battery experts in today’s market, attempts by major technology firms to develop battery capabilities also increases the potential for tightening supply conditions in raw material markets.

With established producers such as Tesla Motors, Foxconn Technology Group, LG Chem and Boston Power already developing battery megafactories, the introduction of major new, financially powerful producers, such as Apple, is likely to put significant strain on upstream suppliers.

**Masters of the supply chain**

Apple is the ultimate modern company in terms of supply chain management.

Since becoming CEO in mid-2011, Tim Cook has turned Apple into the most profitable company in history. Cook has taken the innovative products created by former chief Steve Jobs, and commercialised them to a level never seen before in consumer electronics.

The distribution channels Cook and his team have developed - in addition to cutting manufacturing costs - has seen the portable electronics market boom to levels beyond even the most bullish of expectations. Industry spectators will be curious to see if this success can be replicated in the EV space.

Through the company’s efficient supply chain management and close partnership with manufacturer Foxconn Technology Group, Apple made $18bn in revenue, selling 34,000 iPhones an hour, on average, between October and December 2014. That equated to 74.5m units over the quarter.

It was revealed in March 2015 that Apple was selling iPhones at double the smartphone industry growth rate of 25% a year, primarily thanks to a successful launch in China where higher prices have not deterred consumers in search of the status symbol that Apple products bring.

The logistical operation to execute such huge numbers on a global scale is truly staggering and is one that sees Apple sitting on $178bn in cash.

So the question is: what new global growth market can Apple invest its huge sums of cash in while still play to its strengths?

In Benchmark Mineral Intelligence’s opinion, there are not many options available and the EV sector is the strongest viable market.

In essence an EV is more akin to an iPhone than a car – it is an iPhone on wheels. The software that drives the car’s efficiency is nearly as important as the batteries that power it. Yet EVs are the new technology entering a very well established auto industry that has not seen true disruption since it was founded.

Tesla Motors has already proven what slick design, innovative thinking and good software can do for a high-end EV market.

Tesla has also identified that cheaper and better batteries are the only way that the mass market EV space will succeed and has therefore invested $5bn in building the Gigafactory - a lithium-ion super-plant that will require huge volumes of high-specification graphite, lithium and cobalt to fuel it.

While building a team of battery experts is a start, new market entrants will soon find having supply chain visibility and control all the way upstream to the mine is crucial to any EV or battery plan and the only way to truly dominate the space.

Apple’s entry into this market will intensify the search for a new generation of hi-tech raw material suppliers.
EVs at the tipping point, says Deutsche Bank

Independent report says we are at the point of an ‘unprecedented shift’ in global transport, with electric vehicles and diesel cars set to reach cost parity within five years

Deutsche Bank believes we are at the dawn of a new automotive era with “unprecedented technological and regulatory change” set to come in the next 5 years.

In a new report that analyses the electric vehicle (EV) supply chain, the banking and financial services group explained that in its opinion, “EVs will not be niche”.

In what Benchmark Mineral Intelligence believes is the most bullish independent report to date, Deutsche Bank outlined that with the costs of EVs falling and conventional gas-powered vehicles increasing, the two competing forms of transport will reach parity by 2020.

This, Deutsche Bank says, will be the economic tipping point for mass uptake of EVs.

“Various forms of EV will reach cost parity with conventional diesel powertrains within the next 5 years, and parity with conventional gasoline powertrains by the early 2020s,” the financial group explained.

“This, we believe, will drive an inflection in demand for EVs”

The report has forecasted strong annual EV growth of 21% from 2015 to 2020, with Deutsche Bank citing the primary driver as Tesla Motors’ planned release of the Model X and, most importantly, the Model III in 2017 – a mass market EV that will utilise lower cost batteries produced by the Gigafactory.

While all EVs – hybrids, plug-in hybrids and fully electric vehicles – equated to 4% of the world’s total vehicle sales in 2014, this figure is expected to reach 9% in 2020 and 14% by 2025. With the sale of hybrids flat lining in recent times, full EVs are expected to account for the majority of sales over the next decade.

Benchmark believes that the world is also on the verge of mass uptake of batteries in three major forms: transport, mobile technology (which we are already experiencing) and utility applications.

There is now a global consensus over the need to diversify energy sources, however the economic viability of wind and solar has come under considerable scrutiny. The utilisation of batteries to store this intermittent power will help to overcome some of these obstacles.

Battery systems in utilities, as a result, are starting to see traction. 2014 saw Southern California Edison begin construction of a 400MW lithium-ion storage facility, with Hawaii and New York City following suit with the development of similar systems (the latter using vanadium-flow battery technology).

It is interesting to note that New York City’s impetus for battery storage is from the need for security following two blackouts in under a decade. The first in 2003, which began with a downed power line in Ohio causing the grid to overload, resulted in the world’s second largest blackout in history. It was a blackout that took down the power to most of the US north-east, the country’s financial hub, the bulk of its security and emergency services in these areas, and much of its water system which is powered by electric pumps.

The second blackout was in 2012 as a result of flooding and damage from Hurricane Sandy. It affected most of lower Manhattan, which included Wall Street and the city’s prime business district.

New York City authorities believe that with the installation of a back-up power system, similar blackout chaos could be avoided in the future. It is looking to battery systems as the solution.

![ALL EV SALES AS A % OF GLOBAL AUTO SALES](source: Deutsche Bank)
Steel supply chain faces new lower equilibrium

Slowing growth in steel output forces further raw material and refractory restructuring 2015

Slowing steel output in 2015 is forcing an evolution in the way raw material suppliers and end-market users interact.

As a slow recovery in industrial markets continues, mineral suppliers are being forced to diversify their strategies to cater to new markets and end-users are increasing efforts to secure their supply-chains.

Growth in global crude steel production slumped to 1.2% in 2014 according to the World Steel Association, the lowest growth rate since 2009 when output contracted by 7.8%.

Although the most recent estimates suggest growth could reach 2% over the course of the year, upstream suppliers are unlikely to experience a significant rebound in demand, with capacities still far outstripping demand. This is leading to tough questions as to whether today’s environment is the new norm.

Certain regions such as Africa, South America and the Middle East are anticipated to achieve higher than average growth rates which will lead to a shift in the balance of trade of upstream raw materials.

Nevertheless, the continued slowing of Chinese output alongside the laboured recovery of markets in North America and Europe make for a gloomy outlook in industrial demand for many minerals.

This will compound what has been a difficult few years for those businesses driven by steel, such as refractories and mineral additives.

Raw material impact

Refractories – high temperature resistant bricks and materials - are a critical end-market for many non-metallic minerals such as magnesite and graphite, with steel-based applications accounting for 70% of demand.

Overcapacities throughout the steel and refractories supply chain have had a lingering effect on raw materials as lower production has restricted consumption rates.

These market adjustments have not only limited the quantity of demand, but also the direction of trade.

With China, in particular, restructuring downstream industries and consolidating operations in both refractories and steel, there is a shift from volume to quality of raw material consumption. New growth areas will be required to fuel a substantial rebound in demand for upstream minerals.

Industrial expansion in developing regions such as India, South America and South-east Asia appear the most likely to provide significant growth rates in the short-term.

This has been reflected in attempts by major mineral companies to forge paths into these markets.

In 2014, US-based Mineral Technologies Inc acquired chemical firm Amcol – a specialty minerals firm renowned for supplying bentonite to markets ranging from pet litter to refractories – for $1.7bn as part of a wider strategy to leverage its position in these regions.

More recently, mineral group Imerys SA also widened its portfolio in areas such as India, Indonesia,
Brazil and South Korea, with the $388m* acquisition of S&B Industrial Minerals.

Efforts to expand in these regions signify the growing importance of industrial growth in these areas.

**Refractory evolution**

With steel demand likely to remain at low levels throughout 2015, the challenge for refractory producers will be to retain market share in major regions of Europe, the US and China, while establishing a presence in developing nations.

Leading refractory producer Vesuvius plc increased its foothold in Asia and China, in particular, throughout 2014.

Meanwhile, Imerys reported a divergence in the trajectories of emerging countries, with “particular strong momentum in Asia outside China” providing reasons for optimism in the year ahead.

It will be in these areas that refractory suppliers will depend on over the coming years, as they evolve into hubs of mineral demand.

This will challenge the well-ordered industry structures that have been geared to supplying established western markets for a generation.

While the shifting dynamics of these traditional, industrial sectors are forcing upstream firms to reposition themselves to supply new hi-tech markets, downstream consumers are having to re-evaluate the security of their supply chains.

With competition for the same raw materials rising and geopolitics playing an ever increasing role, companies are also having to consider how they source their minerals and metals.

No longer are raw material markets built to serve only one industry – or in some cases one client. The role of mineral suppliers is being redefined from the delivery of basic concentrates to the manufacturing of value added products for newer markets.

While larger companies turn towards acquisitions as a growth strategy, the few medium-sized mineral producers left are being forced to specialise in emerging hi-tech areas like batteries which have, until now, been dominated by China.

**New industrial equilibrium**

With the global economy continuing to underperform, the recovery of the industrial sector will be gradual.

The excess in downstream capacities will mean the benefits of any potential recovery will be delayed in reaching upstream sectors.

This lagging effect will be particularly prevalent in all businesses related to steel, where capacities have far exceeded demand for a number of years.

With China looking to address these structural issues in steel and refractories, an abundance of supply threatens to prolong the raw material downturn, begging the question of whether we are now in a new equilibrium?

Companies will have to combat this by targeting new markets, reducing costs and optimising production processes. The future focus will be very much quality over quantity in most areas.

While this is likely to see a number of companies forced out of the market, it creates an opportunity for a new generation of suppliers, geared to supply the evolving needs of both industrial and hi-tech sectors.

*Conversion made December 2014.

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**STEEL SUPPLY CHAIN: FROM MINE TO MARKET**

<table>
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<tr>
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<th>REFRACTORIES</th>
<th>STEEL</th>
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<tr>
<td>Magnesite</td>
<td>High purity/ sintered</td>
<td>Magnesia carbon bricks</td>
<td>Semi-finished products including:</td>
<td>Automotive</td>
</tr>
<tr>
<td>Graphite</td>
<td>Medium/ large flake</td>
<td>Alumina carbon bricks</td>
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</tr>
<tr>
<td>Bauxite</td>
<td>Speciality alumina</td>
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</tbody>
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Source: Benchmark Mineral Intelligence

[World Tour 2015]

London, New York, Toronto, Vancouver, Hong Kong, Tokyo, Sydney & Melbourne, for free.

More at: [www.benchmarkminerals.com](http://www.benchmarkminerals.com)
Lithium mining in Chile’s Atacama Desert began in the mid-1990s following commercialisation of an evaporation process to extract minerals from subsurface brines.

This image of SQM’s lithium operation is the biggest of its kind in the world, while Chile hosts one-third of global lithium reserves in landlocked brines.

Pictured is the beginning of the evaporation process which harnesses the elements of the Atacama Desert, the world’s driest location. It can take up to two years for the sun and wind to concentrate the brine to a target of 6% lithium, before it enters a processing plant to become either lithium carbonate or hydroxide.

Lithium eventually finds itself into nearly every cell phone battery in the world, in addition to lightweight aluminium, ceramics, glass, and industrial greases.

Picture Source: SQM
In an exclusive interview with Benchmark Mineral Intelligence, SQM’s COO, Patricio de Solminihac discusses lithium’s ‘spectacular’ rise in portable batteries, but issues caution over history repeating itself in electric vehicles.

In little under two decades, SQM SA has gone from entering the lithium market to dominating global production.

After commercialising a new lithium extraction method from subsurface brines in the Atacama Desert, SQM not only become the world’s largest supplier, but also one of Chile’s most important and strategic mining companies.

Through its production of lithium, potash, iodine and nitrates in the country’s north, SQM enjoyed a renaissance in demand for many of these minerals, and the higher prices that came with it in the mid-2000s.

The price of potash fertiliser increased ten-fold on the back of a global resurgence in demand, especially from China, while iodine’s price spiked after Japan’s Fukushima Disaster owing to its use in radiation emergencies.

But it was lithium’s rise to dominance in smartphones powered by lithium-ion batteries that saw SQM thrust into the global spotlight as one of very few suppliers of the strategic raw material.

“The demand for lithium in energy storage had indeed been a spectacular development between 2004 and 2009,” Patricio de Solminihac, chief operating officer of SQM explained in an exclusive interview with Benchmark Mineral Intelligence.
“The boom of mobile phones, laptop computers and other portable devices saw lithium demand surge, and during the last five years, the successful introduction of smartphones and tablets has further boosted lithium demand.”

It was in 2004 when the lithium industry started to see a supply squeeze translate into higher prices, particularly for lithium carbonate, the precursor material used in battery cathodes. The increased demand from this new market caused friction with traditional markets such as ceramics and glass that were competing for the same raw material, which led to price volatility.

Shipments of lithium-ion batteries rose from 650m in 2003 to over 3,000m in 2009, a trend which caught lithium producers by surprise creating a shortage of material in the market. The major suppliers, however, soon caught up to meet the increasing battery demand which stood at 4,500m cells in 2014.

The industry is now preparing for the next phase of development for lithium-ion batteries with electric vehicles (EVs) looking increasingly promising to the outsider.

Significant new supply of batteries is scheduled for 2017 onwards with Tesla Motors, LG Chem and Foxconn Technology Group all planning lithium-ion megafactories. This is in addition to new plants and expansions by battery majors such as Samsung SDI (p38).

The influx of new players and new production has changed the EV outlook for many from a conservative to a bullish standpoint as lower cost cells could translate to cheaper vehicles and increased uptake.

“We see the development of EVs with much more caution,” explained de Solminihac.

“There are important variables that will impact EV development, positively or negatively. These are: infrastructure availability, range, battery costs and government policies, all of which have difficult challenges to overcome.”

“But there is another variable that may have an even stronger negative impact on the development of EVs: the oil price.”

The price of oil has tumbled since Q4 2014 to lows in Q1 2015 of under $50/bbl, reducing the cost of petrol at the pump and giving the consumer and governments economic breathing space on alternative technologies and lower carbon emitting energy sources.

“I believe that the oil price and its short- and medium-term trend will definitely have an impact on the demand growth for EVs. This situation will delay or reshape some of the larger projects in the pipeline,” de Solminihac said.

Not only could EV uptake be impacted by the low oil price, but solar and wind power are also in the economic firing line. These...
industries have benefitted in recent years from high oil prices and have subsequently seen significant sums of investment flow into the market. For example, China installed more solar panels in 2014 than the US has in its entire history and in the last three years, the country has increased its solar installations ten-fold to 33 GW. There is no doubt other factors were at play, but the high price of oil laid the economic groundwork for such huge projects which have also been eyed as a new market for larger scale, stationary storage batteries.

This also brings into focus the cost of batteries which stands at an average of $250/kWh today. Tesla's Gigafactory is targeting a significant reduction in this cost to $100/kWh by 2020 when its super-plant is expected to hit capacity and achieve the necessary economies of scale.

“The cost of batteries will go down over time, no doubt about it, but to expect that this reduction will compensate the oil price drop seems unrealistic to me,” the SQM operating chief explained.

The discussion over the use of batteries in the utility industry has also been increasing in recent years, particularly in the US, as challenges with an aging national grid system mount with an ever growing population.

Lithium-ion has become the technology of choice in this market primarily owing to the availability of supply. Other batteries such as vanadium-flow have long been touted as an ideal technology for stationary storage but have yet to see significant traction in a market that is embryonic in stage.

SQM expects increased competition in this arena.

“Since there are no restrictions in the size and weight of types of batteries, as you have with those used in portable devices and EVs, we see other technologies competing with lithium in stationary storage applications,” said de Solminihac.

**Reacting to new demand**

Growth in the battery sector and continuing, steady demand in staple markets such as glass, ceramics and industrial grease has onlookers questioning whether lithium supply from the Atacama can meet new demand or if there is room for new entrants.

**Benchmark** put this scenario to SQM's COO.

“SQM has environmental permits in place to extract, if required, up to three times the annual quantities of lithium that are extracted today,” said Patricio de Solminihac.

“Our current production capacity is enough to supply the needs of our customers in the short term. But we have a reaction time of less than 12 months to increase production [to meet new demand].”

Since the influx of lithium exploration companies between 2009 and 2011 following a surge in the price of lithium carbonate, new producers on the market have been limited.

“We were expecting two new players to enter the lithium market this year: RB Energy, with its Quebec Lithium Project, and Orocobre Ltd, with a brine operation in Argentina,” he explained.

“RB Energy filed for Creditor Protection in October 2014 and suspended the project indefinitely. It is unclear when or if the project will come back on stream. Orocobre has just inaugurated its plant and should start supplying some quantities in Q2 2015.”

“Considering the present demand situation, we believe that new production from Orocobre will absorb a good part of this growth and Chile’s position will remain similar.”

SQM, the same as its competitor in the Atacama, Rockwood Lithium, produces lithium in Chile to a production quota set by the government.
While both of the two companies are the world’s most dominant suppliers from brine, both companies have let market share decline by not significantly increasing output in favour of stabilising prices in the market. This however has also given a small window of opportunity for companies like Orocobre to enter the lithium market and fill the new demand.

The Chilean government sets the extraction quotas for its producers and is presently reviewing the situation.

“Last year, President Michelle Bachelet established a National Lithium Commission... tasked to evaluate the future of lithium mining in Chile, including improving the current mining concession system to increase exploration and mining of lithium, and to recommend a new state policy for the exploitation of lithium and development of new lithium products,” de Solminihac said in the interview.

“The Commission is supposed to submit its recommendation very soon. However, some preliminary information anticipates that the status quo on the strategic situation for lithium will prevail,” he said.

Lithium prices: Hydroxide rising

This brings us to the question of prices.

For many years lithium carbonate has been the product of focus, even though its hydroxide counterpart is also used in batteries.

This neglect, it appears, is starting to have an impact on the price of lithium hydroxide in SQM’s eyes.

“In the case of lithium hydroxide, increasing demand for batteries and the fact that there is no relevant new capacity foreseen in the short term is certainly putting some upwards pressure on prices,” de Solminihac explained.

“Although there is room for a production increase in China, I believe that this upwards trend will continue during 2015 and 2016, increasing the premium between lithium hydroxide and lithium carbonate.

“We are also seeing upwards pressure on prices in lithium carbonate, especially in the battery market in Asia that was enjoying lower prices than the rest of the world. This trend will continue during H1 2015, or until Orocobre starts delivering quantities.”

The price of battery-grade lithium carbonate has averaged between $5,500 and $7,000/tonne over the last few years, while hydroxide has fetched at least a 20% premium on this.

The added pressure of increased battery demand in a product stream that has seen little extra capacity could, Benchmark believes, lead to significant price increases in 2015 in what remains an inelastic market.

The recent changes in supply and the very strong existing demand dynamics, which sees average battery growth rates at 8% a year, means lithium is one of most eagerly watched of all critical mineral and metals industries.

And while 2015 is set to be a static year for many, lithium is already seeing new producers, increased demand and price volatility.

This year will be one to watch.
Clayton Valley in Nevada is home to North America’s only active lithium brine operation, Rockwood Lithium / Albemarle Corp’s Silver Peak facility.

In the 1960s US chemical producer, Foote, pioneered the first extraction of lithium from brines in Clayton Valley. Today, this site is still active and producing lithium carbonate and hydroxide.

Pictured is the adjacent exploration project operated by Canada’s Pure Energy Minerals which is undertaking a seismic reflection survey in a search for new lithium resources.

Picture Source: Pure Energy Minerals
Tesla Motors, LG Chem, Boston Power and Foxconn are building battery super-plants that will come on-stream in the next three years. The new supply could revolutionise how we source and use energy, creating a once-in-a-century disruptive event.

By Simon Moores

The battery megafactories are coming

A global race is on to build the world’s biggest battery plant. For what would have sounded like fantasy only a year ago, some of the world’s major corporations are now vying to become the next leading producer of lithium-ion batteries.

Tesla Motors Inc sparked furore with its Gigafactory plan to double the world’s capacity. But subsequent plans of LG Chem Ltd, Boston-Power Inc and Foxconn Technology Group have turned it into a case of when and not if a new scale of battery plant enters production.

All three companies are eyeing rapid growth in electric vehicle (EV) and utility industries as justification for their grand plans.

It is a trend that rapidly gathered pace in 2014 and one that will see the world’s battery capacity rise by over 150% by 2020. Last year, the world produced 35GWh worth of battery cells, but the three megafactory projects alone will add a further 57GWh.

Phase one will supply batteries for at least 100,000 EVs and is set to be completed by December 2015, a year ahead of schedule.

Meanwhile, China is the focus for LG Chem and Foxconn which are planning to build super-plants, Benchmark Mineral Intelligence estimates could bring a further combined capacity of 22 GWh. LG Chem has already broken ground on its lithium-ion facility in Nanjing while Foxconn’s Anhui facility is awaiting final board approval as of Q1 2015.

It is also important to note these projects are not the only new supply planned with battery leaders such as Samsung SDI also opening new plants and seeking expansions of existing operations.

In August 2014, for example, the company broke ground on a new EV battery plant in Xi’an, Shanxi province, China which will start operations in October 2015 and produce lithium-ion batteries.
Elon Musk, CEO, US-based Tesla Motors which is constructing the world’s biggest battery plant, the Gigafactory, in Nevada

Artwork by Benchmark Mineral Intelligence
Multi-billion dollar merge

The major catalyst in the megafactory race has been the disruption caused by Tesla Motors.

The company is not a traditional car manufacturer. The entry into the auto industry by what was, back in 2003, a Silicon Valley start-up, has caused major disruption to a mature industry forcing established companies such as General Motors Co. (GM) and Nissan Motor Co. Ltd to take a more proactive approach in the EV space.

Tesla Motors is also not a traditional battery producer. Yet, the turbulence caused by its Gigafactory plan has also sparked major battery manufacturers such as LG Chem and Samsung to either expand or build new plants.

“Disruptors usually come from the outside,” Tony Seba, a leading expert in disruptive technologies and lecturer at California-based Stanford University, explained to Benchmark.

“Before the [Apple] iPhone, there were three very separate industries: computers, telephones, and communications. These industries have merged. They are now all the same.”

“Previously you had one major industry investing in batteries: electronics. Now, you have three: auto, electronics and energy.”

“This has started a virtuous cycle of investment, lower production costs and demand which will lead to EV adoption and batteries used to store renewables like solar and wind,” Seba explained.

The convergence of these three major industries on the battery space is a critical point. Not only does it provide new funds and new competition, but it takes the problems of battery supply that have restricted demand uptake and forces companies to view the market with fresh eyes.

This disruption sparks others into action. Tesla CEO, Elon Musk, explained the impact of its first EV, the Roadster, had on its launch in 2008:

“When we first announced the Roadster, Bob Lutz of GM saw it and told his engineers that if a small company in California can do it, so can GM. That’s what got the [Chevrolet] Volt rolling and that in turn got Nissan to do the LEAF.”

“It’s what we induce others to do that will have a greater impact than the cars we make ourselves.”

Better batteries, bigger batteries

Battery performance and cost have always been the main talking points of EVs. Common and often correct complaints are that the batteries are too expensive (which in turn makes the cars too expensive) and they do not last long enough on one charge. Electrification of transport will not succeed unless the world has cheap, abundant, longer lasting batteries.

But with the cost of batteries falling and EVs improving, many leading figures in
While the subject has received far less attention than EVs, there were some major developments in 2014.

In December 2014, Tesla revealed that owners of the Roadster, the company's first EV, could receive an upgrade that would boost its range by over 50% to 400 miles (644km).

The move is testament to how much batteries have improved since the Roadster first came on the market in 2008, even without the disruptive megafactories.

Tesla has managed to extend the range of its vehicles in two major ways: by using bigger batteries – more than three times the average size of the Nissan LEAF – and designing its cars around the battery to optimise performance.

Tesla's Model S is equipped with a 60kWh or an 85kWh lithium-ion battery whereas the Nissan LEAF, which is the world's best-selling EV, has a 24kWh battery. A new generation of LEAF set for launch in mid-2016 has been tipped to have double the range of its predecessor and is expected to follow a similar strategy to Tesla.

"The battery chemistry is all about range and energy density," explained Andy Palmer, former executive vice president of Nissan's zero emissions business in 2014.

"This is really game-changing technology," If batteries are the holy grail of EVs then energy density is the holy grail of batteries.14

"Packing more energy into a smaller space while maintaining a light weight is critical if batteries are going to meet modern vehicle expectations, let alone future needs – and this will come down to the raw materials used.

To have a world which runs on batteries, the innovation will need to come from not only the cell producers, but also from the raw material suppliers. Ironically it may not be the car manufacturers that have the final word in the success or failure of EVs.

Utility impact
A more immediate impact of better and bigger batteries that has received less publicity is utility or stationary storage – the ability to store energy off-grid in large scale batteries.

The iPhone effect? Tesla has made the EV functional and desirable, a move which emulates what Apple did with the smartphone

To have a world which runs on batteries, innovation will need to come not only from the cell producers, but also the raw material suppliers

While the subject has received far less attention than EVs, there were some major developments in 2014.

The US has moved forward with utility storage plans in California, Hawaii and New York that will see a mix of battery technologies deployed in major urban areas.

American Vanadium Corp., a Canada-based company focused on energy storage, subsequently struck a deal with New York City’s Metropolitan Transportation Authority (MTA) to develop vanadium-flow battery facilities.

The company plans to install its modular 10kWh system commercially known as CellCube in downtown Manhattan.

"New York's energy distribution grid is the oldest in the world… but the city is now reorganising its utility storage model and is rapidly developing into an energy marketplace," Mike Hyslop, director of American Vanadium explained to Benchmark.

Hyslop emphasised that it is not necessarily about going off-grid for New York – unlike Hawaii that wants to cut its ties to petroleum power generation – but more about securing back-up power, especially after experiencing two blackouts in less than a decade.
back-up power, but for a number of reasons, including environmental, it is less popular now.

“The issue isn’t about energy generation,” American Vanadium president and CEO, Bill Radvak explained in an interview, “It’s about solving the peak load problem.”

“Energy generation today does not fit with people’s consumption patterns,” he said. Using batteries to smooth out the peaks and troughs in energy production is not a new concept, but until now it has not been commercially viable.

With battery back-up systems, energy companies can feed power back into the grid to meet momentary demand rather than ramping up output at their oil, gas, or coal fired plants.

“The education process for utilities has begun and this requires one hundred million dollars of batteries. When it takes off the industry will need billions of dollars of batteries,” Radvak said.

The city’s blackout of 2003 was caused by a downed power line in Ohio, while the second in 2012 was in the wake of Hurricane Sandy which left 6m people within 15 states and 20% of New York City’s population without power for over two days.

Off-grid storage has a wider range of battery technologies competing for the space. The fact they are stationary means weight is less of an issue, while energy density, maintaining charge over long periods of time and discharge rate is of higher importance.

Patricio de Solminihac, the chief operating officer of SQM, the world’s leading lithium brine producer, explained to Benchmark how it sees this battery chemistry competition developing.

“Since there are no restrictions in the size and weight of types of batteries, as you have with batteries used in portable devices and EVs, we see other technologies competing with lithium in stationary storage applications,” de Solminihac said.

Lithium-ion batteries are still being used, while vanadium flow technology is also gaining prominence in this area. Lead acid is the more mature battery chemistry that has been favoured in the past for large scale,
distributors in the US and Europe, such as the US National Grid and Italy’s Enel, in a bid modernise today’s energy distribution model.

Meanwhile, Ambri Inc is pursuing a different line of liquid batteries, originally based on a magnesium and antimony metal solution.

The design involves two liquid state metal electrodes that are separated by a molten salt electrolyte with density differences keeping the layers from mixing.

Future chemistries involve: lithium, sodium, barium (derived from the mineral barite, presently used as an oil drilling agent), calcium and strontium.

With many companies paving the way for battery adoption in the utility industry, a significant increase in installed battery capacity is anticipated towards the end of this decade and into the 2020s.

Navigant Research estimates that we could see an increase from today’s level of 538.4 MW of installed capacity to 20.8GW by 2024.

The company also explained that lithium-ion batteries have “established a clear lead in the market as the technology of choice not only in short-duration applications but also bulk storage.”

<table>
<thead>
<tr>
<th>THE MEGAFACTORIES ARE COMING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capacity</strong></td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>35GWh</td>
</tr>
<tr>
<td>7GWh*</td>
</tr>
<tr>
<td>15GWh*</td>
</tr>
</tbody>
</table>

*Benchmark estimates, not disclosed by company
Source: Benchmark Mineral Intelligence

A vanadium flow battery being developed for use in stationary storage systems

Source: American Vanadium
Benchmark Mineral Intelligence is proud to announce its inaugural World Tour 2015 - Battery Raw Materials | Supply Chain 20/20.

The Benchmark | World Tour 2015 will take place between September and October 2015 across 8 financial hubs over 4 continents.

Hear from Benchmark's independent analysts and public companies on the future of the battery industry and the minerals that supply it: graphite, lithium, cobalt and vanadium.

Topics will include:
- What role do critical minerals play in batteries?
- How much graphite, lithium, cobalt and vanadium will be needed and when?
- At what rate will electric vehicles and utility storage take off?
- What opportunities/challenges will the emergence of major new markets bring?

Between September and October 2015, the Benchmark | World Tour 2015 will be visiting: London, New York, Toronto, Vancouver, Hong Kong, Tokyo, Sydney and Melbourne.

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Contact us today:
Simon Moores - Managing Director
smoores@benchmarkminerals.com
+44 20 3751 0357

Julius Pike - Sales Director
jpike@benchmarkminerals.com
+44 20 3751 0355
Mobile history lesson

Batteries have become so engrained in our lives that it is hard to believe the first commercialised rechargeable lithium-ion battery was launched in 1992.

Just a decade ago, the mobile technology era was just getting started. In 2005, the Nokia N70 was the first smartphone to sell over one million handsets in a year.

Two years later, the inaugural Apple iPhone sold one million handsets in 72 days and in 2014 both iPhone 6 models sold 10m units within three days of launch.

The speed of smartphone uptake is increasing. In March 2015, the smartphone sector was growing at a rate of 25% a year. Apple revealed that sales of its iPhone product line were growing at 49% a year, mainly owing to its successful entry into the Chinese market.

Respected UBS analyst, Steven Milunovich, believes that in Q2 2015 sales will keep on surging with a forecast of 58m units in the quarter compared with 44m in the same period only 12 months ago.

The astonishing growth rates in the smartphone market compared with industrial markets, shows that the industry is still yet to reach maturity. These devices are still finding new uses.

Consumers now use their phones to do far more than make a call, send messages and check emails.

Usage has rocketed, yet the battery that powers the increasingly vital smart phone is not experiencing the same research and development progress.

“Three objects are considered essential across all participants, cultures and genders: keys, money and mobile phone,” said Nokia’s former principal scientist, Jan Chipchase.

While smartphones have been surging, the critical item that powered it, the battery, has always been playing catch.

It is only now that imbalance is starting to be corrected.

If batteries are the holy grail of EVs then energy density is the holy grail of batteries

“The great thing about fact-based decisions is that they overrule the hierarchy”
JEFF BEZOS, FOUNDER AND CEO OF AMAZON

‘If I had asked customers what they wanted, they would have said a faster horse’
HENRY FORD, FORD MOTOR CORP, C. 1919

‘You can’t just ask customers what they want and then try to give that to them. By the time you get it built, they’ll want something new’
STEVE JOBS, APPLE INC, 1989

‘It’s what we induce others to do that will have a greater impact than the cars we make ourselves’
ELON MUSK, TESLA MOTORS INC, 2014, ON PRODUCING ITS FIRST EV, THE ROADSTER

Image sources: Library of Congress (Ford); Matthew Yohe (Jobs); JD Lascia (Musk); Niall Kennedy (Bezos)
Benchmark analyses new demand data for graphite, lithium and cobalt one year on from Tesla Motors announcing its game-changing plan to build the world’s biggest lithium-ion battery plant

**Tesla Gigafactory demand: revisited**

It has been almost exactly a year since Tesla Motors Inc announced a revolutionary plan to build the world’s largest lithium-ion battery plant, the Gigafactory.

In a megastructure, one-mile in length and 70ft high, Tesla wants to produce the equivalent of the world’s battery production in 2013 under one roof - 35GWh worth of cells. It is unprecedented in scale and ambition and is a make or break move for the high end electric vehicle (EV) pioneer that is seeking a mass market position.

To date, Tesla has already experienced strong sales of its Model S, and in mid-2015 is set to begin sales of the Model X - both of which will use a 60 kWh or 85 kWh lithium-ion battery.

The lower cost Gigafactory batteries will be used in both of these existing models, and will, most importantly, give birth to the company’s first mass-market EV, the Model III which is expected to have a 48 kWh battery.

The Gigafactory also holds the power to revolutionise demand for graphite, lithium and cobalt, the key input raw materials that will fuel its production capacity of 500,000 vehicles worth of lithium-ion batteries.

The analysts behind Benchmark Mineral Intelligence calculated and published initial demand data for the Gigafactory in Q1 2014 which has been widely cited around the world.

Now, with the $5bn project a year ahead of schedule, Benchmark has decided to revisit the numbers and the Gigafactory timeframe to see what impact critical mineral and metal industries should be braced for and when to expect it.

**Graphite**

Graphite, the battery anode, will be the largest input raw material into the Gigafactory.

Tesla have the option to go with either natural or synthetic graphite or could even be a blend of both.

The battery industry today is divided on what material it consumes with about 60% of all graphite in batteries from natural flake and 40% from synthetic, man-made sources.

Under a bullish scenario that assumes the company will hit its capacity in 2020,
JB Straubel (right), Tesla’s Chief Technical Officer, on the Gigafactory roof with shareholder Steve Jurvetson. Picture was taken during phase one construction in March 2015, expected to be 20% of the full-size plant.
significant amounts of battery grade graphite will be needed. The chart (p48) outlines that raw material buying for the Gigafactory is expected to start in 2016 when Benchmark estimates that Tesla will need to secure 8,000-10,000 tonnes of spherical battery grade graphite. If this is sourced from natural flake graphite this equates to 25,000 tonne of flake concentrate that will need to be mined.

Today, Benchmark estimates the average capacity of a graphite mine outside of China is 11,600 tonnes. It is also important to note that on average only 60% of the flake concentrate a mine produces can be used as a battery graphite feedstock – the medium and large flake material – therefore at today’s rates the Gigafactory will be consuming the equivalent of 1.4 mines worth of product in 2016 alone.

This will add pressure on the market particularly considering that at present, only medium flake graphite from China is used to produce spherical graphite - a source that Tesla is trying to avoid on environmental grounds.

Once the super plant is approaching capacity in 2020 with raw material buying and stockpiling expected for this expansion in 2019, Gigafactory graphite demand is forecast to be 38,000-42,000 tonnes of spherical graphite or around 100,000 tonnes of flake graphite. By today’s standards, this is the equivalent of 6 mines worth of flake graphite.

Quite simply if Tesla uses natural graphite, new supply will be needed, especially if China is discounted as a source.

The company could also opt to use synthetic graphite, however this raw material has a larger environmental impact than its natural counterpart and is more expensive – with synthetic concentrate powder selling for roughly double the price. It is likely if new supply of natural flake does not come on-stream, synthetic’s importance will grow.

Lithium

Even though lithium has, on the surface, a less critical supply situation than graphite, there are still significant challenges for Tesla in sourcing the right product and at the volume needed.

Lithium carbonate is the primary product in the industry and is a market that is 2.5 times the size of the lithium hydroxide sector, a product that is also used in batteries.

Owing to the Panasonic design of battery the Gigafactory is using, Tesla will need significant volumes of lithium hydroxide which is harder to source than lithium carbonate. At capacity, Tesla will need between 22-26,000 tonnes of battery-grade lithium hydroxide.

At present, the majority of lithium is produced as a non-metallic product in Chile and Argentina from brines, and Australia from spodumene, the hard rock form. These are Tesla’s primary sourcing options.

Australia’s source of lithium is operated by Talison Lithium – the world’s largest hard rock lithium mine – which exports nearly all of the concentrate it produces to China, a country that is heavily reliant on spodumene feedstock for its domestic industry. Chinese producers utilise the older concentrate-to-lithium conversion technology to produce a variety of downstream chemicals.

The only other major sources of lithium
The lithium industry is more geared to supplying the battery sector than graphite since a surge in demand in 2004 as mobile technology took off, most notably with smartphones and tablets using lithium-ion batteries. The doubts are not over whether the industry can supply lithium in general but rather the volumes needed of the right specification can be produced in a cost effective manner.

Cobalt

The battery industry is the largest market for cobalt producers, accounting for over 40% of total demand in 2014. The major challenge with the sourcing of cobalt is overreliance on the Democratic Republic of Congo, one the world’s poorest and most politically unstable countries. While Congo does not have significant processing capacities it supplies an estimated 55-60% of the world’s cobalt.

Orocobre is expected to begin shipments by Q2 2015. Argentina also welcomed a new producer in the form of Australia-based Orocobre Ltd which operates from the Salar de Olaroz. Orocobre is expected to begin shipments by Q2 2015. Argentina also welcomed a new producer in the form of Australia-based Orocobre Ltd which operates from the Salar de Olaroz.

Chile is home to the lowest cost and highest volume producers SQM SA and Rockwood Lithium, while the third largest brine producer FMC Lithium operates from the Hombre Muerto. Both Rockwood and FMC Lithium conduct further downstream processing of its lithium feedstock at plants in the US and Germany.

Argentina also welcomed a new producer in the form of Australia-based Orocobre Ltd which operates from the Salar de Olaroz.

Orocobre is expected to begin shipments by Q2 2015. Argentina also welcomed a new producer in the form of Australia-based Orocobre Ltd which operates from the Salar de Olaroz.

The US produces lithium hydroxide from Silver Peak in Nevada, which is owned and operated by Rockwood Lithium. The output is small however and only a fraction of the supply needed by the Gigafactory.

The closest active potential source of lithium to the Gigafactory, Western Lithium, is presently only producing hectorite clay as a drilling mud for the oil and gas industry today are from the brines of the Salar de Atacama in Chile and the Hombre Muerto and Olaroz salars in Argentina.

With natural graphite, batteries are a newer prospect, lithium is more geared to supplying the industry

“

REMARKS COBALT PRODUCTION BY PRODUCT/METAL TYPE (2013)

<table>
<thead>
<tr>
<th>Product/Metal Type</th>
<th>Tonnes (1,000s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speciality products &amp; chemicals</td>
<td>45,350</td>
</tr>
<tr>
<td>&gt;99.6% Co broken cathodes</td>
<td>11,010</td>
</tr>
<tr>
<td>&gt;99.9% Co cut cathodes</td>
<td>10,300</td>
</tr>
<tr>
<td>&gt;99.8% Co coarse powder</td>
<td>6,650</td>
</tr>
<tr>
<td>&gt;99.8% Co briquettes</td>
<td>6,900</td>
</tr>
<tr>
<td>&gt;99.2% Co ingots</td>
<td>2,400</td>
</tr>
<tr>
<td>&gt;99.9% Co rounds</td>
<td>1,450</td>
</tr>
</tbody>
</table>

Source: Darton Commodities Ltd
concentrate to refineries, the majority of which reside in China.

At capacity the Gigafactory will require 5,000-7,000 tonnes of battery grade cobalt material. Last year, the industry produced 80,000 tonnes of refined product of which 30,000-35,000 tonnes was battery grade material. This equates to an increase in battery demand of 20% from one consumer alone.

Cobalt from the central African country was not cited in the US’ Dodd-Frank conflict minerals act while other minerals mined, transported and traded in the same way were tin, tantalum, tungsten and gold.

There is a school of thinking which suggests that cobalt should have been named as a conflict mineral but owing to its delicate supply situation was not included.

It is thought the main reason for its exclusion was because of a high risk of volatility in the market if consumers were forced to reveal where they source their raw materials from.

If cobalt was given conflict mineral status it would restrict the majority of supply on the market and lead to price spikes and major sourcing problems for technology companies, particularly in the US.

Cobalt has already experienced price volatility between 2003-2009 owing to a number of factors including inelasticity of supply and the emergence of new demand from the battery market.

This will be something that the industry will seek to avoid otherwise consumers could be forced to explore other cathode chemistries.

Demand challenges
It is important to emphasise the number of hurdles Tesla’s Gigafactory will have to negotiate to hit capacity and create the growth expected for graphite, lithium and cobalt.

Here Benchmark explores these challenges:

1. Who will buy the batteries or cars?
Tesla is banking on the lower cost batteries sparking a significant surge in demand for what will be cheaper EVs.

At capacity, the Gigafactory will produce enough battery packs for around 500,000 vehicles which will be a combination of the Model III, Model S and Model X.

The company will use Gigafactory batteries to drive the price of the Model III to below $35,000. It is now a race with General Motors (GM) to produce the cheapest ever fully electric vehicle available in the western world. In January 2015, GM revealed its plan to produce the Chevrolet Bolt for $30,000 by 2017.

This coupled with the significant network of charging infrastructure Tesla has installed over the past three years is hoped to be sufficient to induce sales of 500,000 electric vehicles by 2020 - roughly eight times the amount US consumers purchased in 2014.

Over the last seven years, the company has excelled in the niche, high end market and managed to sell its vehicles on the basis of performance and style, making EVs desirable to consumers with disposal cash.

The challenge is whether Tesla can shift this business model to the mass-market and whether the mass market is ready to accept an EV.

2. What happens if EVs do not take off quickly enough?
Tesla is already putting plans in place to use excess battery output for home and utility/stationary storage applications.

On the roof of the Gigafactory will be solar panels harnessing the power of the Nevada sun. Excess batteries are expected to be used as mass storage devices for this renewable energy, allowing the plant to recall the power when necessary with a goal of being a zero net energy operation.

It is also looking to sell batteries to other producers of renewable energy within the US as well as EV producers rumoured to include BMW.

In 2014, power companies like Southern California Edison (SCE) created energy storage farms in California for a similar purpose and at present, owns the largest of many such facilities in North America at 32 MW.

The company will be looking to boost the already gathering momentum in large scale, stationary storage. And it is a goal that already has US utility companies looking over their shoulders.
3. What are the biggest factors that could stifle the Gigafactory development?

Raw material availability is probably the biggest challenge facing the Gigafactory outside of the need for basic demand. It is also the only area of the EV supply chain where Tesla does not have ownership and control.

Getting the right volumes of pre-cursor minerals and metals - of which graphite, lithium and cobalt are the most critical - is a huge challenge.

Not only does Tesla need to secure long term deals of the right specification for battery-grade raw materials, but it needs to do so at the right price and from sources that fall in line with the companies green, sustainable policies.

While Tesla initially announced it would only source Gigafactory raw materials from North America, it has since clarified that the search will be global.

Today, no spherical graphite or battery-grade cobalt is produced in North America. Meanwhile, the volumes of lithium hydroxide required means the company would need to source the majority from outside of the continent.

Tesla is still set on sourcing ethical raw material that has a lowest possible environmental impact, which is usually is at odds with economics.

This, in essence, eliminates China for graphite and the Congo for cobalt. Lithium appears on safe ground with the majority being produced in Chile from lower impact, subsurface brines, however hydroxide capacities will have to increase.

Eliminating China from the graphite picture is a bold move.

China produces nearly all of the world’s spherical graphite and has been supplying Japan and South Korea’s battery industry for over a decade.

Eliminating a source on environmental grounds leaves Tesla with two main options:

a) To work with the exploration and development sector to build the world’s newest mine, or,

b) To work with established graphite processors that source raw material from around the world but not from China.

These mineral industries are so niche that making one such decision can have wide reaching implications. There is also a huge need for supply chain security: Tesla will require more than one source of each raw material.

This is a problem that will never go away. Raw material sourcing is an ever changing environment that requires constant evaluation and forecasting of competing demand.

**Competition rising**

As has been highlighted by Benchmark on a number of occasions, Tesla is not the only megaproject in the pipeline; LG Chem, Boston Power and Foxconn Technology Group are also planning super-plants in China while smaller plants and expansions are also schedule to come online around the world in the next 3 years.

If all these battery plants come on-stream within a 2 year period of each other, a surge in raw material demand will occur which would be a significantly disruptive event for the market.

Lithium and cobalt experienced price volatility as a result of similar disruptive events in the mid-2000s when battery production for mobile technology increased.

The difference with today is that nearly all the battery plants scheduled are for the much larger EV battery packs requiring more batteries and raw material.

We are entering a period of significant change, with industrial markets such as steel stalling, new technologies such as batteries emerging.

This is causing tensions in the raw material industries that supply both markets as, for the first time in many cases, there is competition for the same minerals or metals from multiple industries.

Tesla and its Gigafactory plan has thrust this discussion into the limelight and forced the most pessimistic of participants to look at a future where batteries are a major global industry on a par with aluminium, ceramics, glass, paint and plastics.

The battery discussion has now moved from the arena of ‘if’ they will become a major part of our lives to predicting when. And the Gigafactory has created the blueprint.
Tesla's path to mass scale

> All sales figures post-2015 are bullish forecasts by Benchmark Mineral Intelligence
> The assumption is that Tesla will produce enough vehicles to consume Gigafactory output

**2003**
- Tesla Motors Inc is incorporated

**2006**
- CEO, Elon Musk outlines masterplan to produce high end niche EVs, and progress to mass produced, lower priced vehicles as fast as possible

**2008**
- Production of the Roadster begins
- Global Financial Crash: Tesla nearly goes bust, receives new funding (H2)

**2009**
- Receives $465m grant from US Dept of Energy

**2010**
- Tesla Motors IPO launches at $17/share, rises to $23.89/share (July)
- Tesla Factory opens in Fremont, California to produce its new car, the Model S (October)

**2011**
- Elon Musk named in Forbes Magazine's America's Top 20 Most Powerful CEOs

**2012**
- Feb: Tesla reveals Model S design
- June: Mode S deliveries begin
- Q4: Car output jumps from 5/week to 400/week

**2013**
- Aug: Netherlands plant opens; 1st deliveries to Europe
- Nov: Elon Musk named Fortune's Businessperson of the Year

**2014**
- Feb: Gigafactory plans revealed
- April: First deliveries to China
- June: Tesla technology made open source; Gigafactory breaks ground
- July: New, mass market EV revealed as Model III
- August: 13,992 Model S cars delivered in H1

**2015**
- All sales figures post-2015 are bullish forecasts by Benchmark Mineral Intelligence
- The assumption is that Tesla will produce enough vehicles to consume Gigafactory output
Tesla’s path to mass scale EV commercialisation

**2015**
- Gigafactory supply deals expected (H1)
- Model X deliveries to begin (Q3)

**2017**
- 1st Gigafactory batteries to be produced (Q2)
- 1st Model III cars to be produced using Gigafactory batteries (Q3)

**2018**
- Gigafactory to ramp up to 300,000 vehicles worth of batteries

**2019**
- Gigafactory capacity to rise to 500,000 vehicles worth of batteries

**2020**
- 300,000 vehicles

**EV SOLD**

- 2015: 30,000
- 2016: 40,000
- 2017: 50,000
- 2018: 75,000
- 2019: 125,000
- 2020: 200,000

**GIGAFACTORY BATTERIES**

- 2015: 0
- 2016: 10,000
- 2017: 20,000
- 2018: 35,000
- 2019: 75,000
- 2020: 125,000

**Telsa Gigafactory**

Credit: Joe C

Credit: Hideya Hamano

www.benchmarkminerals.com
A new dawn for graphite in Sri Lanka

MRL is on track for high-grade graphite production in Sri Lanka in 2015

Countdown to high grade graphite production:

• Sri Lanka hosts the Highest Grade Graphite deposits in the world
• Independent tests show Total Graphitic Carbon grades of up to 99.3%
• Drilling and refurbishment of historic production shafts well advanced
• Mining Licence granted over one project, another one imminent
• High grade, premium product, combined with low operating and capital costs makes MRL a compelling story
BATTERIES consume a wide variety of minerals and metals in their major anode, cathode, separator, and electrode components. Here, Benchmark Mineral Intelligence profiles the raw materials consumed in mainstream and emerging battery chemistries.
Graphite is one of the purest and most crystalline forms of carbon and can be either mined or synthetically made. Natural graphite is mined in three forms: vein, flake and amorphous (microcrystalline). It is flake graphite that is most suitable as a feedstock or precursor to produce the battery-grade material known as spherical graphite. Synthetic graphite powder also competes with its natural counterpart in the battery space. Graphite's other major uses are in steel, as refractories and recarburizers, lubricants and industrial shapes and components such as gaskets and carbon brushes.

**Supply**

**GLOBAL NATURAL GRAPHITE SUPPLY**
- Flake: 71%
- Amorphous: 28%
- Vein: 1%
- Total: 650,000 tonnes

**FLAKE GRAPHITE SUPPLY IN 2014 BY COUNTRY**
- China: 70%
- Brazil: 60%
- India: 50%
- Canada: 40%
- Other: 30%
- Total: 650,000 tonnes

**Demand**

**GLOBAL NATURAL GRAPHITE DEMAND IN 2014**
- Industrial: 74%
- Hi-tech: 16%
- Specialist: 10%

**Prices**

<table>
<thead>
<tr>
<th>Flake graphite concentrate</th>
<th>Spherical graphite uncoated</th>
<th>Spherical graphite coated</th>
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<td>$800-1,300</td>
<td>$3,000</td>
<td>$7,000-12,000</td>
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</table>

*Prices in USD/tonne, Q1 2014. Source: Benchmark Mineral Intelligence*

**Battery role**

Graphite is the anode material of choice for all batteries including handheld mobile technology, electric vehicles and stationary storage. The main substitute is synthetic graphite.
LITHIUM

Lithium is naturally extracted through mineral-rich brine resources or traditional, hard rock mining operations. While lithium is commonly thought of as a metal, its non-metallic form is most widely consumed with batteries being the leading market. Lithium carbonate and lithium hydroxide are the leading products and both are consumed in battery cathodes. Other major uses for lithium are in ceramics, glass and industrial greases.

Supply

GLOBAL LITHIUM SUPPLY BY PRODUCT

LITHIUM CARBONATE 53%
LITHIUM HYDROXIDE 25%
BUTYL LITHIUM 5%
LITHIUM CHLORIDE 5%
LITHIUM METAL 6%
OTHER 6%

LITHIUM SUPPLY IN 2014

CHILE 40%
AUSTRALIA 30%
CHINA 20%
ARGENTINA 10%
OTHER 6%

Demand

GLOBAL LITHIUM DEMAND IN 2014

BATTERIES 35%
CERAMICS/GLASS 21%
AUTOMOTIVE 9%
METALS 7%
GREASE 8%
POLYMERS 5%
METALS 5%
AIR TREATMENT 5%
OTHER 10%

Prices

$4,500-5,000
Lithium carbonate

$6,500-7,500
Lithium hydroxide

Prices in USD per tonne, Q1 2015, CIF North America. Source: Benchmark Mineral Intelligence

Battery role

Lithium is the primary raw material for a battery cathode. It is used as a compound in a variety of chemistries that fall under the lithium-ion battery categorisation. Other cathode chemistries are competing with mainstream lithium-ion batteries in certain applications.

WHAT IS A BATTERY MADE OF?

ANODE
Carbon
Natural flake (spherical)
Synthetic
Hard carbon
Soft carbon
MCMB

CATHODE
Lithium chemicals
Nickel
Cadmium
Phosphate
Cobalt
Manganese
And more...

SEPARATOR
Polymer films
**Cobalt**

Cobalt is mined as a metal concentrate and sold as both a metal and non-metallic or chemical product. Chemicals account for 58% of cobalt output, a market which has risen to dominance over the last decade through the increase in global battery production. A number of cobalt metal products make up the remainder of the market. The majority of primary supply is from the Democratic Republic of Congo, accounting for over half of the world’s output, while China controls over 40% of global refining capacity.

**Supply**

**Demand**

**Prices**

$27,750 - 28,150

Cobalt Metal

**Battery role**

Cobalt is one of a few cathode raw materials used in conjunction with lithium. It is used as a key component in three major lithium-ion battery chemistries: Lithium cobalt oxide, lithium nickel manganese cobalt oxide, and lithium nickel cobalt aluminium oxide. Cobalt chemistries lend themselves to handheld mobile technology and electric vehicles.
Vanadium is mined as primary raw material and extracted as a by-product from steel production that uses vanadium-bearing iron ore. Supply is dominated by China which accounted for over 50% of output in 2014. Russia and South Africa are the other major producers. Vanadium’s main end use is as a strengthening agent in steel, which dominates the demand and supply patterns of the industry. Around 90% is used in steel with China being the primary customer. However, with rising interest in vanadium flow batteries for utility storage, this has the potential to change over the next five years.

**Supply**

**Vanadium Supply in 2013**

**Demand**

**Global Vanadium Demand in 2013**

**Prices**

**$4.85-5/lb**

Vanadium pentoxide*

Source: Metal Bulletin

*European price, January 2015

**Battery role**

Vanadium pentoxide is used as a cathode material for two types of batteries: vanadium flow and lithium vanadium phosphate. The vanadium flow technology and its use for large scale stationery storage is most promising for this sector.
There are a number of other raw materials that are used in the various battery chemistries on the market today. Here Benchmark Mineral Intelligence outlines the major minerals and metals to monitor.

**Pb/Lead**

**Battery technology:** Lead Acid  
**Battery brief:** Most economical for large scale, stationary batteries where weight is not an issue. Used in car batteries and also used for back-up power systems.

**LEAD MINE PRODUCTION IN 2013**

<table>
<thead>
<tr>
<th>Country</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>52%</td>
</tr>
<tr>
<td>Australia</td>
<td>11%</td>
</tr>
<tr>
<td>USA</td>
<td>9%</td>
</tr>
<tr>
<td>Peru</td>
<td>5%</td>
</tr>
<tr>
<td>Mexico</td>
<td>5%</td>
</tr>
<tr>
<td>Other</td>
<td>18%</td>
</tr>
</tbody>
</table>

Total: 5m tonnes*  
*Global production is 10.5m tonnes with recycled material used as a major source  
Source: International Lead Association

**LEAD DEMAND IN 2014**

<table>
<thead>
<tr>
<th>Usage</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batteries</td>
<td>85%</td>
</tr>
<tr>
<td>Pigments</td>
<td>6%</td>
</tr>
<tr>
<td>Rolled and extruded metals</td>
<td>4%</td>
</tr>
<tr>
<td>Other</td>
<td>5%</td>
</tr>
</tbody>
</table>

Source: International Lead Association

**Cd / Cadmium**

**Battery technology:** Nickel Cadmium (NiCd)  
**Battery brief:** The original battery design used in power tools, its low energy density and the fact that it is environmentally hazardous means the design is being phased out in many applications.

**CADMIUM SUPPLY IN 2014**

<table>
<thead>
<tr>
<th>Country</th>
<th>Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>35%</td>
</tr>
<tr>
<td>South Korea</td>
<td>19%</td>
</tr>
<tr>
<td>Japan</td>
<td>9%</td>
</tr>
<tr>
<td>Mexico</td>
<td>6%</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>6%</td>
</tr>
<tr>
<td>Russia</td>
<td>4%</td>
</tr>
<tr>
<td>Canada</td>
<td>4%</td>
</tr>
<tr>
<td>Other</td>
<td>17%</td>
</tr>
</tbody>
</table>

Total: 21,000 tonnes  
Source: International Lead Association

**CADMIUM DEMAND IN 2014**

<table>
<thead>
<tr>
<th>Usage</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batteries</td>
<td>85%</td>
</tr>
<tr>
<td>Pigments</td>
<td>5%</td>
</tr>
<tr>
<td>Stabilisers/Coatings</td>
<td>3%</td>
</tr>
<tr>
<td>Non-ferrous alloys</td>
<td>3%</td>
</tr>
<tr>
<td>Other</td>
<td>4%</td>
</tr>
</tbody>
</table>

Source: USGS, Industry sources
Ni/Nickel

Battery technology: Nickel-metal hydride (NiMH), nickel cadmium (NiCd), lithium-ion

Battery brief: While NiCd is being phased out (see cadmium), NiMH has seen strong usage in mobile applications over the last ten years. Its low energy density and favourable cost has seen the NiMH battery used in the hybrid electric vehicles, power tools and mobile phones. In recent years, however lithium-ion has taken market share away from NiMH in these applications. A nickel compound is also used in some lithium-ion cathode materials such as nickel cobalt aluminium and nickel manganese cobalt.

![NICKEL SUPPLY IN 2014](chart1)

![NICKEL DEMAND IN 2014](chart2)

B/Boron

Battery technology: Lithium-ion, silicon-boron

Battery brief: Adding boron to the anode material, which is traditionally graphite, has improved the performance of a lithium-ion battery on laboratory-scale testing. Boron has also seen increased use in the newer silicon based battery technology in electrodes. Neither of these technologies are yet to be commercialised, but boron’s diverse use means it could be featuring in mainstream batteries in the near future.

![BORON SUPPLY IN 2013](chart3)

![BORON DEMAND IN 2014](chart4)

P/Phosphate

Battery technology: Lithium iron phosphate (LiFePO4)

Battery brief: With a constant discharge rate, little power drop off throughout a full discharge, and a longer life cycle, lithium iron phosphate batteries have found increasing commercial use in power tools.

![PHOSPHATE ROCK SUPPLY IN 2013](chart5)

![PHOSPHATE ROCK DEMAND IN 2013](chart6)
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.
Mn/Manganese

Battery technology: Nickel manganese cobalt, lithium manganese oxide, alkaline
Battery brief: Manganese has found past uses in rechargeable alkaline batteries and increasing use in lithium-ion designs, namely nickel manganese cobalt and lithium manganese oxide cathode materials. The addition of manganese into the cathode compound paved the way for lithium-ion batteries to be used in power tools. Now, the industry is looking at these designs for electric vehicles.

Manganese Supply in 2014

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Africa</td>
<td>22%</td>
</tr>
<tr>
<td>China</td>
<td>18%</td>
</tr>
<tr>
<td>Australia</td>
<td>18%</td>
</tr>
<tr>
<td>Gabon</td>
<td>11%</td>
</tr>
<tr>
<td>Brazil</td>
<td>8%</td>
</tr>
<tr>
<td>Others</td>
<td>23%</td>
</tr>
<tr>
<td>Total</td>
<td>23m tonnes</td>
</tr>
</tbody>
</table>

Source: HDR Silva, MC Group, USGS

Manganese Demand in 2014

<table>
<thead>
<tr>
<th>Use</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>90%</td>
</tr>
<tr>
<td>Batteries</td>
<td>5%</td>
</tr>
<tr>
<td>Aluminium alloys</td>
<td>3%</td>
</tr>
<tr>
<td>Other</td>
<td>2%</td>
</tr>
</tbody>
</table>

Source: HDR Silva, Industry sources

S/Sulphur

Battery technology: Lithium sulphur
Battery brief: Many believe lithium sulphur batteries have the potential to succeed lithium-ion designs and have been in development for some time. Sulphur is used in conjunction with lithium in the cathode giving a higher energy density and a lighter weight to existing designs. The technology is yet to be commercialised however despite successful tests nearly a decade ago.

Sulphur Supply in 2014

<table>
<thead>
<tr>
<th>Source</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil production</td>
<td>48%</td>
</tr>
<tr>
<td>Gas production</td>
<td>49%</td>
</tr>
<tr>
<td>Mined</td>
<td>1%</td>
</tr>
<tr>
<td>Other sources</td>
<td>2%</td>
</tr>
<tr>
<td>Total</td>
<td>70m tonnes</td>
</tr>
</tbody>
</table>

Source: Industry sources

Sulphur Demand in 2014

<table>
<thead>
<tr>
<th>Use</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid feedstock</td>
<td>85%</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>5%</td>
</tr>
<tr>
<td>Metals Leaching</td>
<td>3%</td>
</tr>
<tr>
<td>Other</td>
<td>7%</td>
</tr>
</tbody>
</table>

Source: CRU

Si/Silicon

Battery technology: Silicon air
Battery brief: The silicon air battery is a revolutionary new concept that uses silicon rather than graphite as the anode and eliminates the need for a cathode material which is replaced by the oxygen in the air. The result of the new make-up means it can store far more energy than conventional batteries, last longer, and charge in a fraction of the time however fundamental problems with expansion still exist. The design was created five years ago and is the subject of extensive research. Panasonic attempted to commercialise silicon air in 2009, but is yet to see any concrete results.

Silicon Supply in 2014

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>60%</td>
</tr>
<tr>
<td>USA</td>
<td>5%</td>
</tr>
<tr>
<td>Russia</td>
<td>9%</td>
</tr>
<tr>
<td>Brazil</td>
<td>3%</td>
</tr>
<tr>
<td>Norway</td>
<td>2%</td>
</tr>
<tr>
<td>Others</td>
<td>21%</td>
</tr>
<tr>
<td>Total</td>
<td>7.5m tonnes</td>
</tr>
</tbody>
</table>

Source: Industry sources

Silicon Demand in 2014

<table>
<thead>
<tr>
<th>Use</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium alloys</td>
<td>42%</td>
</tr>
<tr>
<td>Polymers</td>
<td>37%</td>
</tr>
<tr>
<td>Solar panels</td>
<td>15%</td>
</tr>
<tr>
<td>Other</td>
<td>6%</td>
</tr>
</tbody>
</table>

Source: Industry sources
ANATOMY | ELECTRIC VEHICLE

- Model: Chevrolet Volt
- Type: Plug-in electric vehicle (PHEV)
- Battery: 16.0 kWh lithium-ion
- Manufacturer: General Motors

---

PLASTICS

- Talc
- Ground calcium carbonate (GCC)
- Precipitated calcium carbonate (GCC)
- Speciality silica
- Wollastonite
- Mica

TYRES

- Talc
- Calcium carbonate
- Speciality silica
- Sulphur
- Graphite (Brake pads)

BATTERY

- Lithium
- Graphite
- Cobalt
- Rare earths (permanent magnet)
- Borates (permanent magnet)
Notes so far…

Flinders’ graphite start up doubles Europe’s production capability
(22 Sept 2014)

Will Tesla’s Gigafactory sink or swim?
(29 Sept 2014)

Inside Australia’s graphite boom
(8 Oct 2014)

Batteries leave lithium hydroxide facing tight supply
(15 Oct 2014)

China admits 40% of magnetic rare earths supply is illegal
(21 Oct 2014)

Asbury expands graphite and carbon foothold into Europe
(23 October 2014)

Benchmark Notes launches with online archive
(3 Nov 2014)

Tesla Gigafactory one year ahead, supply deals close
(17 Nov 2014)

The battery megafactories are coming
(1 December 2014)

Has China reached peak graphite?
(9 December 2014)

Deutsche Bank: EVs at the tipping point
(18 Dec 2014)

China lifts rare earths export quota, but grip still remains
(9 Jan 2015)

How battery markets can learn from smartphone disruption
(15 January 2015)

SQM issues caution over EVs in Benchmark exclusive
(27 Jan 2014)

Timeline: Battery commercialisation
(9 Feb 2015)

Has China reached peak graphite?

New data from Benchmark Mineral Intelligence shows China’s share of global natural graphite output in 2014 falls to mid-1990 levels

9 December 2014

40% of China’s magnetic REs illegal

World’s dominant supplier of rare earth elements reveals a huge portion of supply used in magnets is illegally mined; much larger than initially anticipated

21 October 2014

Lithium shortage in 2015?

2015 could see a battery surge as lithium hydroxide faces a shortage on strong global demand, says Benchmark

15 October 2014

Timeline: Battery commercialisation
(9 Feb 2015)

Source: Benchmark Mineral Intelligence

Lithium production share by country in 2013

- Chile 34%
- Australia 22%
- Argentina 11%
- China 10%
- Other 23%

Source: Benchmark Mineral Intelligence
Moving from exploration to evaluation phase

Graphite Creek, Alaska
USA’s premium, large flake graphite deposit

› Large, high grade, at-surface resource
› Simple geology and good mineralization continuity
› Direct access to Pacific port & markets

Preliminary Economic Assessment expected Q2 2015
Metallurgical, product & market evaluations ongoing

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