A flake's chance in cell: quantifying graphite demand

As a follow up to Start me up - EV's and grid storage to drive lithium demand (18 May'16), in this report, we attempt to quantify the impact on demand for graphite from the rapidly growing Lithium-ion battery ("Li-B") sector.

**A major increase in installed Li-B capacity to 2025 is anticipated to drive a major increase in demand for graphite:** Based on our modelled growth in the Li-B market (and certain assumptions for penetration rates for various battery chemistries), we estimate total demand for graphite (natural + synthetic) from Li-B's to increase from 140kt in 2015, to +1Mt in 2025, representing a CAGR of 23%.

**However, demand growth for natural flake graphite in Li-Bs is reliant on a shift by end users away from synthetic graphite:** Our research suggests that 60% of Li-B anode material is currently sourced from synthetic graphite. While the current preference for synthetic appears driven by requirements for consistent purity and lower quality Chinese graphite dominating global mined supply, cost savings of using flake versus synthetic represent a significant opportunity in our view. If natural graphite can achieve and maintain 60% market penetration by 2020, we estimate that annual demand could increase by +660% to 792ktpa by 2025.

**Traditional markets represent the largest market opportunity for natural graphite in the medium term:** Traditional graphite markets (ex-Li-Bs) accounted for an estimated 86% of demand for natural graphite in 2015. Looking forward, we see an opportunity for natural flake to capture market share from synthetic/alternative carbon sources due to improved product quality and cost advantages. We estimate that by 2020, demand for flake graphite from these markets could exceed 776ktpa, representing a market share of 74% (vs Li-Bs at only 26%).

**Everyone wants exposure to the Li-B market - the fact is the market isn't that large...yet:** While demand could increase significantly over the coming decade, this is offset by the potential for a significant supply side (ex-China) response. We estimate flake graphite demand from the Li-B market at 276kt by 2020, versus potential production from ASX-listed graphite companies targeting the battery market of 440kt. Longer term (by 2025), we estimate that global mined flake graphite supply would need to increase by +350% to 1.7Mtpa to satisfy forecast demand from the Li-B market and traditional applications.

**Graphite prices:** Our forecasts for a benchmark (95% TGC) graphite product call for average "basket" prices of US$770-US$926/t between 2016-2025, compared to current basket prices of US$750-850/t. We note that prices have fallen by 50-60% from their highs in 2012, despite a ~40% reduction in mined output and evidence of increasing demand from the both the Li-B and traditional markets.

**CGAu Graphite coverage:**
Syrah Resources (SYR:ASX | Target: A$5.30 from A$6.45 | Rating: SPEC BUY).
Investment Summary

Graphite is an essential raw material in Li-Bs – overall graphite demand could grow by +730% to 2025...

- Based on our research in Start me up – electric vehicles and grid storage to drive lithium demand (18 May’16), we estimate that rapidly increasing sales of Electric Vehicles (EVs) and continued development of the grid storage industry will drive a +200% increase in installed Li-B manufacturing capacity to +250GWh by 2020.
- Our research indicates an average “battery grade” graphite consumption ratio of 0.92kg/1kWh of Li-B energy capacity dependent on cathode chemistry used. Based on our modelled growth in the Li-B market (and certain assumptions for penetration rates for various battery chemistries), we estimate demand for graphite (synthetic and flake) feedstock from Li-B’s to increase from 140kt in 2015, to +1Mt in 2025, representing a CAGR of 23%.

...but natural flake graphite has competition – opportunity for graphite miners in battery anode materials is reliant upon a significant shift by end users away from synthetic

- Our research suggests that ~60% of Li-B anode material is sourced from synthetic graphite, with the current preference for synthetic driven by a desire for consistent product purity (essential in determining Li-B performance) and low quality Chinese flake graphite dominating global mined supply. We understand that only 84kt (from a total market of ~650kt) of natural graphite was used in Li-Bs in 2015.
- That said, cost savings associated with Li-B anode material derived from flake (versus higher priced synthetic) represent a material market opportunity in our view (Li-B manufacturers continue to target aggressive reductions in battery costs). If natural flake graphite can achieve a +5% YoY increase in penetration from current levels of ~40%, to 60% from 2020, annual demand could increase to 792ktpa by 2025, giving natural flake graphite for Li-Bs a 39% share of what could then be a ~2Mtpa global flake graphite market.

Traditional markets (as dull as they are...) still represent the largest market opportunity for natural flake graphite in the medium term

- Traditional markets for natural graphite comprise recarburisers (carbon additives used in electric arc furnace [EAF] steel production), foundries, refractories and other industrial applications (i.e. lubricants, friction products). Together, these markets accounted for an estimated 86% (+500kt) of demand for natural graphite in 2015. This compares with a total market share (across synthetic and natural) of ~90% or, 1.7Mt.
- Key considerations for natural graphite to capture market share from synthetic include consistent product purity and competitive costs. That said, our research suggests a significant market opportunity for increased use of natural flake graphite through a shift to increasing crude steel production from EAFs, and displacement of lower quality amorphous graphite in the cast iron market. By 2020, we estimate that demand for natural graphite from traditional markets could exceed 770kt (versus Li-Bs at ~275kt).
The elephant in an already crowded room – everyone wants exposure to Li-Bs but the market isn’t that large...yet

- We note a number of aspiring graphite producers seeking to target the Li-B market for their production plans – however, based on our estimates of possible future demand, only 275kt of natural flake will be required by the Li-B sector by 2020. This compares with production from existing and potential new supply (as per announced project timetables from various ASX-listed companies) of ~440kt.

- We believe the most advanced of this group of companies is Syrah Resources (SYR:ASX | Rated SPEC BUY), which plan to produce ~340ktpa of graphite concentrate with first production expected in H2’17. Balama will be the largest project of its kind ever built, and once at full production, will produce an average of 25% of global mined output between 2017 and 2020.

- In the longer term, we anticipate that the growth of the Li-B sector and potential for natural flake to capture increased market share in traditional applications could see demand increase sufficiently to support much of the planned production being targeted by ASX-listed graphite companies. Our longer term expectations are for the natural flake graphite market to increase in size by +100% to ~800kt by 2020, and to +1.7Mt by 2025, representing a CAGR of 16%.
Unusual pricing environment – natural graphite prices falling vis-à-vis supply reductions and rising demand

- We have revised our graphite pricing assumptions across the various product size fractions (Figure 3), which now calls for an average “basket price” between 2016-2025 of US$770/t – US$926/t. Revisions represent an average 22% reduction versus previous basket price assumptions.
- In Figure 4, we highlight an unusual pricing dynamic currently evident in the flake graphite market – despite global (i.e. Chinese) production falling by ~40%, and evidence of increasing demand from both the Li-B sector and traditional markets, graphite prices have fallen by 50-60%, suggesting that lower priced substitutes are capturing market share.

**Figure 3: Natural flake graphite basket pricing revisions**

**Figure 4: Historical natural graphite production vs weighted avg basket price**

Source: Company Reports, Canaccord Genuity estimates

CG Graphite Coverage

Syrah Resources (SYR:ASX | Target: A$5.30 ↓ from A$6.45 | Rating: SPECULATIVE BUY)

Appendix I – ASX-listed graphite company overview

- Black Rock Mining (BTR:ASX | Not rated) – Mahnege Project, Tanzania
- Hexagon Resources (HXG:ASX | Not rated) – McIntosh Project, Western Australia
- Kibaran Resources (KNL:ASX | Not rated) – Epanko Project, Tanzania
- Magnis Resources (MNS:ASX | Not rated) – Nachu Project, Tanzania
- Metals of Africa (MTA:ASX | Not rated) – Montepuez Project, Mozambique
- Volt Resources (VRC:ASX | Not rated) – Namangale Project, Tanzania
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SYR: THE ELEPHANT IN THE ROOM - SUPPLY COULD OUTPACE DEMAND TO 2020

EVERYONE WANTS EXPOSURE TO THE LI-B THEMATIC – FACT OF THE MATTER IS DEMAND IS NOT YET THAT LARGE

Key forecast risks

Product Pricing & Forecasts

NATURAL FLAKE GRAPHITE PRICES STILL FALLING DESPITE LOWER SUPPLY AND INCREASING DEMAND

FALLING FEEDSTOCK COSTS FOR SYNTHETIC IMPACTING NATURAL FLAKE PRICES?

OTHER PRICING INFLUENCES

ASX Listed Graphite Companies – Peer Comparison

Company Updates

Syrah Resources Ltd (SYR:ASX)

Appendix I - ASX Listed Graphite Companies

Black Rock Mining Ltd (BKT:ASX)

Hexagon Resources Ltd (HXG:ASX)

Kibaran Resources Ltd (KNL:ASX)

Magnis Resources Ltd (MNS:ASX)

Metals of Africa Ltd (MTA:ASX)

Volt Resources Ltd (VRC:ASX)
Graphite Fundamentals

WHAT IS GRAPHITE?

- Graphite is the hexagonal crystalline form of carbon and occurs naturally as disseminated crystal flakes in high-grade metamorphic rocks, as veins, and as microcrystalline ‘amorphous’ graphite associated with metamorphosed coal seams. Graphite sits in the middle phase of the three forms of carbon between coal (amorphous carbon) at the lower end of carbon content, and diamond at the higher end.

- Graphite has many properties which lends itself to a number of different uses across a broad range of product markets. These properties include lubrication, reactivity, strength and resilience to high temperatures (for use in refractories). More significantly, graphite has conductive properties (known as reversible capacity) which makes it suitable for use as an anode material within Li-ion batteries. Graphite is consumed as a number of different product types and can be derived from both Natural and Synthetic sources. 

SYNTHETIC VS NATURAL

- The global graphite market can be broken down into its two key primary sources, Synthetic, and Natural. Based on an estimated total market size (2015) of ~1.85Mtpa, synthetic graphite represents ~65% of all graphite production/consumption, with natural graphite comprising the balance of ~650ktpa (Figure 5).

![Figure 5: "Family tree" of graphite products and estimated market share in 2015](image)

Source: Industrial Minerals, Company Reports, Canaccord Genuity estimates

**Synthetic Graphite**

- Synthetic graphite is produced when calcined pet coke (CPC) is mixed with a pitch based binder, baked and extruded into a shape. The shape can be round (electrode) or block form (mould stock specialty graphite). After baking, the material is subjected to high temperatures (+2700 °C) in order to convert the carbon to graphite. This process is typically carried out in an Acheson furnace in which a DC current of low voltage and very high current is applied to the furnace...
charge in an anaerobic (oxygen depleted) environment. This simulates the “mesophase” melting that occurs in the geological formation of natural graphite.

- Within this intermediate process the carbon bonds within the lattice structure re-orientate and cure to replicate natural graphite. The duration for this process can be as long as 2-3 weeks due to controlled cooling requirements. Synthetic graphite typically has fixed carbon levels of >99%, volatiles <0.5% and sulfur <0.02%. After graphitization the material is classified (screened) to its final product specifications.

- Synthetic graphite can be segmented into primary (direct) applications and secondary applications that require further manufacturing steps. The primary use of synthetic graphite (representing 43% market share) is as an electrode for use in electric arc furnaces in the steel production process. Synthetic graphite also forms part of the much larger Alternative Carbons Market (includes products derived from coal or bitumen sources), as well as being used as an anode material within rechargeable batteries.

**Natural Graphite**

- There are three main forms of natural graphite:
  - **Amorphous Graphite** (~ 40% of market): Amorphous Graphite is a seam mineral formed by the local metamorphism of previously existing anthracite coal seams rather than a distinct graphite deposit (as for flake graphite). Amorphous graphite is typically recovered at lower purity than natural graphite (at ~75-85% total graphitic carbon, or TGC) due to the adhesion of the graphite crystalline structure with surrounding mineral ash. The affinity of graphite and ash results in conventional recovery methods such as flotation that rely on surface properties being highly inefficient.

    Mineral processing methods (i.e washing, classification) to recover amorphous graphite typically result in lower operating costs (<US$200/t) but produce a lower quality product (~75-85% purity). The “ashing” properties of amorphous graphite assist in coating and lubricant applications. Amorphous graphite is unlikely to compete in the same markets as high quality carbon products.

- **Flake Graphite** (~59% of market) Crystalline flake graphite is recognizable by its high metallic lustre, and plate-like particle morphology. It is formed in metamorphic rock, in concentrations of 5%–12% carbon content (TGC) in the ore body. Depending on the metamorphic conditions (heat, pressure,
duration) that were present as the deposit formed, gangue materials such as ash, iron and sulphides can be ‘intercalated’ within the graphite flake structure, which affects overall product purity. This impacts overall processing costs (mostly through flotation reagent consumption) and the ability for potential producers to place their product in higher end applications such as feedstock to the lithium-ion battery sector.

Concentrate purities for further conversion to spherical graphite are typically +95% TGC with the level of impurity intercalation a key determinant in the costly and hazardous requirement for hydrofluoric acid leaching prior to coating for a broad range of applications (see Spherical Graphite section below). Our view is this will be a key determinant in a project’s ability to provide reliable, comparable product that can displace synthetic graphite as an anode material.

- **Vein Graphite** (<1% of market). Vein graphite is a very high grade crystalline graphite that contains in-situ grades of over 95% TGC. The only country producing commercial quantities of material is Sri Lanka with only ~2kt of material produced from 2 operations. While the benefits of direct whole ore extraction and superior product pricing (>US$1,500/t) offer attractive project features the difficulties of extraction through shallow shafts (water ingress, ventilation, mining rate) present as likely barriers to any major increase to supply over the short/medium term.

**NATURAL GRAPHITE – MAKING SENSE OF GRADES, FLAKE SIZE, AND PURITY**

- In situ graphite content of an ore deposit is typically quoted as a percentage of total graphitic carbon (%TGC). However, unlike most other metals and mineral commodities, tonnes (size) and grades are not the only considerations when assessing what constitutes an economic deposit.

- Flake size and product purity are also other key considerations, which are a geological feature inherent to the deformation of carbonaceous sediments such as shales and sandstones within the deposit.

- Ore bodies with higher in-situ grades (+10% TGC) such as those found in Mozambique are usually associated with a finer flake distribution (i.e <100µm). Conversely, larger flake deposits (50% >180µm) are typical of those found in the Paleoproterozoic Usagaran Belt within Tanzania, East Africa, albeit at a lower in-situ grade (<8% TGC).

**Figure 9: Natural flake graphite size fractions**

<table>
<thead>
<tr>
<th>Flake</th>
<th>Microns</th>
<th>Mesh size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jumbo</td>
<td>&gt;300</td>
<td>&gt;48</td>
</tr>
<tr>
<td>Large</td>
<td>&gt;180</td>
<td>&gt;80</td>
</tr>
<tr>
<td>Medium</td>
<td>&gt;106</td>
<td>&gt;150</td>
</tr>
<tr>
<td>Small</td>
<td>&gt;75</td>
<td>&gt;200</td>
</tr>
<tr>
<td>Fine</td>
<td>&lt;75</td>
<td>&lt;200</td>
</tr>
</tbody>
</table>

Source: Company Reports

- In general terms, a higher in-situ grade will result in lower operating costs due to less processing being required to achieve the same level of purity in the concentrate. More specifically, processing costs are impacted by the required amount of flotation stages and reagent consumption which is a function of flake size distribution.

- Due to flotation being a recovery method exploiting graphite’s hydrophobic (water repelling) properties, cleaner, larger flakes are usually recovered first at higher purities which is the general trend presented in Figure 10. Additional flotation
stages are likely as presented in Figure 11, to increase product purity for natural flake ore bodies with a greater proportion of fine flake.

Figure 10: Graphite flake size and purity relationship

Source: Company Reports

Natural Graphite production methods

- Mining of natural flake graphite is relatively straightforward through the extraction of ore from sedimentary hosted or metamorphic (schist) deposits. Graphite is quite friable (i.e. free digging) in nature with deposits typically requiring minimal blasting.
- Dependent on the morphology and weathering within the deposit, flake graphite can be quite easily liberated from gangue (usually quartz, silica and feldspar) using conventional crush>grind>float processes as indicated in Figure 11 below. The end product is a high purity (+95% TGC) graphite concentrate.
- The effect of head grade, expressed as % TGC is most apparent when determining flotation circuit configuration and the quantity of material that will report to the concentrate product (mass pull). Graphite is well suited to flotation due to being a hydrophobic mineral (concentrate purities of +95% TGC can generally be achieved without the need for reagents beyond high quality water and air).
- One of the key features to assist aspiring graphite producers to displace current natural graphite supply is achieving a concentrate purity of +97% TGC. Depending on the metamorphic conditions (heat, pressure, duration) that were present as the deposit was formed, gangue materials such as ash, iron and sulphides can be ‘intercalated’ within the graphite flake structure and can’t be removed without the use of thermal/chemical purification.
GLOBAL RESOURCES

- The USGS estimates known global resources at +800Mt of recoverable graphite. Figure 12 below shows East Africa to host the majority of known global graphite resources, predominantly the large scale deposits in Mozambique.

Figure 12: Global resources by country (contained graphite)
Market supply

NATURAL GRAPHITE PRODUCTION DOMINATED BY CHINA
- Due to the opaque nature of the industry, updated production data is difficult to obtain, but it is estimated that global flake graphite production was ~650kt in 2015. This was dominated by Chinese domestic production (~76%, Figure 13) from operations mainly located in the Shandong, Heilongjiang and Jixi regions of China. These operations are usually small in size and often prone to poor environmental practices.
- According to Benchmark Minerals (Figure 14), global production is estimated to have decreased by 45% since 2013, mainly due to the supply of marginal, lower quality Chinese amorphous production coming under pressure from influences such as increasing government intervention (i.e. closure of mines), and plateauing of demand from Chinese steel production.

OTHER KEY PRODUCTION SOURCES
- **Brazil**: Two main companies dominate production - Nacional de Grafite (~70ktpa) and Grafite de Brasil (~20ktpa). Brazil is endowed with ~2.5Mt reserves of graphite mostly located in the province of Minas Gerais. Brazilian production is unlikely to increase materially in the future (i.e. compete with other natural flake sources) owing to the poor grade (<4%) and flake size distribution (~25% as flake and 75% as amorphous).

PROJECTED SUPPLY - CHINA’S DOMINANCE TO BE CHALLENGED BY HIGHER QUALITY RESOURCES OUTSIDE CHINA?
- China’s dominance in the production of natural graphite is expected to diminish over the coming years, primarily through the closure of smaller operations (Figure 15) and through competition from emerging sources of higher quality production from projects mostly located in East Africa.
PROJECTED SUPPLY

- Our research indicates that there are +20 natural flake graphite projects globally (ex-China) which have had various levels of project feasibility completed on them in the last 4 years (Figure 17). The largest and most advanced of these is Syrah Resources’ 340ktpa Balama project, located in Mozambique, which is currently anticipated to achieve first production in mid’17.

- Between them, these projects represent a potential +1.7Mtpa of natural graphite production (versus 2015 global production of ~650ktpa), requiring in excess of US$2.6bn in capital.

### Figure 15: China Natural Graphite production 2012A, 2015E

<table>
<thead>
<tr>
<th>Province</th>
<th>Type</th>
<th>Operating Mines</th>
<th>2012 Production</th>
<th>2015E Production</th>
<th>Capacity (ktpa)</th>
<th>2015E Production</th>
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<tr>
<td>Hunan</td>
<td>Amorphous</td>
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<td>Hulunxiang</td>
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<td>170</td>
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<td>70</td>
<td>160</td>
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<td>780</td>
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Source: Industrial Minerals, Roskill

### Figure 16: Projected China Natural Graphite production

Source: Industrial Minerals, Canaccord Genuity Estimates

### Figure 17: Global development projects

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<th>Study Date</th>
<th>Type</th>
<th>Property</th>
<th>Country</th>
<th>Reporting Company</th>
<th>Ticker</th>
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<th>Capital Cost (US$m)</th>
<th>Production LOM (ktpa)</th>
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<td>Canada</td>
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<td>Epanko</td>
<td>Tanzania</td>
<td>Kibaran Resources Ltd.*</td>
<td>KNL-AU</td>
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<td>78</td>
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<td>Canada</td>
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<td>USA</td>
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<td>Campoooa</td>
<td>Australia</td>
<td>Archer Exploration Ltd.</td>
<td>AXE-AU</td>
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<td>Canada</td>
<td>Canada Carbon Inc.</td>
<td>CCB-CA</td>
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<tr>
<td>12/10/16</td>
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<td>Namangale</td>
<td>Tanzania</td>
<td>Volt Resources*</td>
<td>VRC-AU</td>
<td>66</td>
<td>TBC Q4’16</td>
<td>TBC Q4’16</td>
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</tbody>
</table>

**Total** 1790 2558 1766

Source: SNL Mining; * See Appendix 1 for company overview ** See company update section
In our view, the viability of any new natural graphite projects will be largely determined by the ability for any project’s production to disrupt markets currently supplied by inferior amorphous graphite and pet coke products. This in itself will be a function of product purity and costs for the end user.

Assuming new natural production can displace alternatives such as synthetic graphite and products from the alternative carbons market, Figure 18 below illustrates a potential (CGe) supply curve for the natural graphite market. This sees production grow from ~650ktpa to 2Mtpa by 2025. Within this, we highlight SYR:ASX’s Balama project, which is expected to be the largest of its kind in the world once in production, producing an average of 25% of total global mine supply between 2017 and 2020.

Key underlying assumptions include:
- Falling Chinese production on account of inferior product quality versus potential ex-China production
- No major change to existing baseline production levels from outside China
- From 2020, new supply is brought on in line with rising demand (see Market Demand), with the sequence with which new projects are brought on line determined by a ranking of individual project characteristics as detailed below.

Figure 18: Forecast (CGe) potential supply curve

In assessing when new natural graphite supply is brought on-line, we have looked at the following key project characteristics:
- **Deposit Size**: we have considered only projects of meaningful size (>=1.0Mt of contained graphite; Measured and Indicated category). Large deposit size ensures economics of scale which will assist with placing production at the lower end of the cost curve (this is key when attempting to displace incumbent Chinese production).
- **Location**: sovereign, legal, financing, logistics risk
- **Product Purity/Size Distribution**: This is a key consideration as it will ultimately dictate the operating cost of downstream purification for higher end...
applications such as spherical graphite for lithium-ion batteries. In the advent of an oversupplied market it is our view that products with higher specifications will be at a distinct competitive advantage with regard to end user requirements.

- **Offtake agreements**: we consider binding agreements as key in helping attract both equity and debt finance for new projects.
- **Stage of development**: All other things being equal, the more advanced (i.e. DFS vs PFS), the sooner the project could be developed.
- **Capital costs**: This considers financing requirements, balance sheet and quantum of capital expenditure. We estimate that global capital requirements exceed combined market capitalisation by ~1.5x. With traditional project finance a rarity in the natural graphite sector, a projects capex/market cap ratio is a key determinant in the project being able to secure development funding.

**OTHER KEY CONSIDERATIONS**

**Battery anode supply chain**

- It is well acknowledged that the lithium ion battery industry contains a labyrinthine array of suppliers and customers all featuring differing levels of integration along the supply chain (see Figure 19). This is even more apparent within graphite where substitute products (natural vs synthetic), additives (silicon influence) and cathode chemistry (metal oxide blend) all influence the ultimate end use objective (discharge performance vs safety aspects).

![Figure 19: Anode Supply Chain](Source: Washington Post, Canaccord Genuity)

- Due to the critical performance that the anode plays relative to its low input cost (~5% of total battery cost in US$/kWh terms) we view that the transition to natural flake graphite will be progressive and have assumed this to peak at 60% of anode material by 2020.
- We note with interest the challenge for most ASX listed graphite developers to progress product offtakes to binding status. We view that the recent period of lowering feedstock prices for synthetic graphite have meant that anode manufacturers are more willing to take time to qualify potential natural graphite feedstock rather than commit to quantities and prices from one supplier.
In addition while the economics of integrating downstream to produce spherical graphite are compelling (our SYR estimates indicate an un-risked 63% EBITDA margin) we note that internalizing this capability is likely to prolong the product qualification process which in turn could further delay securing offtake.

Market demand - overview

- Key product markets for the graphite (synthetic and natural) market include:
  - Recarburisers – carbon additives used in steel and cast iron production as a hardening agent
  - Foundries – production of metal castings (primarily cast iron)
  - Refractories – materials used in linings for furnaces, kilns and reactors
  - Lithium-ion batteries – use as an anode material
  - Other industrial markets - these include friction products (carbon brushes, brake pads and hard metals) which utilize graphite’s superior wear properties, lubricants, and other applications including metallurgical powders, foils and gaskets.
TRADITIONAL MARKETS THE MAIN SOURCE OF DEMAND; DEMAND GROWING FOR BATTERIES BUT MARKET REMAINS COMPARATIVELY SMALL

- It is estimated that carbon additives (recarburisers), foundries and refractories (i.e. traditional carbon market) dominate demand for both synthetic and natural graphite with a total +90% of market share. Splitting out natural graphite, recarburisers, refractories and foundries consume half (~80%, or ~500ktpa) of all natural graphite produced.
- The emergence of the lithium-ion battery sector has seen demand for graphite (synthetic + natural) for use in battery anodes increase by an estimated ~40% from 2014-2016 to ~200kt. However, we point out that compared with traditional carbon markets, batteries represent only a relatively small proportion of the market with a current estimated market share of 11%, of which <50% (~100kt) is derived from natural sources.

SYNTHETIC DOMINATES BUT OPPORTUNITY FOR NATURAL TO INCREASE MARKET SHARE

- We note that synthetic graphite is currently the dominant graphite product used in these end-markets (1.1Mt vs 0.65Mt in 2015). In our view, the potential for natural graphite to displace existing synthetic graphite and/or capture any increase in demand is reliant on key considerations including consistent product purity, performance and cost.
- We understand synthetic graphite to cost >US$10,000/t dependent on application, with input energy the key cost driver. This is more likely to be in the range of US$12,000 - 20,000/t to produce a product for the battery anode market compared with ~US$7,000/t for coated natural flake as presented in Figure 25.
- We highlight in Figure 59 that falling energy costs have likely influenced the demand for flake graphite over the last several years contributing to suppressed pricing.
That said, we highlight that the historic preference for the use of synthetic graphite in key end markets appears to be driven by poor quality natural production (high proportion of amorphous graphite), compounded by recent decreases in Chinese production. On this basis, we acknowledge an opportunity for higher quality flake production from outside China to capture existing market share and/or incremental demand growth.

Demand analysis - Lithium-ion batteries

LITHIUM ION (Li-Bs) BATTERIES – A RECAP

- In Start me up – electric vehicles and grid storage to drive lithium demand (18 May ’16), we outlined the key principles of how Li-Bs work, and the raw materials required for the various battery components. As a recap:

  - Li-Bs all contain a positive cathode, a negative anode, and an electrolyte which act as the conductor of Li ions as they move back and forth between the cathode and anode during charge and discharge cycles.

  - The cathode is manufactured from a lithium-metall oxide compound, while the anode is manufactured from a porous carbon (graphite). Graphite used in the anode is derived from both synthetic and natural sources, shaped into spheres to improve density and hence energy storage characteristics (i.e. tapping density). A larger proportion of synthetic graphite has historically been used (ratio can vary widely depending on the specific battery chemistry employed by the anode manufacturer’s preferences; we understand the market in 2015 to be ~70% synthetic in use as anode material currently) due to its more consistent purity characteristics.
SPHERICAL GRAPHITE – AN OVERVIEW

- Spherical graphite is the physically and chemically altered form of natural graphite that is used in the manufacture of carbon anodes for use in Li-Bs. A contained purity of 99.95% TGC is essential for battery use, which requires a graphite feedstock grade of +95% TGC.
- The conventional processing route for producing spherical graphite involves the following key processing steps (Figure 27) and is explained in further detail below.

Figure 27: Process Flowsheet for Spherical Graphite Production from Mine Site (Red) to Spherical Plant (Blue)

Source: Company Reports, Canaccord Genuity
- **Milling:** the natural flake feed (-100 US mesh or 150 µm) is milled to a product size for spherodisation of \(d_{50}\) (50% passing). A jet milling reduces particle size on a ratio of ~5:1.

- **Spherodisation:** involves converting flat graphite particles into spheres, thereby allowing the graphite to be more efficiently packed into any given space (“tapping density”). This tapping density combined with high purity levels are the key factors in being able to produce the high electrical conductivity that is required for battery anodes. This proprietary process is believed to again use jet milling technology to shape the natural graphite particles. Depending on purity, flake size and the required dimensions of the product, yields can be between 30-50%.

---

**Figure 28: Microscopic image of natural flake graphite**

![Microscopic image of natural flake graphite](Source: Adbury Carbons)

**Figure 29: Microscope image of uncoated Graphite Spheroids**

![Microscope image of uncoated Graphite Spheroids](Source: Magnis Resources)

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- **Recarburiser Briquettes:** As part of the spherodisation process graphite fines or “shavings” are produced with typical yields from spherical products of 30-40% depending on the characteristics of the spheroids produced as well as the size distribution of the feedstock. The residual material (shavings) can be converted into high quality recarburisers briquettes via further agglomeration/sintering.

- **Purification:** Produced spherical graphite is upgraded from a feed purity of ~95% TGC to meet product specifications of ~99.95% TGC. This is usually via leaching (using a ratio of hydrofluoric and hydrochloric acid) to remove entrained impurities (such as ash and silica) that are intercalated within the adjacent voids between the graphene layers. Leaching is a lower cost purification step than alternative thermal treatment with the main input costs being that of reagents at around US$200/t of treated graphite. A more expensive (at US$700/t) route is thermal purification which however is less restrictive in terms of environmental regulations. )

- **Coating:** The final step is coating in which a pitch impregnation process to heat treat and coat the spherical graphite occurs. Coating reduces the surface area of the particles, thereby increasing the long term capacity of the battery. Due to the complexity and energy requirements of this process, coated spherical graphite currently sells for around +US$10,000/t (coated with synthetic graphite) and between US$7,000/t- US$10,000/t (coated with amorphous graphite). This compares with uncoated product selling for
US$3,000/t - US$4,000/t. We understand the coating stage costs to be around US$2000/t (~25% of processing costs as presented in Figure 25).

- **Classification:** Once coating has occurred a producer will plan to split the spherical graphite product into various size fractions as specified by the anode customer. For example a $d_{50}$ of 23µm for grid storage applications and a $d_{50}$ of 16µm and 10µm for use in EV/Hybrid vehicles and consumer electronics are examples of particle size specifications.

**SYNTHETIC VS NATURAL GRAPHITE ANODES – NATURAL NOW COMPETING ON A PERFORMANCE BASIS**

- The ability to customize synthetic graphite is in direct contrast to the natural variability of flake graphite, and perceived as a potential limitation to the broad range use of lower cost spherical natural graphite in battery anodes. That said, continual refinements to the production process have seen the performance of spherical natural flake graphite improve to now be comparable with synthetic graphite.
- Figure 30 and 31 below compare the reversible capacity of natural graphite and synthetic, with natural being >360mAh/g which approaches theoretical limits of 372mAh/g. This suggests that on a like for like purity basis, natural graphite can compete with synthetic graphite in determining battery performance.

- A key limiting factor of battery performance is the formation of solid electrolyte interface (SEI, Figure 32 & 33), which initially coats the graphite anode to offer protection against solvent degradation (within the electrolyte) at higher voltages. SEI is essentially formed on the graphite surface, hence the irreversible charge loss on the first cycle will be dictated by the properties of the surface area that is exposed to the electrolyte solution. These properties include particle size, coating thickness, crystallographic structure and particle morphology (shaping etc).
Each anode application will have specific material requirements which will influence the preferred source of graphite (natural or synthetic). It should also be noted that this is likely to influence the product qualification process (duration, consistency, limits) that new sources of natural flake will encounter to take market share from synthetically produced graphite.

Our research suggests that ~40% of ~100kt of anode material is derived from spherical natural flake graphite. The remaining 60% is from a source of synthetic graphite materials which will depend on the specific performance required (see Figure 24). Early stage test work from a number of graphite companies indicates that coated natural flake graphite products have comparable if not superior discharge performance versus synthetic graphite.

**HOW MUCH GRAPHITE GOES INTO A LI-B?**

- In Start me up – electric vehicles and grid storage to drive lithium demand we investigated the composition of raw materials used in the various types of Li-B (based on varying cathode chemistry, Figure 34).

<table>
<thead>
<tr>
<th>Battery Chemistry</th>
<th>Lithium Cobalt Oxide</th>
<th>Lithium Manganese Oxide</th>
<th>Lithium Iron Phosphate</th>
<th>Lithium Nickel Manganese Cobalt</th>
<th>Lithium Nickel Cobalt Aluminium Oxide</th>
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<tr>
<td>Short Form</td>
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<td>LMO</td>
<td>LFP</td>
<td>NMC</td>
<td>NCA</td>
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<td>Good</td>
<td>Poor</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Specific Power</td>
<td>Fair</td>
<td>Good</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Heat Capacity (J/kg)</td>
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<td>850</td>
<td>950</td>
</tr>
<tr>
<td>Safety</td>
<td>Fair</td>
<td>Good</td>
<td>Excellent</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Performance</td>
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<td>Fair</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Life Span</td>
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<td>Fair</td>
<td>Excellent</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Cost</td>
<td>Good</td>
<td>Good</td>
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<td>Good</td>
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<tr>
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<td>3.70V</td>
<td>3.30V</td>
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<td>700</td>
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<td>Power tools, medical devices</td>
<td>Large Scale grid storage, Buses</td>
<td>E-Bikes, EV’s (performance)</td>
<td>E-Bikes, EV’s (range, disposable)</td>
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We have reviewed the material specification sheets of a number of established battery manufacturers’ products to determine the bills of materials for Li-B types as presented in Figure 36 below. This indicates that on average 0.92kg/kWh of coated graphite is required in spherical natural flake or synthetic form. From this work, we see that the non-nickel based cathode chemistries use the most graphite with Lithium Cobalt Oxide (LCO), Lithium Manganese Oxide (LMO) and Lithium Iron Phosphate (LFP) batteries requiring the most amount of graphite per...
kWh versus Lithium Nickel Cobalt Aluminium Oxide (NCA) which only uses 0.66kg/kWh.

**Figure 35: Bill of Materials for standardized Li-ion battery (contained graphite shown in kg/kWh).**

**QUANTIFYING GRAPHITE DEMAND FROM LI-B’s**

*Expectations for significant growth in the Li-B market driven by e-transport and grid storage*

- Figure 36 below illustrates our modelled installed battery energy capacity from the electric transport (EV’s, e-buses etc), grid storage, and electronic device markets (for further detail, see *Start me up – electric vehicles and grid storage to drive lithium demand*).
- We anticipate that the electric vehicle/electric transport markets will be the key driver of demand for Li-B’s, with an estimated CAGR of installed battery energy capacity across the electric transport market of 24% to 2025, and a CAGR of 20% across the entire Li-B sector.

**Figure 36: Li-B energy requirements across Segments**

Source: Company Reports, Canaccord Genuity estimates
Based on the above, we estimate total battery capacity requirements of +250GWh by 2020, representing a CAGR of 21% from 2015. To support this, we further estimate an additional ~150GWh of battery manufacturing capacity will be required by 2020 alone, in the absence of any material impacts of battery recycling and/or adoption of new battery chemistries/technologies. This is illustrated in Figure 37, which shows global announced/required battery manufacturing capacity estimates to 2020.

Figure 37: Installed battery manufacturing capacity (GWh)

Source: Company Reports, Canaccord Genuity estimates

Not all Li-B’s are created equal – specific graphite demand for Li-B’s based on battery chemistry

- Our modelled forecasts for the growth in the e-transport and grid storage sectors are based on the various Li-B battery chemistries as shown in Figures 35 and 36 above (i.e. different batteries are used in different applications). Based upon our projected installed battery capacity, we have broken this down into projected demand (in GWh of installed capacity) according to cathode chemistry (Figure 38).

Figure 38: Installed Battery Capacity by Cathode type

Source: Company Reports, Canaccord Genuity estimates
Use of natural graphite in Li-B’s will depend on a significant shift away from synthetic

- Based upon our projections for Li-ion battery demand depending on the various cathode chemistries and graphite raw material requirements, we have estimated the required demand for natural flake graphite in Figure 39 below. This shows that demand for flake graphite from the Li-B market could grow by a CAGR of 25% from 2015 to 2025 to 792kt (from ~84kt).

Figure 39: Natural Flake Demand from the Li-ion battery market

- As part of our projections, we have assumed a spherical graphite yield (from natural flake feedstock) of 40% increasing to 50% by 2020 (based on an assumption that production processes improve and higher volumes of higher quality non-Chinese flake feedstock). Against this we present three scenarios relating to the penetration rates of natural graphite as battery anode material:
  - **Business as usual (40%)**: This projects a business as usual scenario whereby natural flake graphite only supplies 40% of all future battery anode material. In this case we forecast natural graphite demand to double from ~80kt in 2015 to ~180ktpa in 2020 and to ~200ktpa by 2025, implying a CAGR of 20%.
  - **Mid Case (50%)**: For comparison we have forecast the impact of 50% of battery anode being from natural flake from 2016-2025. This implies a CAGR of 23% to 2025 with 660kt of natural flake expected by this stage.
  - **Base Case (60% from 2020)**: Under this scenario we assume that the cost savings associated with using spherical graphite derived from natural flake (~US$7/kg vs +US$10/kg) will translate to a rapid shift in preference away from synthetic graphite. We also assume that as further test work validates performance characteristics, acceptance of naturally sourced anode materials will become more widespread. This is expected to translate to a 5% YoY increase in natural flake use from 40% to 60% from 2020 onwards. Under our base case, we forecast natural graphite demand to more than treble from ~80kt in 2015 to ~300ktpa in 2020 and to ~820ktpa by 2025, implying a CAGR of 26%.
Demand analysis – traditional markets

- Traditional markets for graphite include recarburisers (steel production), foundries (metal casting), refractories, lubricants, and other industrial applications such as friction products. Within these markets, we have identified four key opportunities for increased demand for natural flake:
  - Adoption of electric arc furnaces in crude steel production.
  - Replacement of lower-quality recarburisers in cast iron production.
  - Replacement of lower-quality amorphous graphite in traditional markets
  - Replacement of lower-quality industrial anodes in aluminum smelting

RECARBURISERS – AN OPPORTUNITY FOR NATURAL FLAKE BUT MARKET DOMINATED BY ALTERNATIVE CARBONS

- Recarburisers are additives in the steel and cast iron production process that are used to adjust carbon content and hardness properties. Recarburisers for steel production and foundries currently account for an estimated ~31% of total graphite (synthetic and natural) demand, and ~45% of demand for natural flake.
- The recarburiser market is estimated at ~3Mtpa, of which 76% is attributed to Gray Iron and Ductile Iron production, and 24% to electric arc furnace (EAF) steel production (Figure 40). The supply of carbon products into this market is dominated by Alternative Carbon sources including metallurgical coke, pet coke and synthetic graphite, with ~195ktpa of natural graphite currently used (despite recent falls in natural graphite prices).

In our view, these segments are likely to continue to be the foundation market for natural flake graphite on the basis that it contains lower sulphur and other impurities, and is expected to increase in use as regulatory and customer requirements in these markets become more stringent.
Growth in EAF steel production a positive for natural graphite recarburisers

- Global steel production is currently ~1.6Btpa, with global demand for steel directly correlated with gross domestic product. China produces ~50% of world crude steel, with an annual CAGR from 2000-2015 of 12%. This compares with global (ex-China) CAGR’s of 2%.

![Figure 42: Historical crude steel production profile 2000-2015](image.png)

![Figure 43: Global steel production – BOF vs EAF](image.png)

- The global steel industry has undergone significant change over the past two decades as steel production from EAFs has increased significantly (in volume terms), driven by an increase in environmental regulations in the developed world and the increased capacity to process recycled steel. Of the global crude steel market, approximately 28% is now produced via EAF (6% in China), which has increased by +80% in the last 10 years in absolute terms (Figure 43).

- Due to the ability to use larger volumes of scrap steel, EAF offer several advantages over basic oxygen furnaces (BOF) including:
  - Lower carbon emissions
  - Lower raw material requirements
  - Lower energy requirements
  - Lower capital intensity

- While the use of graphite as a recarburiser in BOFs is limited (autogenous oxidation and difficulties with furnace ignition using graphite), the growth of EAF steel production offers a potential market opportunity for natural graphite. EAFs require higher purity recarburisers, which gives natural graphite carbon additives a clear advantage given superior purity levels (+95% TGC vs met coke at ~85% TGC).

However, major shift from BOF to EAF not yet evident

- Tighter environmental standards in China and around the world could provide impetus for increased conversion to EAF (e.g. China’s commitment to cut CO₂ emissions by 60-65% of GDP by 2030 as part of 2016 Paris Climate Agreement), with other factors including increased supply of scrap/recycled steel and better electric energy supplies.

- However, we note that only 6% of steel production in China (representing 3% share of global production) comes via EAF. A large-scale conversions of BOF to EAF steel production in China does not yet appear evident, while on a global scale, we note that the global market share of EAF steel production has remained largely unchanged since 2010 (Figure 43).
Quantifying natural graphite demand from recarburisers (EAF steel production)

- Figure 44 details assumptions used as the basis for our demand projections for natural flake from the EAF recarburiser market.

Figure 44: Crude steel segment assumptions

<table>
<thead>
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<th>Base Case Parameters</th>
<th>Historic 2010-2015</th>
<th>Forecast Global (ex China)</th>
<th>China</th>
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<td>Crude Steel Production Growth Rate</td>
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<td>Adoption to EAF Furnaces</td>
<td>% YoY</td>
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<td>2.50%</td>
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<td>Carbon Addition in EAF Furnaces*</td>
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<td>0.15%</td>
</tr>
</tbody>
</table>

**Scenario 1 - Peneration of new growth**

| Base Case | % Natural flake | 7.6% |
| Low Case -10% peneration | % Natural flake | 10% |
| High Case - 50% peneration | % Natural flake | 50%  |

**Scenario 2 - Adoption to EAF Furnaces**

| Base Case | % YoY | 2.5% |
| Low Case Growth | % YoY | 5.0% |
| High Case Growth | % YoY | 10% |

Source: Global Castings Magazine, company reports, Canaccord Genuity estimates

- Figure 45 highlights two scenarios for possible growth in natural flake demand from crude steel production. These include growth to ~330ktpa by 2020 (vs ~300ktpa for Li-Bs) if natural flake graphite accounts for 50% of all new recarburiser demand, and growth to ~280ktpa by 2020 if the adoption rate to convert from EAF to BOF grows at 10% CAGR. Under these scenarios, steel production via EAF would be 44% globally and 19% in China by 2020 versus current estimates of 28% globally and 6% in China.

Figure 45: Forecast natural flake graphite demand from crude steel segment (2012-2020e)

Source: Company reports, Canaccord Genuity estimates
CAST IRON RECARBURISERS

- Cast iron production provides a strong source of demand for recarburisers through the inherent requirement for higher carbon content additives versus other ferroalloys. Cast iron is usually produced in EAFs through the melting of pig iron along with other input materials such as scrap iron, limestone and coke. Within this process it is necessary to adjust carbon levels depending on the type of cast required. These usually range between 2-4%.

  - **Gray Iron**: This is a lower-quality ferroalloy that requires carbon in the form of graphite (flake or highly refined coke products) and silicon to create a graphitic microstructure within the melting iron. It is estimated only 12.5% of carbon feed is from natural flake graphite.

  - **Ductile Iron**: This is a higher-quality ferroalloy that possesses superior material properties than gray iron (ductility, malleability, strength) due to the graphitic microstructure within the melting iron. The shape of the graphite is in the form of spheroids due to the addition of magnesium or cerium. As a result, carbon content is typically higher than gray iron – due to the requirement for graphite spheroids, ductile iron is more susceptible to impurities. This results in high-purity natural flake graphite being less likely to be displaced by lower-quality alternative carbons or amorphous graphite.

Figure 46: Historical cast iron production by product type

Figure 47: Cast iron segment assumptions

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<thead>
<tr>
<th>Base Case Parameters</th>
<th>Historic 2010-2015</th>
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<td>Carbon Addition - Ductile Iron</td>
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<td>3.50%</td>
</tr>
</tbody>
</table>

**Gray Iron Scenarios**

| Base Case | % Natural flake | 7.6% |
| Low Case - 10% generation | % Natural flake | 10% |
| High Case - 50% generation | % Natural flake | 50% |

**Ductile Iron Scenarios**

| Base Case | % Natural flake | 7.6% |
| Low Case - 50% generation | % Natural flake | 50% |
| High Case - 100% generation | % Natural flake | 100% |

- Figure 48 highlights two scenarios for possible growth in natural flake demand within the cast iron recarburiser market. These include growth to ~400kpta by 2020 if natural flake graphite accounts for 100% of all new recarburiser demand from ductile iron, and growth to ~340kpta by 2020 if natural flake graphite accounts for 50% of all new recarburiser demand from gray iron. If both of these scenarios were to occur, then natural flake graphite would account for 25% of the cast iron recarburiser market (1.6Mtpa) by 2020, up from our current estimate of ~5%. Our forward base case forecasts assume 3%.
REPLACING LOW-QUALITY AMORPHOUS GRAPHITE IN TRADITIONAL MARKETS

- We have combined the high-growth demand projections from the steel and cast iron segments to evaluate a feasible upper demand limit for natural flake graphite in the recarburiser market. This is presented in Figure 5.1 indicating up to ~700kpta of demand is expected by 2020, which would be an increase in total market penetration of natural flake in the recarburiser market from ~7% to 20%.

While it’s conceivable that natural flake graphite will represent the majority of growth in demand, the influence of amorphous graphite supply in China must be considered. Our estimates of the historical composition of the supply of natural graphite to the recarburiser market is presented in Figure 49. This indicates the
shift over the last few years to flake graphite in preference to amorphous as a result of falling prices and the forced shutdown of lower-quality projects in China.

- We have assumed for the purposes of our forecasting that growth in demand for natural graphite will be via the capture of new demand rather than widespread displacement of alternative carbons in the present market. This approach has also been used to reflect the elasticity of supply that has occurred in recent years as alternative carbons have substituted natural flake graphite.

- We currently estimate flake (versus amorphous) comprising ~58% of overall natural graphite supply to the recarburiser market, so have run low and high scenarios of future natural flake graphite supply of 50% and 100%. The low scenario captures any synthetic graphite that may compete with natural flake in the future given we have assumed that the contribution of amorphous graphite to the recarburiser market will be negligible.

- Based on this analysis, we estimate that natural flake graphite demand for the recarburiser sector as a whole will grow from ~130kt in 2015 to ~400kt in 2020, with a CAGR of 20% to 2025 for 817t.

Figure 51: Forecast natural flake graphite demand – high-growth and adoption in each segment (2012-2020e)

Source: Company reports, Canaccord Genuity estimates

REPLACING LOW-QUALITY INDUSTRIAL ANODES IN ALUMINUM INDUSTRY

- Petroleum coke is currently the preferred feedstock for large carbon-based anodes in aluminium smelting due to the high purity (low sulphur, ash) required – this precludes amorphous graphite and lower-quality flake graphite from being used.

- The Hall-Héroult method is the major industrial process for smelting aluminum and typically consumes 450kg of anode per metric tonne of aluminum produced. With an estimated ~60Mt of aluminium produced globally in 2015, the addressable market is significant. That said, calcined petroleum coke is likely to remain a preferred source of carbon due to pricing being <US$250/t, lower than the marginal cost of production for any natural flake graphite producer.
OTHER INDUSTRIAL MARKETS

- These markets combined represented an estimated ~36% (or ~230kt) of natural flake demand.
- Within our demand estimates for natural flake graphite we have assumed that smaller segments of the industrial markets such as friction products and lubricants will grow at historic rates of ~2%, in line with global GDP. We also view these segments as unlikely to materially drive increased demand for natural flake on account of amorphous graphite being more widely used in the lubricant industry (11% of market demand in 2015) due to the “ashing” properties of amorphous material.
- For the purposes of our modelling we have assumed that 50% of future demand from foundries and industrials will utilize amorphous graphite most likely on a price rationale. We consider that 100% of lubricant and “other” categories will provide baseline demand for amorphous graphite.

Figure 53: Forecast industrial use demand (2014-2025e)

Source: Company reports, Canaccord Genuity estimates
Other graphite product markets

EXPANDABLE GRAPHITE (50kt produced in 2015)
- Expandable flake graphite is a form of intercalated graphite. Intercalation is a process where chemical species such as alkali metals, sulfides and organics are placed within the crystalline structure of the host graphite. The resultant graphite material takes on enhanced properties in terms of structure, surface area, density, electronic properties and chemical reactivity.
- Expandable graphite is mostly used in applications such as fire retardants, high-performance gaskets and refractory products.

GRAPHENE: (<20tpa in 2014)
- Graphene, with its potential applications, has been a widely publicised breakthrough in nano-science technology since it was discovered in 2004 by professors at the University of Manchester through isolating one-carbon-atom-thick graphene sheets using the ‘Scotch Tape’ mechanical exfoliation method. Since this time, key attributes such as unsurpassed strength, optical, permeability and electronic conductivity properties have been identified.
- While the graphene industry is nascent with few applications at commercial scale the addressable market is enormous. Applications besides battery anode materials include paints, coatings, galvanics, polymers and building materials – a sector collectively worth over US$620 billion annually.

**Graphene is highly abundant but economic production the key challenge**
- When assessing the suitability of a graphitic ore body to commercial graphene potential, a number of inherent geo-metallurgical factors are important. These include a high in situ grade (TGC%), a highly crystalline structure with consistent homogeneity and the nature and ratios of the non-graphite minerals dispersed through the ore (gangue). About 3 million layers of graphene sheets exist in 1mm of graphite, hence developing economic separation methods is the current challenge.

**Forms of graphene:**
- Graphene exists in many forms, generally determined by the method of production, source of precursor and the method used to stabilize the product.
- **Single layer graphene:** This is the purest and typically the most expensive form. Desirable to high-tech end-users and product markets, the graphene exists in a single-atom-thick sheet, with bonded carbon atoms adhered to a substrate or freely suspended.

- **Few-layer graphene (FLG) and multi-layer graphene (MLG).** This typically ranges from two to ten layers thick, either free-standing or substrate bound. It is typically used in composite materials and reinforcements.

- **Graphene oxide.** This chemically modified graphene prepared by oxidation and exfoliation. Graphene oxide is a monolayer material with a high oxygen content. Major uses are for thin membranes that allow water to pass through but block off harmful gases.

- **Graphite nano-platelets, graphite nano-sheets, graphite nano-flakes, and 2D graphite materials** with a thickness and/or lateral dimension of less than 100 nano-metres. The use of nanoscale terminology here can be used to help distinguish these new ultrathin forms from conventional finely milled graphite powders, whose thickness is typically more than 100 nano-metres. These materials are excellent for electrically conductive composites.

**Methods of production:**

- **Bottom-up approaches** involve organic synthesis of carbon from small molecules via their deposition on a substrate through a reduction process. Substrate-based growth of single layer graphene can be achieved through chemical vapour deposition (CVD) or via the reduction of silicon carbide. Both of these processes are limited however by the heating requirements (+1000°C) and the high substrate cost due to removing the underlying metal layer. This impacts the ability to scale up these processes to produce commercial levels of graphene.

- **Top-down approaches** isolate graphene layers from the parent graphite ore under various physico-chemical conditions. Alongside mechanical exfoliation (the “Scotch Tape” approach), liquid phase exfoliation offers the most likely path to produce few layer graphene (FLG) within a one-step process. Liquid phase exfoliation (LPE) has been used in the production of carbon materials upon the reduction of graphene oxide since the 1950s. This shear-based method is known as the “Hummers” method and, due to the structural defects introduced by the oxidation process, results in structural defects within the graphene that degrade the conductive and morphology (dimensional) properties.

**Paths to commercializing graphene**

- An advancement on the “Hummers” LPE method with the assistance of sonication is the “Chemical Exfoliation” method described above. It is our understanding that this method might provide the most likely path to commercial production of graphene based on the work of advanced materials company Talga Resources (ASX:TLG | Not rated).

- During ultra-sonication, the growth and deformation of micro-bubbles within the liquid induce pressure fluctuations at the surface of the immersed graphite block and induce exfoliation. The liquid (usually a non-volatile organic solvent) needs to have a chemical affinity that keeps isolated graphene sheets dispersed. Sonication properties (frequency and duration) impact the form of graphene that is exfoliated (either single layer (SLG), few layer (FLG) or multi-layer (MLG) and the subsequent yield.
Natural graphite demand – putting it all together

- We have considered the six main product markets for natural graphite, and combined our forecasts to project total estimated demand out to 2025. Based on this, we estimate the market for natural graphite to grow from ~640ktpa in 2015, ~1.1Mtpa in 2020, and to +2.0Mtpa by 2025, representing CAGR’s of 5% and 12% respectively.

Figure 56: Overall Natural graphite demand 2015-2025e

- Our forecasts are based on the following assumptions:
  - **Lithium-ion batteries**: We have incorporated our demand projections for our base case scenario for Li-B demand into our total market demand. This results in the battery anode market shifting from 21% of natural flake graphite demand to 26% in 2020E, and 39% in 2025E.
Recarburisers: we have modelled demand in this segment based on our high-demand scenario parameters set out in Figure 51. This implies an annual growth rate of 12% until 2020 for 400kt of natural graphite. From 2020 onwards we have assumed 15% growth to arrive at a market of 816kt by 2025, representing total market share of 40%.

Foundries: According to estimates by Roskill (July’16), the casting (foundries) industry is expected to grow at 3% p.a with graphite use growing at 2.5% p.a. We have assumed a steady growth rate of 2%, noting the large influence that alternative carbons and amorphous graphite still have on overall supply. This results in forecasts that flake graphite will represent 50% of total demand against our current estimated market share of 40%.

Industrials, lubricants and other: we have assumed that natural flake graphite will share with amorphous 50% of future demand growth within the industrial and other segments. Lubricants are likely to dominate the market for amorphous graphite owing to the favorable viscosity that comes from the ash content.
Supply vs demand

SYR: THE ELEPHANT IN THE ROOM – SUPPLY COULD OUTPACE DEMAND TO 2020

- We have combined our assumed market supply and projected demand forecasts for natural graphite in Figure 62 below. Based on this, our current assumptions/forecasts suggest the potential for an over supplied market as soon as 2018.

- As we have noted earlier, SYR’s Balama project is expected to be the largest project of its kind, representing an average of 25% share of global production from 2018-2020. We recognize the first-mover advantage that SYR enjoys as a large-scale, low-cost future producer. This will present as a hurdle for aspiring natural flake graphite developers to place competing products until such time as demand in higher-growth markets (such as battery anode materials) increases.

- We have forecast a 5% YoY reduction in supply from Chinese natural (flake and amorphous) production consistent with commentary around industry consolidation and increased environmental regulation. We do, however, recognize that this appears to be the most like market that can be replaced owing to the lower-quality material (<95% TGC) produced.

Figure 62: Natural graphite market – supply vs demand (2017-2020e)
EVERYONE WANTS EXPOSURE TO THE LI-B THEMATIC – THE FACT OF THE MATTER IS DEMAND IS NOT THAT LARGE...YET

- Our research has shown that demand for natural graphite for the Li-B sector could increase by up to ~500% to 2025, representing a CAGR of 25%. With such significant growth potential, it’s no surprise a large number of aspiring graphite producers are seeking to target this market for their production.

- While we acknowledge the significant growth potential of the Li-B sector and impact on demand for natural graphite, when we compare this to the scale of potential production seeking to enter the Li-B market and consider competition from synthetic graphite, we see the potential for significant oversupply until 2021 (Figure 64). This assumes that production from future producers attracts finance, meets project timelines and gets into production.

![Figure 63: Market surplus/(deficit) forecasts for natural graphite by flake size](image)

![Figure 64: Flake demand from Li-B's vs announced supply into Li-B market (2016-2025e)](image)
The recarburiser market (as boring as it is) should remain a highly important market to aspiring producers

- Based on the above, we believe many graphite companies are failing to acknowledge the significantly less “sexy” but equally important demand center in graphite’s more traditional markets.
- As shown in Figure 57 and 58, recarburisers together are estimated to comprise 39% total market share by 2020 and 40% by 2025, against forecast market share for Li-B’s of 26% and 39% respectively.

Key forecast (market) risks

- Key downside risks to our forecasts include:
  - **Slower than expected EV/grid storage penetration owing to changes in policy** (i.e. removal of government subsidies).
  - **Battery manufacturing capacity**: With key demand drivers for Li-B’s being EV’s and grid storage, insufficient battery manufacturing capacity could hamper growth in these industries and result in lower demand.
  - **Change in battery technology**: As rechargeable battery market grows, further R&D may lead to development of competing technologies. However, we consider risk of this in the next ~10 years is low due to 1) incumbency of Li-B technology 2) long lead times to commercialization of new battery technologies 3) desire for return on capital from investments in new battery facilities
  - **Changes in anode materials**: these include inclusion of silicon within the anode (research has shown significant increases in reversible capacities can be achieved when blended with graphite) and/or other changes in anode raw materials which could be driven by a desire to reduce battery costs or improve battery performance.

One example is the solid-state lithium-metal battery in which the carbon anode is completely replaced with an ultra-thin lithium metal, reducing the dead weight of the carbon anode with an active lithium structure to host lithium ions. These batteries have already found commercial applications in some portable electric devices. More ambitious batteries such as Li/sulphur (500Wh/kg) and Li/air (+10kWh/kg) are at a nascent stage of development.

**Figure 65: Battery types**

![Battery types diagram](image)

Source: Company reports, Nature magazine
**Cost Incentive to change battery anode materials:** We highlighted earlier in Figure 19 the exhaustive process that customers will undertake to qualify potential natural flake as an alternative battery anode material. We currently understand that product ion costs for Li-ion batteries are around US$350/kWh with materials comprising around US$60/kWh (see Figure 66). Given the relatively low input cost that graphite has in the overall cost of a Li-ion battery, we present in Figure 67 the change that moving battery anode material from 40% flake (as per 2015) to 60% from 2020 will have on overall battery costs. We conclude that across an average of the investigated cathode chemistries only a 5% drop (from 34% to 29%) in material costs could be expected. This results in a saving of US$3/kWh or 1% of overall battery costs on 2015 or 1.5% on 2025 based on overall costs presented in Figure 66.

**Product pricing & forecasts**

**Natural flake Graphite prices still falling despite lower supply and increasing demand**

- Due to the opaque nature of the graphite market and the various product specifications, obtaining accurate pricing information is a futile exercise. Some historic natural flake graphite prices are presented in Figure 68, which illustrates a significant fall in prices since 2012.
- We note that the fall in prices coincides with lower supply (closure of Chinese mines) and growing demand for carbon products – this leads to the likelihood that lower-priced substitutes are capturing market share. Understanding the markets

**Battery recycling:** Unlikely to influence supply and demand for the foreseeable future due to the relatively low cost of the raw input material and the cost of recycling.

**Slower conversion to EAF steel production:** Steel from EAFs require higher purity recarburisers (i.e. natural flake graphite vs met coke), but slower conversion of BOF to EAF and/or inability for graphite to displace alternative carbon products could impact demand for natural flake graphite.

**Lower rates of growth in global crude steel and cast iron production:** A slowdown in global crude steel and cast iron production will negatively impact demand for carbon products.
that natural graphite currently service provides insights to the alternative carbon products that may have filled the gap. For example, ~30% of total natural graphite (~195kt) goes into the much larger ~3Mtpa recarburiser market.

Figure 68: Various sized graphite prices (FOB Qingdao)

Figure 69: Historical natural graphite production vs weighted average basket price

FALLING FEEDSTOCK COSTS FOR SYNTHETIC IMPACTING NATURAL FLAKE PRICES?

- Raw material costs for synthetic graphite can be presented by coal and oil prices as per Figure 70. This highlights that the high fixed cost (thermal treatment) to get bituminous feedstock to comparable purities of natural flake is being offset by a significant drop in raw material cost.

- It also illustrates the strong correlation over recent years between the decline in natural fine flake prices with the prevailing decline in metallurgical coking coal and Brent oil prices. We present this as a background to the likely influences that synthetic graphite supply will have on the prevailing natural flake graphite price.

Figure 70: Raw material cost for synthetic graphite VS natural graphite fines VS quarterly Chinese steel production (2012-2020e)
OTHER PRICING INFLUENCES

- Graphite is sold on contract terms between a producer and an intermediate. This pricing structure is dependent on primary factors associated with ore characteristics (flake size, TGC%, impurities) and secondary factors associated with terms and conditions of shipment which impact the cost of delivered product.

- An important feature of graphite is how different product markets are distinguished upon flake size, purity and dimensions (angular or rounded surfaces). Due to large flake being in scarce supply from the majority of Chinese producers, large flake currently commands a significant price premium. Graphite concentrate product that grades below 94% TGC competes with marginal amorphous product out of China, which our research suggests is priced at US$400-600/t dependent on purity levels.

Figure 71: Oct’16 graphite pricing

<table>
<thead>
<tr>
<th>Size</th>
<th>Grade</th>
<th>Low (US$/t)</th>
<th>High (US$/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spherical (15µm)</td>
<td>99.95%</td>
<td>2500</td>
<td>3000</td>
</tr>
<tr>
<td>(+200µm)</td>
<td>94-97%</td>
<td>850</td>
<td>950</td>
</tr>
<tr>
<td>(-200µm)</td>
<td>94-97%</td>
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<tr>
<td>(-150µm)</td>
<td>94-97%</td>
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</tr>
<tr>
<td>(-150µm)</td>
<td>+97%</td>
<td>700</td>
<td>750</td>
</tr>
</tbody>
</table>

Source: Industrial Minerals

PRICING FORECASTS

- We have assessed the natural flake graphite market balance until 2025 across four distinct flake size distributions; Jumbo flake (+300 µm), Large (+150 µm), Medium (+75 µm), Fine/Amorphous (-75µm). In addition we have classified our four key market sectors by growth potential and present our assumptions in figure 71.

Figure 72: Assumed natural flake distribution

<table>
<thead>
<tr>
<th>Growth rate (CAGR)</th>
<th>Low Growth Lubricants</th>
<th>Low Growth Industrials</th>
<th>Mid Growth Foundries</th>
<th>Mid Growth Recarburisers</th>
<th>High Growth Batteries</th>
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</thead>
<tbody>
<tr>
<td>1.8%</td>
<td>1.8%</td>
<td>1.8%</td>
<td>18.6%</td>
<td>19.7%</td>
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Flake Distribution

<table>
<thead>
<tr>
<th>Growth Distribution</th>
<th>Lubricants</th>
<th>Industrials</th>
<th>Foundries</th>
<th>Recarburisers</th>
<th>Batteries</th>
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<tr>
<td>300µm (50mesh)</td>
<td>0%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
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<td>150µm (100mesh)</td>
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<td>75µm (200mesh)</td>
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<td>-75µm Fines</td>
<td>100%</td>
<td>50%</td>
<td>50%</td>
<td>40%</td>
<td>40%</td>
</tr>
</tbody>
</table>

Source: Canaccord Genuity estimates

- As we have previously pointed out, product purity (grade and deleterious elements) is as important in determining product pricing as flake size. While we have used a benchmark 95% TGC purity natural flake, we acknowledge that many developers aspire to produce superior grade flake concentrates directed toward higher-growth markets such as Li-ion battery anode materials. These concentrates are likely to command a premium to the prices we have presented, underpinned by the prevailing market balance.

- Presented in Figure 73 is our resultant pricing forecast for a benchmark 95% TGC purity product across the various flake size fractions.
Figure 73: CG natural graphite price forecasts

<table>
<thead>
<tr>
<th></th>
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<tr>
<td>Updated CGe - Benchmark 95% TGC purity</td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>300um (50mesh)</td>
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<td>$1,813</td>
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<td>Previous CGe - Benchmark 95% TGC purity</td>
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<tr>
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<td>$1,135</td>
<td>$1,127</td>
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</table>

Source: Company reports, Canaccord Genuity estimates

ASX-listed graphite companies – peer comparison

- As per Figure 17, we have identified +20 companies globally (ex-China) that have had various levels of project assessment (PEA, PFS, DFS etc) completed on them in the last four years. We have refined this list further in Figure 74 below, where we include those ASX-listed companies whose projects are the most advanced, or, where individual project characteristics set them apart from the peer group (we provide more detailed summaries in Appendix 1 (pages 50-65).
- In Figures 75 to 86 below, we compare and rank key project characteristics.

Figure 74: ASX-listed graphite developers

<table>
<thead>
<tr>
<th>Ticker</th>
<th>Market Cap ($m AUD)</th>
<th>Property</th>
<th>Country</th>
<th>Type</th>
<th>Capital Cost (US$m)</th>
<th>Prod'n LOM (ktpa)</th>
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<tr>
<td>Syrah Resources Ltd</td>
<td>SYR-AU</td>
<td>891.50</td>
<td>Balama</td>
<td>Mozambique</td>
<td>Construction</td>
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<td>Magnis Resources Ltd.</td>
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<td>Nachu</td>
<td>Tanzania</td>
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<td>Hexagon Resources Ltd.</td>
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<td>VRC-AU</td>
<td>65.50</td>
<td>Namangale</td>
<td>Tanzania</td>
<td>Pre-PFS TBC Q4’16</td>
<td>TBC Q4’16</td>
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<td>Black Rock Mining Ltd.</td>
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<td>Epanko</td>
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</table>

Source: Factset, company reports, Canaccord Genuity estimates (Prices as at 14/11/16)
**Figure 75: Resource size (Meas + Ind + Inf)**

![Resource size graph](image)

Source: Company reports, Canaccord Genuity estimates;

**Figure 76: EV/resource tonne (contained graphite)**

![EV/resource tonne graph](image)

Source: Company reports, Canaccord Genuity estimates;

**Figure 77: Resource size vs in-situ grade**

![Resource size vs in-situ grade graph](image)

Source: Company reports, Canaccord Genuity estimates

**Figure 78: Resource flake size distribution**

![Resource flake size distribution graph](image)

Source: Company reports, Canaccord Genuity estimates

**Figure 79: In-situ resource grade vs % large flake**

![In-situ resource grade vs % large flake graph](image)

Source: Company reports, Canaccord Genuity estimates

**Figure 80: Flake size distribution vs concentrate grade**

![Flake size distribution vs concentrate grade graph](image)

Source: Company reports, Canaccord Genuity estimates
Figure 81: Project capital costs (US$m)

Source: Company reports, Canaccord Genuity estimates

Figure 82: Capital intensity

Source: Company reports, Canaccord Genuity estimates

Figure 83: Capital hurdle ratio

Source: Company reports, Canaccord Genuity estimates

Figure 84: Planned production (ktpa concentrate)

Source: Company reports, Canaccord Genuity estimates

Figure 85: Operating cost estimate (as per CGe/study results)

Source: Company reports, Canaccord Genuity estimates

Figure 86: Stage of development vs capital costs vs production (bubble size = production)

Source: Company reports, Canaccord Genuity estimates
Company updates
Syrah Resources Ltd (SYR:ASX)

(SYR:ASX:A$3.04 | M/Cap: A$802M | Target: A$5.30 from A$6.45 | SPECULATIVE BUY)

See “Downstream strategy update” 21 Nov 2016

Balama mine development - expect a prolonged production ramp up: Further detail around the projected production ramp-up now sees nameplate production rates (~340ktpa) not achieved until Q3’18, nine months later than prior guidance. While development of the mine remains fully funded, we note that the longer ramp-up could see working capital get tight by year-end 2017. We note that SYR are advancing a possible US$30-50M revolving debt facility, which while earmarked by the company as a contingency, could likely be called upon, in our view.

BAM strategy now better defined: Syrah Resources plans to achieve improved margins through downstream integration, based on a multi-faceted strategy which includes: 1) development of a 60ktpa coated + uncoated spherical graphite plant in Louisiana, USA; 3) construction of a 2ktpa facility ahead of the commercial plant to accelerate product qualification; and 4) Construction of a "Technology Centre" to be based in Perth, Australia, for in-house training, product test-work and R&D. We also note that the company has suggested the potential for additional production capacity in Asia as a medium-term objective.

BFS due 1H’17, first BAM production 2019: While SYR’s overall BAM strategy is now more defined, some project specifics remain unknown (e.g., capex, opex, funding requirements etc). We expect these to now be firmed up as part of a BFS (bankable feasibility study) scheduled for completion in 1H’17. Updated project timetables call for first production from the BAM facility in Q1’19, with a progressive ramp-up to 60ktpa within 12-15 months.

Offtake remains a missing piece of the puzzle: While the proposed BAM plant capacity is covered by binding offtakes, we see greater near-term importance in placing so far uncommitted mine production. We estimate that 35% of planned Balama production remains subject to a binding agreement, and, noting that the BAM plant will not be up and running until 2019, up to 50% of estimated 2018 production remains uncommitted. Further binding agreements are a key de-risking of the project, in our view.

Graphite pricing revisions: We have published separately a detailed investigation of the graphite market in "A flake's chance in cell: quantifying graphite demand" (21 Nov’16), in which we have also revised our flake graphite pricing assumptions. Revisions include an average 24% reduction in "basket prices" to US$770-926/t between 2017 and 2025.

Valuation

Revisions to our model include revised project timetables, revisions to pricing assumptions and balance sheet items, as well as updated assumptions for SYR's BAM project. Net of the changes, our target price (NPV12% for Balama, 50% risked NPV12% for the BAM project, net of corporate and other adjustments) moves to A$5.30 from A$6.45.
### FINANCIAL SUMMARY

**Syrah Resources Limited ASX:SYR**

**Analyst:** Reg Spencer

**Date:** 17/11/2016

**Year End:** December

#### Market Information

- **Share Price:** A$ 3.04
- **Market Capitalisation:** A$m 801.8
- **12 Month H:** A$ 6.66
- **12 Month Lo:** A$ 2.96
- **Issued Capital:** m 263.76
- **Options:** m 6.25
- **Fully Diluted:** m 270.00

#### Valuation

<table>
<thead>
<tr>
<th>Description</th>
<th>2015a</th>
<th>2016e</th>
<th>2017e</th>
<th>2018e</th>
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<tbody>
<tr>
<td><strong>Balama Graphite</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash &amp; S/term Deposits</td>
<td>924</td>
<td>1,122</td>
<td>1,084</td>
<td>1,101</td>
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<tr>
<td>Corporate &amp; O'heads</td>
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<td></td>
<td></td>
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<tr>
<td>Exploration &amp; Projects</td>
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<td></td>
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<tr>
<td><strong>Total Cash Costs (US$/t)</strong></td>
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<td><strong>Exploration (Expensed)</strong></td>
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<tr>
<td><strong>Operating Cash Flow</strong></td>
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<td>-59.0</td>
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<tr>
<td><strong>Investing Cash Flow</strong></td>
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<td>-144.0</td>
<td>-158.7</td>
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<tr>
<td><strong>Debt Drawdown (repayment)</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>26.4</td>
<td>-26.8</td>
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<tr>
<td><strong>Net Interest</strong></td>
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<td>16.6</td>
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<td>0.0</td>
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<tr>
<td><strong>Other Liabilities</strong></td>
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<td></td>
<td>113</td>
<td>113</td>
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<tr>
<td><strong>Total</strong></td>
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<td>1,118</td>
<td>1,118</td>
<td>1,021</td>
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#### Production Metrics

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<th>2017</th>
<th>2018</th>
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<tr>
<td><strong>Total Cash Costs (US$/t)</strong></td>
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<tr>
<td><strong>Balama Graphite</strong></td>
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<td><strong>Graphite Production (kt)</strong></td>
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<td><strong>Graphite Price (140 mesh flakes)</strong></td>
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<td><strong>Changes in input variables</strong></td>
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<tr>
<td><strong>Graphite price (140 mesh flakes)</strong></td>
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<tr>
<td><strong>Graphite price fines</strong></td>
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<tr>
<td><strong>Discount Rate (NPV @ 12%)</strong></td>
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#### Assumptions

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<th>2016e</th>
<th>2017e</th>
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<tr>
<td><strong>W/Avg Graphite Price (US$/t)</strong></td>
<td>0.73</td>
<td>0.75</td>
<td>0.76</td>
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<td><strong>A/DUSD</strong></td>
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#### Reserves & Resources

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<tr>
<th>Description</th>
<th>2015a</th>
<th>2016a</th>
<th>2017a</th>
<th>2018a</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>1,321</td>
<td>1,118</td>
<td>1,118</td>
<td>1,021</td>
</tr>
</tbody>
</table>

#### Exploration & Projects

<table>
<thead>
<tr>
<th>Description</th>
<th>2015a</th>
<th>2016a</th>
<th>2017a</th>
<th>2018a</th>
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</thead>
<tbody>
<tr>
<td><strong>NPAT</strong></td>
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<td>0.0</td>
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<tr>
<td><strong>NPAT (reported)</strong></td>
<td>-3.5</td>
<td>-12.1</td>
<td>-78.1</td>
<td>-1.0</td>
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</table>

#### Company Description

Syrah Resources (SYR:ASX) is an Australian based mineral development company whose primary project is the world class Balama graphite project located in Northern Mozambique. The company recently completed a DFS which demonstrates the viability of a >40 year, >350ktpa graphite operation. Production is estimated to commence in early 2017. SYR is also advancing its 25-50ktpa spherical graphite development project.

#### Profit & Loss (A$m)

- **Revenue:** 0.0 0.0 0.0 277.4
- **Operating Costs:** 0.0 0.0 36.6 142.0
- **Royalties:** 0.0 0.0 8.3 8.4
- **Corporate & O'heads:** 8.2 14.9 18.2 18.6
- **EBITDA:** -7.9 -12.1 -56.7 110.9
- **Dep’n:** 0.3 0.0 20.1 104.8
- **EBIT:** -8.2 -12.1 -76.8 6.1
- **Net Interest:** 0.2 2.8 1.9 1.1
- **Tax:** 0.2 0.0 0.0 5.2
- **NPAT:** -8.4 -12.1 -78.1 -1.0
- **Non-recurring:** 4.8 0.0 0.0 0.0
- **NPAT (reported):** -3.5 -12.1 -78.1 -0.0

#### Cash Flow (A$m)

- **Cash Receipts:** 0.0 0.0 0.0 277.4
- **Cash paid to suppliers & emp.:** -3.9 -14.9 -54.8 -167.3
- **Tax paid:** 0.0 0.0 0.0 5.2
- **Net Interest:** 0.2 2.8 1.9 0.1
- **Operating Cash Flow:** -3.7 -12.0 -53.0 105.0
- **Investing Cash Flow:** -15.9 -144.0 -158.7 -144.0
- **Debt Drawdown (repayment):** 0.0 0.0 26.4 -26.8
- **Share capital:** 211.0 194.3 0.0 0.0
- **Dividends:** 0.0 0.0 0.0 0.0
- **Financing Expenses:** -8.9 0.0 0.0
- **Net Cash Flow:** 202.1 188.8 26.4 -26.8
- **Opening Cash:** 0.0 191.8 215.4 30.2
- **18.2 -52.8 -185.3 63.8
- **Closing Cash:** 191.8 215.4 30.2 94.0

#### Balance Sheet (A$m)

- **Cash:** 191.8 215.4 30.2 94.0
- **Cash + S/Term Deposits:** 191.8 215.4 30.2 94.0
- **Other current assets:** 12.5 10.9 54.1
- **Current Assets:** 202.2 227.9 40.7 148.5
- **Property, Plant & Equip.:** 3.8 18.1 30.0 20.9
- **Exploration & Develop.:** 48.7 49.1 64.1 64.7
- **Other Non-current Assets:** 17.7 146.8 253.6 171.6
- **Payables:** 0.0 0.3 0.3 27.8
- **Short Term debt:** 0.0 13.4 13.4 0.0
- **Long Term Debt:** 0.0 0.0 0.0
- **Other Liabilities:** 7.8 5.1 7.1 9.5
- **Total Liabilities:** 254.5 446.8 366.7 366.8
- **Shareholders Funds:** 296.7 491.1 491.1 491.1
- **Reserves:** 1.8 1.8 1.8 1.8
- **Retained Earnings:** -33.9 -46.1 -124.2 -124.2
- **Total Equity:** 246.8 446.8 366.7 366.8

## 20 November 2016
Appendix I – ASX Listed Graphite Companies
Black Rock Mining Ltd (BKT: ASX)

(BKT: ASX : A$0.15 | M/Cap: A$48M | Not Rated)

We do not provide a rating, estimates, or a target price for Black Rock Mining.

Overview

- BKT’s primary asset is the Mahenge flake graphite project, located in the Morongo region of southern Tanzania. The project consists of 4 tenements, covering an area of 533km², with over 14,000m of RC and 3,000m of diamond drilling occurring since 2015 to define a maiden JORC resource in Feb’16 that has since been updated to 162.5Mt @ 7.8% TGC for 12.7Mt of Graphite.
- The project is proximal to power infrastructure and the major TAZARA railway to the major port at Dar es Salaam.

Geology: Graphite mineralisation at the Mahenge Project is described as schist-hosted flaky graphite. The mineralization is hosted within upper amphibolite facies gneiss of the Mozambique Mobile Belt.

Resources/Reserves: With a deposit totalling 163Mt @ 7.8% for 12.7Mt Mahenge is one of the top 5 graphite deposits by size globally. ~75% of resources are contained within the north/south-trending Ulanzi deposit. ~2km away is the Cascades deposit of which a 30-hole drill program to ~12m deep indicates higher grades than those at
Ulanzi. A drilling program is expected to be completed over Q1’17 to augment the current 12.3Mt @ 9.5% for 1.2Mt Inferred resource estimate.

**Metallurgy:** Testwork conducted in Jul’16 on a primary composite from Ulanzi and Epanko North indicated that flake purities of ~99% could be obtained on material <75μm (80% of feed). According to company reports, these purities could be obtained across oxide and fresh portions with early indications the oxide from the Cascades deposit displays similar characteristics.

In Sep’16 the company indicated that 99.98% TGC spherical graphite could be manufactured from Mahenge feed with current testwork aimed at bypassing conventional acid purification.

Samples have been received by end-users in the battery anode space for evaluation along with development work based on the indications of Mahenge’s product suitability to expandable graphite applications.

**Figure 90: Mahenge Flake Size distribution**

<table>
<thead>
<tr>
<th>Screen Size</th>
<th>Mass %</th>
<th>TGC Assay</th>
<th>Cumulative Weight</th>
<th>Weighted Average Purity TGC%</th>
</tr>
</thead>
<tbody>
<tr>
<td>+300 μm</td>
<td>17.4</td>
<td>98.8</td>
<td>17.4</td>
<td>98.8</td>
</tr>
<tr>
<td>+180 μm</td>
<td>34.8</td>
<td>99.2</td>
<td>52.2</td>
<td>99.1</td>
</tr>
<tr>
<td>+150 μm</td>
<td>10.4</td>
<td>99.0</td>
<td>62.7</td>
<td>99.1</td>
</tr>
<tr>
<td>+106 μm</td>
<td>14.7</td>
<td>98.8</td>
<td>77.4</td>
<td>99.0</td>
</tr>
<tr>
<td>+75 μm</td>
<td>11.1</td>
<td>99.4</td>
<td>88.5</td>
<td>99.1</td>
</tr>
<tr>
<td>+25 μm</td>
<td>11.1</td>
<td>98.6</td>
<td>99.6</td>
<td>99.0</td>
</tr>
<tr>
<td>-25 μm</td>
<td>0.4</td>
<td>95.5</td>
<td>99.9</td>
<td>99.0</td>
</tr>
</tbody>
</table>

Source: Company reports

**Feasibility, development & production:** The company completed a scoping study in Mar’16 calling for a 52ktpa project with an initial mine life of 25 years and capital expenditure of US$57M. Base case assumptions were for a 500ktpa capacity plant with cash costs of US$450/t. The company expects to complete a PFS in DecQ’16 followed by a DFS in Q2’17.
Figure 91: Mahenge project timetable

Source: Company reports

Product marketing and offtake: BKT is targeting first offtake negotiations by the end of 2016. Bulk 99.2% TGC concentrates have been distributed to test facilities and end users for test work.

An analyst has not visited the properties held by Black Rock Mining Limited
Hexagon Resources Ltd (HXG:ASX)

(HXG: ASX : A$0.27 | M/Cap: A$65M | Not Rated)

We do not provide a rating, estimates, or a target price for Hexagon Resources.

Overview
- HXG’s (formerly Lamboo Resources) primary asset is the McIntosh flake graphite project located in the Kimberley region of Western Australia, approximately 100km north of Halls Creek. The project was acquired in 2012, and covers an area of 330km². The tenements are owned 100% by HXG.
- The project area is located ~295km by all-weather road from the deep water port of Wyndham. The port features ship-loading infrastructure, and numerous bulk storage options.
- HXG is currently completing feasibility studies to assess the development of the McIntosh project.

Geology: The McIntosh Project graphite schist horizons occur in the high-grade metamorphic terrain of the Halls Creek Mobile Zone of Western Australia. The host stratigraphy is the Tickalara Metamorphics which extend for approximately 130 km along the western side of a major fault line. HXG has identified graphite schist horizons and accompanying aerial EM anomalies over a strike length in excess of 15 km within the granted tenements, with outcropping graphite mineralisation identified a number of deposits. HXG have noted the potential for another 35 km strike length of graphite schist in EL applications.

Resources/Reserves: HXG reported updated Resources for the McIntosh project in Jan’16, with the project now hosting Indicated (46%) and Inferred (54%) Resources of 17.2Mt at a grade of 4.63% TGC across four main deposits. The largest of the...
resource positions is at Emperor, which hosts Indicated and Inferred resources 8.4Mt at 4.6% TGC. There are currently no defined Reserves at the project.

Flake-size analysis of the McIntosh Resource has shown that 44.5% lies within the Jumbo and Large flake categories.

**Figure 94: McIntosh Flake Size distribution**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Microns (µm)</th>
<th>Mesh Size (#)</th>
<th>% in interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very fine</td>
<td>&lt;75</td>
<td>-200</td>
<td>1.4</td>
</tr>
<tr>
<td>Fine</td>
<td>75-106</td>
<td>-140 to +200</td>
<td>10.5</td>
</tr>
<tr>
<td>Small</td>
<td>106-150</td>
<td>-100 to +140</td>
<td>27</td>
</tr>
<tr>
<td>Medium</td>
<td>150-180</td>
<td>-80 to +100</td>
<td>16.7</td>
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<tr>
<td>Large</td>
<td>180-300</td>
<td>-48 to +80</td>
<td>35.9</td>
</tr>
<tr>
<td>Extra Large 'Jumbo'</td>
<td>&gt;300</td>
<td>+48</td>
<td>8.6</td>
</tr>
</tbody>
</table>

Source: Company reports

**Metallurgy:** HXG has reported that bulk scale test work has shown the flake graphite at McIntosh to have few deleterious inclusions, allowing high purity concentrates to be produced via a simple crush/grind/float process. HXG reported that concentrates with grades up to 99% TGC can be produced, thereby avoiding chemical or thermal purification.

HXG has also reported that bulk scale flotation test work shows that high purity concentrates can be produced across the entire flake size range.

**Feasibility, development & production:** HXG commenced a PFS for McIntosh in Mar’16, which the company currently expects to be completed in Q1’17. A DFS is scheduled to then be completed by mid’17.

The company has not reported potential project parameters.

**Figure 95: McIntosh project timetable**

**Product marketing and off-take:** HXG reported that it has prepared a bulk sample from the McIntosh project to be sent to potential offtake parties.

*An analyst has not visited the properties held by Hexagon Resources.*
Kibaran Resources Ltd (KNL:ASX)

(\text{KNL: ASX : A$0.19 | M/Cap: A$44M | Not Rated})

We do not provide a rating, estimates, or a target price for Kibaran Resources.

Overview

- KNL’s key project is the Epanko flake graphite project, located ~450km SW of the Tanzanian capital and port city of Dar es Salaam. The project features a granted mining licence covering a total area of ~10km$^2$, and lies within proximity to other major infrastructure including grid power and rail. KNL completed a BFS on Epanko in 2015 which demonstrated the viability of a 40ktpa open pit project. KNL is currently finalising debt funding for the project, supported by various binding offtake agreements. A Scoping Study for the development of a 15ktpa spherical graphite plant was completed in Aug’15.

- KNL also has a 100% interest in the Merelani-Arusha graphite project, located 55km SE of the Arusha, in NE Tanzania.

Geology: Graphite mineralisation at the Epanko Project is hosted within a quartz–feldspar-carbonate graphitic schist, part of a Neoproterozoic metasediment package, including marble and gneissic units. Two zones of graphitic schist have been mapped, named the East Zone and the West Zone.

Resources/Reserves: Epanko hosts total Resources of 23.3Mt at 9.4% TGC, with 62% in the Measured and Indicated category. KNL BFS for Epanko estimated total reserves of 10.9Mt at 8.6% TGC. Total Resources at the Merelani-Arusha project stand at 17.2Mt at 6.5% TGC.

Flake size analysis completed in 2015 showed a clear bias of flake size distribution to larger size fractions, with 55% in the Jumbo and Large categories.
Metallurgy: Test work has been reported to show Epanko graphite to have high purity levels, with an average carbon grade of 96% across all size fractions. The proposed process flow sheet (as per BFS) comprises two-stage crushing, grinding and four-stage flotation to produce a graphite concentrate.

Feasibility, development & production: KNL completed a BFS for Epanko in Jul’15, which demonstrated the viability of a 25-year, 440-500ktpa open pit mining and flotation operation to produce 40ktpa of graphite concentrate. Capital costs for the project were estimated at US$77.5M, with estimated operating costs of US$570/tonne of product FOB.

KNL is advancing project financing with indicative (subject to completion of due diligence and other milestones) debt funding proposals having been received from the German bank KfW-Ipex Bank (US$40M, supported by German Government Loan Guarantee) and the South African bank Nedbank (US$30M). The company anticipates completing this process in early 2017.

KNL has subsequently commenced feasibility studies on the development of a spherical graphite production facility in Tanzania, to be supported by the potential expansion of flake graphite production from Epanko to 60ktpa.

Product marketing and off-take: KNL has binding offtake agreements with the following groups:

- ThyssenKrup - refractory market - 20ktpa
- EGT (European Trader) - expandable graphite market - 10ktpa
- Sojitz - battery anode materials - 14ktpa

An analyst has not visited the properties held by Kibaran Resources.
Magnis Resources Ltd (MNS:ASX)

(MNS: ASX : A$0.73 | M/Cap: A$326M | Not Rated)

We do not provide a rating, estimates, or a target price for Magnis Resources.

Overview

- MNS’s primary asset is the Nachu natural flake graphite project, located in south-eastern Tanzania. MNS own 95% of the project with the national government retaining 5% free carry equity. The company (then known as Uranex Limited) first discovered the deposit in 2013 with trench sampling, EM survey and ground mapping leading to a maiden resource (156Mt at 5.2% for 8.1Mt) being declared in Nov’14.
- The tenement areas of ~200m² are situated ~220km by sealed road from the regional centre of Mtwara, which hosts a population of ~80,000. Mtwara has an underutilised deepwater port (serviceable by oceangoing container vessels) and is serviced by an airport.
- Since a maiden resource was declared in 2014, MNS progressed development work leading to a bankable feasibility study (BFS) being released in March 2016. The BFS is based on a 5.0Mtpa processing plant using a conventional crush float screen flowsheet for the production of ~240ktpa of graphite over a variety of product sizes.

Geology:
Proterozoic basement rocks of the Mozambique Mobile Belt system which comprise principally metamorphic rocks ranging from schist to gneisses including marbles, amphibolite, graphitic schist, mica and kyanite schist, acid gneisses, hornblende, biotite and garnet gneisses, quartzite, granulite, and pegmatite veins. Within the project area, there are widespread occurrences of outcropping Graphite, which typically has grades in the range of 5-10% Graphitic Carbon.

Resources/Reserves:
The maiden resource that was completed in Nov’14 was updated during Feb’16 to 2012 JORC standards with Nachu now containing 174Mt at 5.4% Graphitic Carbon at a 3% cut-off. 71% of the resource is contained within the
Measures or Indicated categories. The Mineral Resource is split into 5 deposits with the mineralisation predominately hosted in graphitic schist at or near surface. The orientation of the Mineral resource model follows shallow dipping limbs of opening folding within the deposit.

An Ore Reserve estimate has been completed with Proven and Probable Reserves of 76Mt at 4.8% for 3.6 Mt which supports an initial 15-year mine life at ~220ktpa of concentrate production.

**Metallurgy:** Flotation testwork indicates over 40% of concentrate product reports to the premium Super Jumbo fraction at purity of 97% with the remaining finer flakes at a purity of >99%.

X-ray analysis of the Nachu concentrate indicates that most impurities are on crystal surfaces. The importance of this high purity of the finer flake offers cost savings to downstream processing such as spherical graphite production for the lithium ion battery market.

Testwork by MNS indicates that high purity (99.99% TGC) spherical graphite can be produced without thermal purification (hydrofluoric acid leaching). In addition testwork has indicated the potential for the use of Nachu graphite as battery anode feedstock.

**Feasibility, development & production:** MNS is a development-ready project with the final phases of front end engineering now being completed. The BFS indicated the project would require pre-production capital of US$269M with operating costs of US$559/t (FOB) for the Life of Mine.
Product marketing and off-take: MNS signed an MOU with South Korean industry leader POSCO E&C in October 2015 outlining the basis for co-operation on the procurement of funding and construction of the Nachu Graphite Project.

An analyst has not visited the properties held by Magnis Resources Ltd.
Metals of Africa Ltd (MTA:ASX)

(MTA: ASX: A$0.10 | M/Cap: A$40M | Not Rated)

We do not provide a rating, estimates, or a target price for Metals of Africa.

Overview

- MTA is a Mozambiquan-focused graphite explorer and developer. Its main projects are the 100%-owned Montepuez and Balama central graphite projects, located in the Cabo del Gado province of Mozambique. The project areas is situated 260km (~210km of sealed roads) from the port city of Pemba.
- MTA is undertaking feasibility studies for the development of the Montepuez project.

Geology:

Graphite-bearing mica schist and gneiss are found in different tectonic complexes in the Cabo Delgado Province of Mozambique. Local geology comprises dolerite, meta-sediments, amphibolites with graphicitic metasediments and graphicitic schists. The deposit is disseminated with graphite dispersed within gneiss.

Resources/Reserves:

The Montepuez project hosts total JORC compliant resources of 61.6MT at 10.3% TGC, with ~45% of the total in the Indicated category. The resources are hosted within three main deposits at Lion, Buffalo and Elephant. Flake-size analysis has revealed 28% in the Jumbo and Large flake size fractions.

At Central Balama, graphite mineralisation is hosted within two main deposits (Lennox and Byron), with total Indicated and Inferred Resources 16.3Mt at 10.4% TGC. Balama Central displays a more favourable flake size distribution versus Montepuez, with 51% in the coarser size fractions.
Feasibility, development & production: MTA completed a Concept Study for the Montepuez project in Feb’16, which assessed a 60-year, 1.2Mtpa open pit project producing 100ktpa of graphite concentrate. The concept study included the development of a spherical graphite plant which would use feedstock from the concentrator to produce 25ktpa of coated spheroidal graphite. Total capital costs were estimated at US$166M (including the spherical plant at US$80M), with estimated operating costs of US$300/t for large flake graphite products and US$3,500/t for coated spherical graphite. MTA anticipate the completion of a DFS in Dec’16.

Product marketing and off-take: n/a

An analyst has not visited the properties held by Metals of Africa.
Volt Resources Ltd (VRC:ASX)

(VRC:ASX:A$0.07 | M/Cap: A$69M | Not Rated)

We do not provide a rating, estimates, or a target price for Volt Resources.

Overview

- VRC’s primary asset is the Namangale flake graphite project, located in south-eastern Tanzania. The project consists of 11 tenements, covering an area of ~2,000km², with the 100% interest in the project acquired in mid’15. The tenements are subject to a 3% royalty on production to the previous holders, which can be reduced to 1.5%.

- The tenement areas are situated ~140km by sealed road from the regional centre of Mtwara, which hosts a population of ~80,000. Mtwara has an underutilised deepwater port (serviceable by oceangoing container vessels), and is serviced by an airport. Grid-based electricity (gas-fired power station) is available in Mtwara.

- VRC is currently undertaking feasibility studies to assess the development of the Namangale graphite project.

Geology:
Proterozoic basement rocks of the Mozambique Mobile Belt system which principally comprise metamorphic rocks ranging from schist to gneisses including marbles, amphibolite, graphitic schist, mica and kyanite schist, acid gneisses, hornblende, biotite and garnet gneisses, quartzite, granulite, and pegmatite veins. Within the project area there are widespread occurrences of outcropping Graphite, which typically has grades in the range of 5-10% Graphitic Carbon.
Resources/Reserves: The key deposits within the project area are the Namangale North and Namangale South deposits, located ~35km apart on a north-easterly trend. Total Measured, Indicated (33%) and Inferred (62%) JORC-compliant resources were last updated in Oct’16 to 446Mt at 5.01% TGC, defined to a depth of <100m. Namangale North hosts a majority of the resource with +86% of the total.

Preliminary flake-size analysis conducted in Jul’16 on near-surface (oxide) bulk samples from various test pits revealed a graphite flake size distribution heavily skewed to larger flake, with ~57% in super jumbo (+500um) and jumbo (+300um) flake sizes, and 81% including large (+180um) flake size.

Figure 108: Namangale Flake Size distribution*

Metallurgy: Subsequent test work was reported to have shown that graphite concentrates can achieve a +99% purity using milling and flotation, with no chemical leaching.

Feasibility, development & production: VRC’s most recent reported project timetable calls for the completion of a PFS in Q4’16, with off-take agreements scheduled to be finalised during Mar/Q’17, ahead of the completion of a BFS by Jun/Q’17.

No proposed project parameters have been reported and are expected to be released with the project’s PFS.
**Product marketing and off-take:** VRC has signed three Offtake MoU’s with various Chinese-end users totaling 100kt. These include:

- 60ktpa with OptimumNano
- 20ktpa with Huzhou Chuangya
- 20ktpa with Shenzhen Sinuo

Product samples have been sent to potential end-users (including Groups subject to MoU’s) for test work in North America, Europe and China.

*An analyst has not visited the properties held by Volt Resources.*
Appendix: Important Disclosures

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Investment Recommendation
Date and time of first dissemination: November 20, 2016, 14:59 ET
Date and time of production: November 20, 2016, 15:28 ET

Target Price / Valuation Methodology:
Syrah Resources Limited - SYR

Our target price is derived using a diluted net asset valuation approach, comprising our NPV12% for operating assets and projects, a nominal valuation ascribed for other projects and resources, net of corporate and other adjustments.

Risks to achieving Target Price / Valuation:
Syrah Resources Limited - SYR

The key investment risks for SYR include: Technical Risk: There remain few comparative graphite prospects in the world similar to the robust grades and nature of deposit representative to SYR’s project. Understanding all elements of the technical risk involved in mining and processing graphite have been determined independently by third parties and are naturally inherent to risk. Financing Risk: The ability for SYR to fund the development of Balama should be considered a key investment risk. Whilst we believe that SYR will comfortably secure debt financing, markets could become conducive to securing the required funds to complete construction of the project. Marketing and Off take Risk: Graphite is not traded on open exchanges such as the LME and therefore markets and pricing are generally set by off-take agreements between supplier and trader and or end customer. We expect that SYR will establish multiple off-take agreements with traders and end-users. Establishing off-take agreements for economic quantities and prices is a key risk to SYR and our valuation and recommendation. Commodity price risk: All revenues derived from SYR will be subject to the contract prices received on the graphite product. Graphite is not a publically traded commodity; therefore, SYR is subject to commodity price risk via contract pricing that is agreed upon between SYR and its customer(s). We have factored in our modelling five different contract prices derived from the different mesh quality of graphite accepted into the market. Capital Expenditure Risk: Capital costs could come under pressure and exceed budget/or exhaust available funding before completion. This could result in a number of major impacts at the project and company level. Management and labour risk: An experienced and skilled management team is essential to the successful development of Balama to take it into production and operations of the project. We view the current management team as complementary to the project; however, any additions or withdrawals to the current team could bring risk to the project.

Distribution of Ratings:

Global Stock Ratings (as of 11/20/16)

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*Total includes stocks that are Under Review

Canaccord Genuity Ratings System

BUY: The stock is expected to generate risk-adjusted returns of over 10% during the next 12 months.
**HOLD:** The stock is expected to generate risk-adjusted returns of 0-10% during the next 12 months.

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