Black Rock Mining BKT.AX

The most compelling graphite project

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Executive summary

Black Rock Mining (BKT.AX) is developing the Mahenge Graphite Project in south-eastern Tanzania. The company acquired the prospecting licenses in 2014, and completed a Pre-Feasibility Study (PFS) in April 2017, just as the current management team were being installed. The Definitive Feasibility Study (DFS) was published in October 2018.

Unjustifiably cheap. The project has a post-tax, unlevered NPV_{10} of US$895m, and an IRR of ~43%, both net of the Tanzanian government's 16% stake. The NPV is ~7x the initial capex requirement of US$115m. Despite these strong metrics, Black Rock's market capitalisation is less than 2% of NPV. Assuming total initial capital required of US$140m, 80:20 debt-to-equity funding, equity being issued at A$0.10 to A$0.15 per share, and a fair EV valuation, 12 months from now, of 30-50% of NPV, then Black Rock's EV could be US$269m to US$448m. **This equates to a valuation of A$0.16-0.40 per share, ~4-11x the current share price.**

Opportunity knocks: In a sample of eight ASX-listed African graphite developers, there is only a US$16m difference in market capitalisation between the largest and smallest. The market is not differentiating between projects, meaning it has so far failed to take advantage of the opportunity in Black Rock.

Compelling project, with substantial cash flows: The DFS envisages a three-phase project ultimately producing 240,000 tpa high-grade graphite. When completed, Black Rock is likely to be the 2nd largest miner of natural flake graphite in the world ex-China. Based on DFS figures of a US$1,301/t basket selling price, and US$401/t C1 costs, annual EBITDA will be around US$216m, equating to an EBITDA margin of 69%. The project is expected to generate US$313m in EBITDA over the first three years. This strong cash generation is expected to support a high-level of debt financing, limiting the dilution to existing shareholders.

Risk mitigation a key part of the DFS: The DFS was compiled after more than 25,000 man-hours of work. It incorporates the results from a large-scale pilot plant, improvements in the plant design over 15 iterations, a decision to use dry-stacking, development of an ultra-high-grade graphite product, logistics tests on the Tanzania Zambia Railway Authority (TAZARA) railway, customer testing of Mahenge graphite products, and operational readiness work designed to provide a smooth ramp-up, and to address concentrate transportation. Management's approach has been to reduce as many risks as possible.

Significant advantages, both geological…: Mahenge hosts the 2nd largest graphite reserve, and the 4th largest JORC-compliant graphite resource globally. The resource is biased towards larger flake sizes. Strip ratios are low. Impurities are at a minimum. Black Rock has demonstrated the ability to produce amongst the highest quality products globally, without chemical interference. This means lower capital and operating costs, less environmental impact, and a differentiated high-value product. The use of dry-stacking means there is no need for wet tailings dams, and the risks they impose. There is no need to dispose of used hydrofluoric acid, which can be difficult.

…And geographical. Access to key infrastructure is excellent, and provides the Mahenge project with a long-term sustainable cost advantage. This includes the TAZARA railway line, which feeds directly into the port of Dar es Salaam. The port is an internationally vital trade link serving seven countries. It handles 95% of Tanzania's trade cargoes. There is frequent shipping to key markets in Asia. The Tanzania Electric Supply Co Ltd (TANESCO) will provide grid power. Excellent logistics ensures there is no need for unsafe several hundred-kilometre truck journeys, no uncertainty as to available port capacity, no barging and reloading, and no need for expensive diesel generators on site.

Phases 1 and 2 are already sold out: Critically, Black Rock spent the past year demonstrating a path to market. A large-scale pilot plant, an order of magnitude larger than the next, enabled delivery of certified samples to customers and laboratories. Feedback has been hugely positive. Three offtake agreements have been signed for a combined 205,000 tpa (in the third year), representing 85% of planned production, and an astonishing ~23% of 2017 global natural graphite demand. Notably, two of the agreements – those with Heilongjiang Bohao and Taihe Soar – are believed to be the two largest offtake agreements signed by any graphite company, either in production or development. The agreements cover a variety of end-use applications including expandable graphite, and energy storage. The agreements will enable Black Rock to establish branding in the energy storage market. The agreements are a testament to Black Rock's notion that Mahenge graphite has unique properties that make it highly desirable to end-users.

Graphite demand growth accelerating: The births of the electric vehicle and energy storage systems markets have transformed the graphite market from a mature one, to one with rapid growth prospects. Both these industries are embryonic in nature, and growing at a terrific pace. There is also huge pent-up demand for expandable graphite for use in the foil and fire retardant segments. Demand for fire retardants is being driven by technological developments and more stringent safety standards in automotive, aerospace, and in building and construction after a number of large fires. Demand for natural flake graphite (excluding amorphous graphite) is expected to more than double over the next decade from ~630,000 tpa in 2017 to ~1.4m tpa in 2027. Even before accounting for any further curtailment in Chinese supply, the world could need the equivalent of three "Mahenges" to meet demand over the next decade.

Chinese supply is under pressure: Supplies of large flake graphite from China are dwindling as resources are depleted. Combined with strong growth in the expandable market, China is now short of large flake graphite, and has started importing +50 mesh material from East Africa. Environmental controls, mainly aimed at restricting the use of acids in graphite beneficiation, are being more strictly enforced. Over time, purer graphite sources are likely to attract premium prices.

Outlook for prices is excellent: The combination of new industries experiencing peak demand growth, and challenged supply out of China, the world's largest producer, suggest a strong outlook for graphite prices. Experience from the iron ore and coal markets in the mid-2000s, suggests that increasing Chinese imports (or decreasing exports), may have a significantly positive impact on market prices. As a result, there is an immediate opportunity in large flake graphite, with new suppliers of high-quality materials able to sell into a rapid growth market that is seeing shortages.

Not all graphite is created equal; market segmentation is key: The market can be broadly divided into three categories;

Large flake: The market for 80 mesh and larger has massive pent-up demand, and is supply constrained. Changes in building regulations and challenged Chinese supply suggest an increasingly tight market with strong price outcomes. There is a step change in pricing above 98% purity and 80 mesh.

Battery grade: Typically, 150 to 80 mesh. The market has been demand constrained, though forecasts of exponential growth in the electric vehicle space suggest this will change quickly. High-grades, and spheronizing performance are differentiating factors. ‘Dirty’ concentrates containing impurities such as vanadium and others, will attract lower prices, and are at risk of stricter environmental controls in China. Selling directly to larger battery makers, where qualification can take years, is difficult. Establishing channels is critical.

Refractory grade: Generally, smaller flakes and lower grades, used in steel making and other metallurgy. Lower prices, and essentially the market of last resort for a graphite company. (Some high-end applications require premium product).

Black Rock has unearthed significant demand for large flake, high-purity graphite. The company has also established channels for the battery sector through offtakes with Heilongjiang Bohao (which supplies the German automotive industry), and Qingdao Fujin Graphite (anodes for consumer electronics). Black Rock’s initial battery tests were conducted at a US-based, ISO-compliant laboratory. Battery cells produced from surface coated, spheronized natural flake from Ulanzi, exceeded 300 cycles, with a 94% recharge rate. The cells also had flatter performance curves than an existing commercial battery, indicating potential for longer battery life. This is a significant result that bodes well for future development.

Few new projects are of global scale. The combination of strong demand, and challenged Chinese supply, has motivated a plethora of new projects in East Africa. Most of these are relatively small scale. The obvious hurdle many will face is completing a detailed DFS study that will be necessary to secure funding. Black Rock has set the bar in this regard. Further, many projects seem focused on the electric vehicle revolution. Though exciting, the market is currently small, and qualification periods, as for anything in the automotive sector, are long. Companies focusing on this space will need to find other markets to sustain themselves through this qualification period. It seems likely that over the next few years, supply from East Africa will become dominated by two large producers in Syrah Resources (SYR.AX), and Black Rock, with a number of smaller players serving niche markets.

Tanzania: Tanzania’s reset of its legislative code in 2017/18 negatively impacted risk perceptions, and the capacity to raise debt finance from traditional sources, and hit share prices. Yet over the past year, Tanzania has made great strides. Companies report that engagement with the government has been positive, and that projects that contribute positively to Tanzania’s development are being approved. **Black Rock expects its mining licenses to be approved in early-2019.** The country has a fast-growing economy, benefits from a young and educated workforce, and there is rapid investment in infrastructure. The government’s vision is for Tanzania to be semi-industrialised (manufacturing represents 40% of GDP) by 2025.

In summary, the Mahenge graphite project has been thoroughly conceived. It boasts significant and sustainable natural advantages, it stands to benefit Tanzania directly through shared ownership, upgraded infrastructure, and increased employment, and it looks like coming on stream into a period of peak demand growth. Consequently, it also seems likely to reward shareholders.

Simon Francis   January 2019

Key financial data

Figure 1: Shareholding structure

ASX code		**BKT**
Share price, 16 January, 2019	A$/share	0.038
Shares on issue	Millions	521.8
Options	Millions	63.9
Performance rights	Millions	1.0
Fully diluted shares	Millions	586.7
Fully diluted market capitalisation	A$ millions	22.3
Cash on hand, 30 September, 2018	A$ millions	2.7
Top 20 shareholders		**~50%**
Copulos Group		21.6%

Source: Black Rock Mining

Key Management:

John de Vries, CEO and Managing Director: Mining Engineer with over 35 years' experience in mine development and operations. Previously, General Manager Technical Services with St Barbara and integral in the 2014 turnaround. John has held positions at BHP Ni West, and was Global Business Manager, Advanced Mining Solutions with Orica Mining Services. John's geographic experience includes Africa, the Pacific, the FSU, North America and South America.

Richard Crookes, Non-Executive Chairman: A geologist with over 30 years' executive experience in the resources and investments industry. He is currently an Investment Director of EMR Capital and was formerly a Director of Macquarie Bank's Metals Energy Capital Division and was Chief Geologist with Ernest Henry Mining.

Raymond Hekima, Vice President – Corporate (Tanzania): Holding qualifications in Environmental Sciences and Management with over 13 years' experience with Government and Corporate sectors. Raymond is responsible for overall business and operations in Tanzania and manages relationships and interactions with, National Government, Local Government, NGO's and Community relations.

Figure 2: Black Rock Mining share price chart; advances in the project, but tough year in junior mining

Source: ASX

Snapshot of the DFS

- The DFS boasts a post-tax NPV_{10} of US$895m and an IRR of 43%, net of the government's stake, and based on capacity of 240,000 tpa in three phases coming on stream over the next six years
- Positive customer feedback, and a substantial resource, suggest the project will need to be accelerated, and perhaps expanded
- Pricing assumptions are conservative; internal studies, based on customer feedback, suggest prices could be US$190/t higher than assumed in the DFS, potentially boosting the NPV_{10} to US$1.1bn

The Mahenge graphite project is located in south-eastern Tanzania, about 300 km southwest of Tanzania's largest city, Dar es Salaam, or about 450 km by road, or road and rail via the town of Ifakara. It is 250 km north of Mozambique. The project is held under four prospecting licenses, which were acquired by Black Rock in 2014. A Pre-Feasibility Study (PFS) was completed in April 2017, just as the current management team, was being installed. The DFS was completed in October 2018.

The DFS was compiled after more than 25,000 man-hours of work. It incorporates the results from the pilot plant, various improvements in the plant design, development of an ultra-high-grade graphite product, logistics tests on the TAZARA railway, and customer testing of Mahenge graphite products. **The study is of an incredibly high standard, and one to which financiers will probably expect other companies to adhere.**

The project has been led by Mr John de Vries, Black Rock's CEO. Mr de Vries seems ideally suited to the task of engineering the Mahenge project. A mining engineer with 30 years' experience, Mr de Vries was General Manager Technical Services for St Barbara from 2011 to 2015 where he was responsible for strategic mine planning, productivity improvements and delivery of major project studies. In prior roles, he was responsible for mine planning and optimisation at AMC Consultants, Orica Mining Services and BHP Billiton NiWest.

The DFS envisages production of 240,000 tpa, in three phases, with an average graphite grade of 97.5% LOI (loss on ignition – a test used in analytical chemistry to determine organic carbon content). Construction of Phase 1 is expected to commence in 2Q19, with first production scheduled for 4Q20. Phases 2 and 3 are expected to start two years and four years after Phase 1. The DFS is based on Black Rock reaching full capacity of 240,000 tpa by year 5, which is 2024. **Given the strong customer response and the offtake agreements signed over the past few weeks, this timetable is likely to be accelerated.** There is also scope to increase the size of the project by adding one or two additional lines.

Strong financials

The project is expected to generate cumulative EBITDA of US$313m over the first three years. **Longer-term, using a basket selling price of US$1,301/t and C1 costs of US$401/t, annual EBITDA will be around US$216m. This equates to an EBITDA margin of 69%.** Not surprisingly, the project boasts compelling financial metrics. The post-tax NPV_{10} is US$895m. The IRR is ~43%. Notably the post-tax NPV_{10} to initial capex is ~7x.

Figure 3: Key DFS parameters

Annual production	tpa	240,000
Graphite product	LOI	97.5%
Life of Mine	Years	32
Mine life under Reserve	Years	25
Ore Reserves	Tonnes, m	70
Ore Reserves	Grade, TGC	8.5%
Resources	Tonnes, m	212
Resources	Grade, TGC	7.8%
Pre-production capex	US$ m	115.0
Capex for Phase 2	US$ m	69.5
Capex for Phase 3	US$ m	84.2
Operating costs - ex-mine	US$/t	321
Operating costs - FOB Dar es Salaam	US$/t	397
Brook Hunt, C1 costs	US$/t	401
Basket selling price, FOB Dar es Salaam	US$/t	1,301
Cumulative EBITDA first 3 years	US$ m	313
NPV 10, post-tax	US$ m	895
NPV 8, post-tax	US$ m	1,191
IRR		42.8%

Source: Black Rock Mining, DFS, October 2018

Black Rock plans to mine 1.0m tpa of ore per phase of project. Management regards this scale as optimum in balancing the ability to achieve scale economies, whilst limiting the need for larger-scale equipment and impacting the market. The expected mine life is 32 years. Phases 1 and 2 will process ores predominantly from Ulanzi, and Phase 3 will process ores from Cascades. It is expected that in Phase 1, the plant will be fed run-of-mine ores at an average grade of 8.74% total graphite content (TGC), and will recover 93% of this material to produce 83,000 tonnes of graphite products per annum.

Figure 4: Key process plant parameters

Parameter	Units	Stage 1	Stage 2	Stage 3	Total
Commence Operation	Year	1	3	5	
Nominal Mine Life	Years				32
Process Throughput	Tonnes, 000s pa	1,000	1,000	1,000	
LOM Ore Treated	Tonnes, millions	31.0	27.8	26.3	85.1
Average Feed Grade	TGC %	8.2	8.2	8.4	8.3
Recovery	%	93.0	93.0	93.0	93.0
Target Concentrate Grade	LOI %	97.5	97.5	97.5	97.5
Graphite Concentrate Production	Tonnes, millions	2.46	2.21	2.15	6.82

Source: Black Rock Mining, DFS October 2018

Substantial resources

Mahenge hosts the 2nd largest graphite reserve, and the 4th largest JORC-compliant graphite resource globally. Total resources are 212m tonnes at an average grade of 7.8% TGC, containing 16.6m tonnes of graphite. Ore reserves are 70m tonnes at an average grade of 8.5% TGC, hosting ~6.0m tonnes graphite. At the proposed production rate, Black Rock will mine JORC-classified reserves for the first 25 years of the project, only getting into what are today classified as resources in the latter part of the 32-year project. **There is scope to increase the scale of the project, given that less than half of the current resource will be mined over the 32-year mine life.**

Figure 5: Mahenge resources

Location	Category	Resource	TGC, %	Contained graphite
		Tonnes, m		Tonnes, m
Ulanzi	Measured	13.3	8.9	1.2
	Indicated	49.7	8.2	4.1
	Inferred	50.2	8.1	4.1
	Sub-total	**113.3**	**8.2**	**9.3**
Cascade	Measured	12.1	8.3	1
	Indicated	20.8	8.3	1.7
	Inferred	27.3	7.9	2.2
	Sub-total	**60.2**	**8.1**	**4.9**
Epanko	Measured	-	-	-
	Indicated	17.6	6.4	1.1
	Inferred	20.8	5.9	1.2
	Sub-total	**38.4**	**6.1**	**2.3**
Combined	Measured	25.5	8.6	2.2
	Indicated	88.1	7.9	6.9
	Inferred	98.3	7.6	7.4
	Total	**211.9**	**7.8**	**16.6**

Source: Black Rock Mining, DFS October 2018

Low capital costs

Initial capital expenditure for Phase 1 is US$115m, including a 10% contingency. There is an additional US$10m for a grid connection that is a prepayment, and will be refunded over time through reduced tariffs. More than 90% of this capex estimate is based on direct quotes from vendors. Critical plant items were estimated from the pilot plant. Black Rock has partnered with an experienced Chinese engineering company, Yantai Jinyuan Mining Machinery Ltd (Yantai). Yantai has constructed four graphite projects in the past decade, and thus not only brings experience, but also adds credibility to Black Rock's Chinese marketing efforts. Yantai will construct the process plant; keeping the plant assembly to one vendor should reduce risks. Capex for Phases 2 and 3 are US$69.5m, and US$84.2m, and will be funded from cash flows from Phase 1.

The long (32 years) project life at Mahenge is important both in helping to attract debt financing and in spreading upfront capital costs over greater production. The pre-production capex of US$115m compares to project life production of ~6.8m tonnes of graphite. This is only ~US$17/t.

Black Rock has undertaken substantial engineering work over the past 18 months. This should greatly reduce the risk of cost overruns, and unforeseen steps in the final fabrication.

Figure 6: Mahenge graphite project capex

	Phase 1	Phase 2	Phase 3
	US$ m	US$ m	US$ m
Mining	10.4	-	-
Ifakara	1.4	1.0	0.7
Infrastructure	14.3	3.3	4.7
Process plant	50.9	45.3	53.2
Site support	1.8	0.2	0.2
Indirect	9.9	7.0	8.5
Owners costs	15.8	5.2	6.3
Contingency	11.0	7.5	10.5
Grid connection	10.0	-	-
Total	**125.2**	**69.5**	**84.2**

Source: Black Rock Mining, DFS, October 2018

Low operating costs

According to the DFS, Phase 1 operating costs (C1) are US$401/t. Low operating costs reflect:

- The geological combination of high-grade and low life-of-mine strip ratios
- Logistics solutions including the TAZARA railway, the Port of Dar es Salaam, and grid power
- Development, and multiple iterations of, a large-scale pilot plant
- The use of mainly local labour – the expatriate staff footprint being kept to a minimum

Sensitivity to selling prices

Black Rock's price deck has been developed following detailed discussions with potential customers. Graphite is not an exchange-traded commodity. The prices that are publicly available are generally for low-grade refractory materials and are not relevant to Black Rock. Pricing in the premium market is opaque, with contracts usually commercially sensitive, and thus kept secret. Few companies selling high-grade industrial minerals submit prices to the usual surveys.

Figure 7: Pricing used in the DFS, fob Dar es Salaam

Mesh size	Price	Basket	Shipping	Agent fees	Contract discounts	Basket
	US$/t	weight, %	US$/t	US$/t	US$/t	US$/t
32	1,579	5	2	2	2	73
50	1,449	18	6	7	7	242
80	1,444	36	12	13	13	481
100	1,379	9	3	3	3	118
-100	1,314	32	11	10	10	386
	1,404	**100**	**33**	**35**	**35**	**1,301**

Source: Black Rock Mining, DFS, October 2018

Discussions with industry experts suggest that the weighted average price selling price for 97.5% LOI material could be as high as US$1,490/t. Prices for 99.0% LOI material could be as high as US$2,313/t. **These prices have not been used in the DFS, where a more conservative price of US$1,301/t was used.** This suggests, that once Black Rock is fully up and running, selling prices could be as much as US$190/t higher than those adopted for the DFS.

Valuations are often highly sensitive to selling prices. **Raising the average selling price to US$1,490/t, would increase the post-tax NPV_{10} to ~US$1.1bn.**

Excellent management team

Black Rock's management team, have conducted a thorough DFS study. The journey from PFS to DFS included:

- The construction of a pilot plant, substantially larger than anything else constructed in the sector to date. The final design of the plant comes after 15 iterations of the circuit.
- Trial shipments (530 tonnes) to demonstrate that Tanzania's TAZARA rail was a workable and more affordable logistics solution, and that 10 days from plant to port is deliverable
- The delivery of graphite product samples to 24 customers
- A decision to use dry-stacking (described in the PFS as difficult in humid environments)
- A decision to construct a rail siding on unused land at Ifakara
- Demonstrating that 99%+ concentrates can be produced without chemical interference
- Upsizing the crusher feed size to prevent clogging
- The discovery of, and decision to use, the colonial era road, thus by-passing the steeper and twisting mountain road
- Introduction of semi-automatic bagging
- Introduction of a reprocessing capability for off-spec product
- A detailed operational readiness assessment, whereby 400 risks were identified, and 86 business systems and 44 standards were developed to manage those risks.

It is likely that Black Rock's DFS has set a new standard, one that financiers are likely to expect other companies to adhere to. This is especially true, given that some companies completed feasibility studies 2-3 years ago, and are not yet financed or in production.

Next steps

The next steps are to progress discussions on financing and additional offtake agreements, and to secure mining licenses with the Tanzanian government. Black Rock expects to secure its mining licenses in early 2019. In 1H19, we would expect Yantai, the likely plant fabricator, to complete due diligence and to order long lead time items. Work on connecting the electricity grid will commence as well.

By the end of this year, management would hope to have completed the foundation work for the plant, upgraded the access roads, completed the resettlement, pre-stripped the mine and commenced mine development, and to have recruited people for the operating roles. Adherence to this timetable will allow Phase 1 to be fully ramped up in 2020. Qualification for the battery market is expected to commence in 2020 as well.

Looking over the site plans, October 2018

John de Vries

Simon Francis

Core being stored at Mahenge

The station at Ifakara, in need of new business

General topography from the top of Ulanzi

Sampling the outcrops, top of Ulanzi

Rich graphite seams

Valuations unjustifiably cheap

- ➢ Black Rock looks incredibly cheap at <2% of NPV; the market is failing to discriminate between companies or projects
- ➢ Black Rock stands out amongst Australian peers with the highest NPV to Initial Capex ratio, and the second lowest capex per tonne annual production
- ➢ Based on Black Rock being financed, in development, and a year or less from achieving first cash flows, the shares could trade at 4x-11x the current price

Market cap versus NPV

Black Rock's market cap (US$16m) is less than 2% of the project NPV. This is the biggest valuation gap in the sector, and reflects several factors:

- Mahenge is a superb project with a high NPV
- The DFS was published in October 2018, and probably hasn't been digested by the market
- 'Noise' in the graphite space – lots of companies all claiming to have strong projects, making it difficult for investors to discern real value
- Syrah Resources' (SYR.AX) Balama plant has had teething problems. Syrah's share price has fallen by 65% from its 2017 close; the market seems to be tarring all companies with the same brush.
- Mahenge is not yet fully funded.
- The terrible current market for junior mining companies

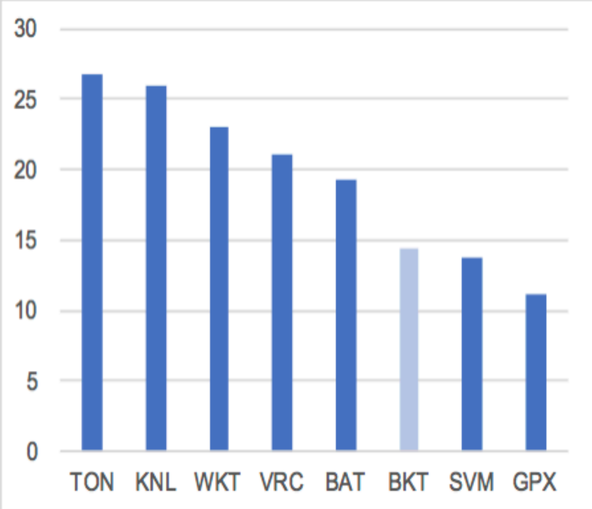
Investors are not discriminating

It's obvious that beyond Syrah Resources (SYR.AX) and Magnis Energy Technologies (MNS.AX), investors are not discriminating between the other Australian owned projects in Africa, irrespective of location, stage of advancement, or the prospects for achieving funding. In a sample of eight ASX-listed African graphite developers, there is only a US$16m difference in market capitalisation between the largest and smallest. This probably reflects a general sense of 'project confusion' among investors, and a poor year in junior mining generally. It also suggests that, so far, the market has failed to take advantage of the opportunity that Black Rock presents.

Black Rock lies towards the lower end of the market cap. range, but has:

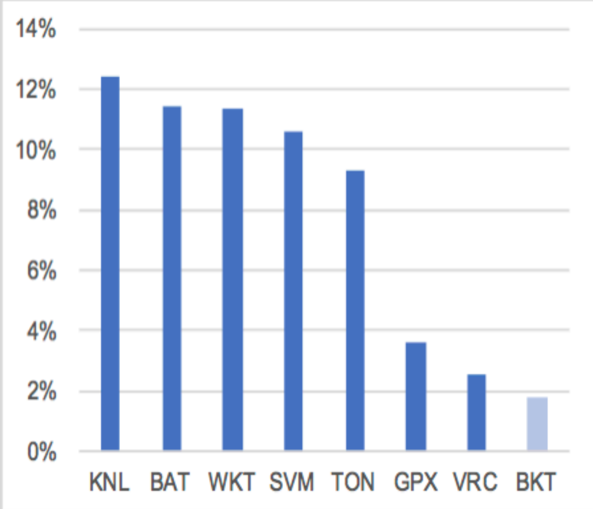
- The lowest market cap. to NPV ratio (<2%)
- The highest NPV to initial capex requirement (~7x)
- The second lowest initial capex per tonne of annual production (US$479/t).

Figure 8: Market cap, US$m



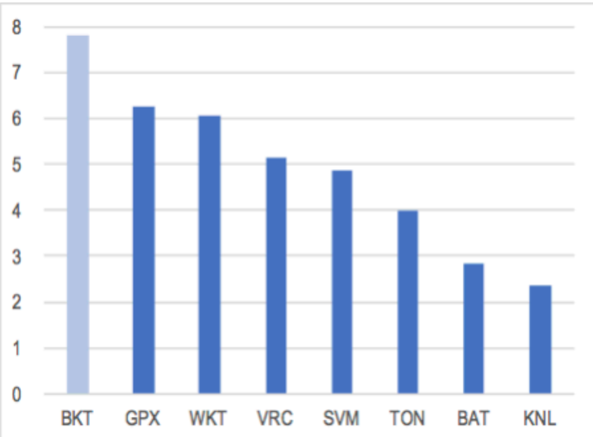
Source: Company data, Orior Capital estimates

Figure 9: Market cap as % NPV



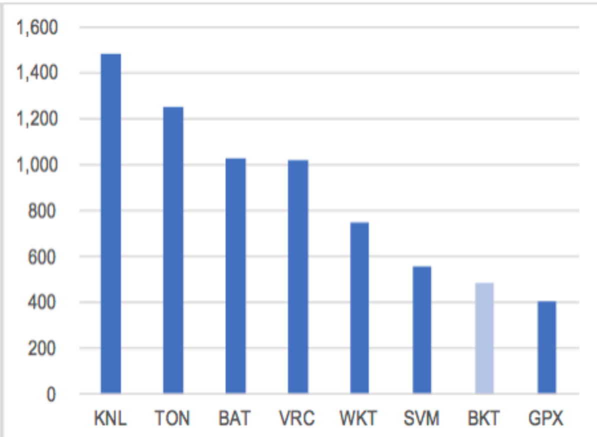
Source: Company data, Orior Capital estimates

Figure 10: NPV / Initial capex (x)



Source: Company data, Orior Capital estimates

Figure 11: Initial capex per tonne, US$



Source: Company data, Orior Capital estimates

NPV based valuations

As an admittedly, rather broad rule of thumb, projects that are one year or less away from cash flow, fully financed and fully approved, can tend to attract valuations of 30%-50% of NPV. Even this is a broad range, and depends upon a variety of factors including jurisdiction, scale, perception of management, how 'hot' the commodity is at the time, and others. At this stage, Black Rock is probably two years away from cash flow. Construction of Phase 1 is expected to commence in 2Q19, and to take until 3Q20. Based on the DFS, Phase 1 will ramp up from 4Q20. A year from now (1Q20), when the company is nearer cash flow, it could trade at US$269m to US$448m (30-50% of NPV). Given the strong demand for product, management is looking to accelerate development.

How much dilution?

The project still has to be funded, and that means a degree of equity dilution. The company probably has to raise about US$140m (A$196m) in all, being US$115m project capex, US$10m to fund power supply development (recoverable over the project life) and some working capital. Assuming 80:20

debt-to-equity at a share price of A$0.10 to A$0.15, Black Rock would issue between 259m and 388m new shares. This would increase the total shares outstanding to between 845m and 975m. The company would have US$112m (A$157m) of debt.

Based on these figures, Black Rock could be worth A$0.16 to A$0.40 (16 to 40 cents) a year from now. This suggests that on a one-year view, **the shares could be worth 4x to 11x the current share price.** Obviously, this is fairly broad-brushed, and it is a wide range.

Could the project support US$112m of debt? Yes. In fact, with a fixed loan, repaid at the end of say five years, the project could probably be 100% debt financed. Based on DFS figures of a US$1,301/t basket selling price, and US$401/t C1 costs, annual EBITDA will be around US$216m. The project is expected to generate US$313m in EBITDA over the first three years. Even assuming debt costs of 15% pa (Chinese financing is likely to be significantly cheaper than this), the interest costs on a US$112m loan would be ~US$17m pa. Interest coverage would be high. Consequently, the project looks capable of supporting a high-level of debt financing. This could limit the dilution to existing shareholders.

In terms of sensitivity to the debt assumption, using a debt-to-equity assumption of 70:30 suggests a valuation range to A$0.15 to A$0.36, and a debt-to-equity assumption of 60:40 suggests a valuation range to A$0.14 to A$0.33.

Also, one might balk at the prospect of issuing shares at a premium. Yet, the current share price (market cap. <2% of NPV) is hardly a fair reflection of the quality of the project or the company's growth prospects. Like most junior mining companies, Black Rock's shares are not very liquid. Only about 37m shares were traded in November and December 2018, turning over about US$1.0m. Illiquid shares tend of get punished in weak markets (such as 2018) but do well when things turn. It should not take too much renewed interest in the sector to lift the share price. On this basis, issuing shares at a premium to today's price is entirely possible.

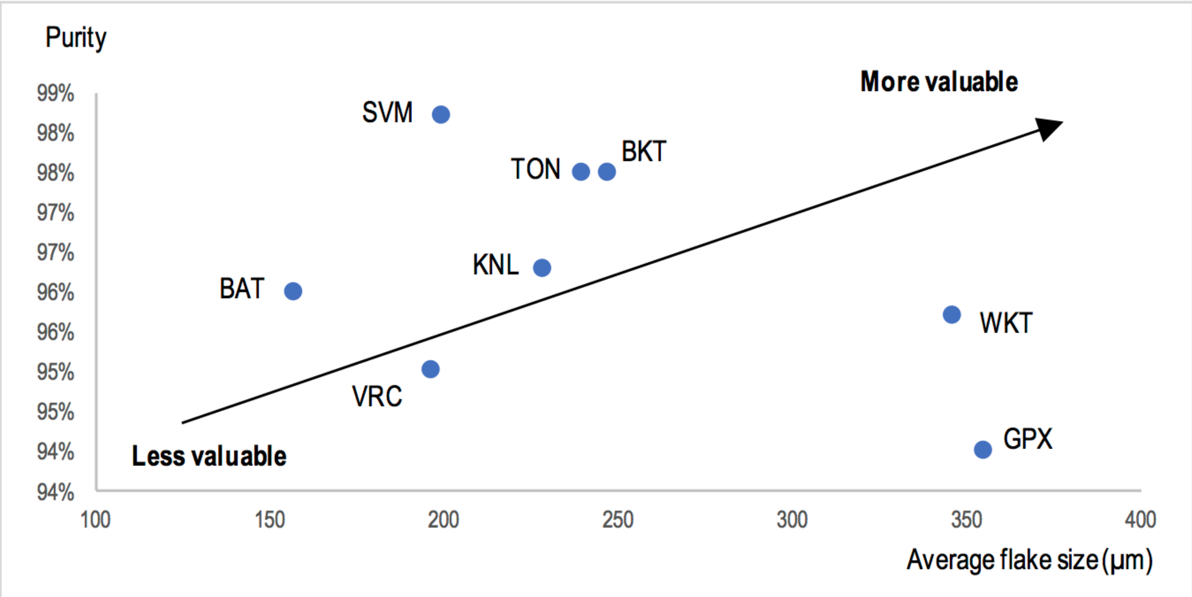
Figure 12: Broad based view of possible dilution and valuations

A$:US$ fx rate		1.385				
NPV	US$ m	895	Post-tax, and net of government stake			
Initial capex	US$ m	140	Project capex, power, working capital			
Debt portion	%	80%	Reasonable assumption given strong cash generation			
Debt funding	US$ m	112				
Equity portion	%	20%				
Equity funding	US$ m	28				
Fully diluted share o/s	millions	587				
New shares issued	**A$/share**	0.04	0.08	**0.10**	**0.12**	**0.15**
New shares issued	millions	970	485	388	323	259
Total shares after issue	millions	1,556	1,071	975	910	845
Valuation as % NPV		**30%**				
EV	US$ m	269				
Market cap.	US$ m	157				
Implied valuation	A$/share	0.10	0.15	**0.16**	**0.17**	**0.19**
Valuation as % NPV		**50%**				
EV	US$ m	448				
Market cap.	US$ m	336				
Implied valuation	A$/share	0.22	0.31	**0.34**	**0.37**	**0.40**

Source: Orior Capital estimates

One difficulty for investors in comparing companies on an NPV basis, is the lack of consistency in the key drivers applied to these valuations. Companies have different flake size distributions, and different purities. As a result, selling prices, a key driver of NPV valuations, vary widely. Graphite is not an exchange traded commodity, and there is little publicly available data on prices for higher-grade material. To some extent, this gives companies license to 'print their own' price decks. From an investment perspective, it is important to understand exactly how these price decks have been arrived at. Black Rock's prices, used in the DFS, are based on customer communication, and data from Roskill.

Figure 13: Comparison of flake size and purity



Source: Company data, Orior Capital estimates

Industrial/technical minerals valuations

There are few peers in production

It is difficult to find direct peers in graphite because there are few producers, and even fewer are listed. Graphite is still a small market. In 2017, global flake graphite (excluding amorphous graphite) production was ~630,000 tonnes, and only about 235,000 tonnes were non-Chinese production. There have only been two new projects come on stream in the west in the past few years. In terms of comparisons, Syrah is still ramping up, and has had some hiccups along the way. Magnis Energy Technologies is moving into Gigafactories and looking for financing. Mason Graphite is in development, after publishing a feasibility study in 2015. Ashbury Carbons is private.

There are downstream companies that produce graphite products, such as electrodes for the electric arc furnace (EAF) steel industry and specialised products for the automotive and aerospace industries. They are not comparable to Black Rock. These companies have typically invested heavily in industrial plant. This group includes companies such as GrafTech International (EAF), Tokai Carbon (5301.T) and FangDa Carbon New Material Co Ltd (600516.SH). GrafTech is the only graphite electrode producer that is substantially vertically integrated into petroleum needle coke. Tokai claims to produce the largest electrodes (3m long and 80cm in diameter). FangDa trades at around 100x P/E reflecting the fact that in the Chinese markets there is a vast pool of capital chasing relatively few listed companies. SGL Carbon has disposed of its steel related businesses, and now focuses on supplying high-end composite materials and graphite products for the lithium-ion battery, solar, semiconductor, LED, chemical and automotive sectors.

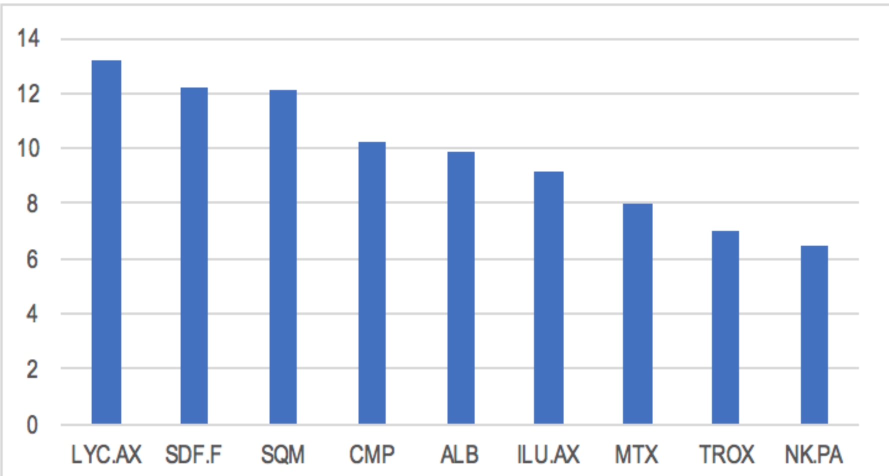
Industrial minerals companies tend to be diversified across minerals

Looking beyond graphite, there are a number of listed industrial minerals companies. This includes companies such as Imerys (NK.PA), Abermarle (ALB), Minerals Technologies (MTX), Sociedad Química y Minera de Chile (SQM), Compass Minerals (CMP) and others. Many industrial minerals markets are fairly small. The global silica sand market was ~US$11.3bn in 2017, but the global markets for kaolin, fluorspar and bentonite were ~US$5.0bn, ~US$2.0bn and ~US$1.1bn respectively. The global potash fertilisers market was ~US$18.5bn in 2017, but the market for potassium sulphates was ~US$3.7bn. As a result, these markets have tended to become consolidated, and the main players are diversified across a range of minerals.

Black Rock will produce a variety of high-end, branded graphite products, such as "Mahenge ULTRA", for a variety of specialised industrial applications. Demand in the sector will be driven by the battery sector, and minerals such as graphite, lithium, cobalt, vanadium and others will be in demand. In future, Black Rock may market itself as an industrial or technical minerals company.

Longer-term, the focus will be on earnings multiples. Looking at a broad range of nine of these companies, active across a range of minerals, geographies, and listed in different markets, the group is trading at ~9.8x (range 6.5x to 13.2x) trailing EV/EBITDA. PE-based valuations are trickier; the range is much wider, with a couple of the companies making net losses in 2017. **Importantly, Black Rock has a long-life project which, once up and running, should justify these types of valuations.**

Figure 14: Industrial minerals companies, trailing 12 month EV/EBITDA multiples (x)



Source: Company data, Orior Capital estimates

Applying the bottom end of the range, and the average, to Black Rock's expected attributable annual EBITDA of US$181m (240,000 tonnes x (US$1,301/t - US$401/t) x 84%) suggests an EV valuation of US$1,179m (bottom end) to US$1,778m (average). This is 1.3x to 2.0x NPV. This might seem high now, but well into the project, Black Rock could be throwing off cash earnings after tax of more than US$100m pa. (Attributable EBITDA of US$181m, less say US$10m in debt costs, and

US$50m in taxes, would be US$121m).

Assuming this is achievable in say, six years' time, and investors demand a 25% pa return (this is still junior mining), we can discount this valuation range back to get to a current valuation range of US$309m to US$466m. This is 35% to 52% of NPV and broadly in line with the 30-50% of NPV expected a year from now.

Figure 15: Industrial mineral company snapshots

SQM (SQM): Global. Specialty plant nutrition, iodine, lithium, potassium, industrial chemicals.
Abermarle (ALB): Global; 5,400 employees across 100 countries. Speciality chemicals, lithium, bromine, refining catalyst leading positions.
Compass Minerals (CMP): US and Mexico. Salt, sulphate of potassium, magnesium chloride.
K+S Group: Global; 15,000 employees. Potash and magnesium products, salt.
Imerys (NK.PA): Global; 18,300 employees 50 countries. Mineral resources (clay, bentonite, diatomite, feldspar, kaolin, mica, wollastonite), formulations (ceramic bodies, continuous casting fluxes for steel, monolithic refractories), and synthetic minerals (synthetic graphite, zirconia)
Minerals Technologies (MTX): Global; 3750 employees across 35 countries. Bentonite, chromite, leonardite, precipitated calcium carbonate, limestone, talc, monolithic and shaped refractory materials, calcium metal and metallurgical wire products.
Iluka Resources (ILU.AX): Global; 900 employees, and a similar number of contractors across 23 locations. Zircon, and titanium dioxide products rutile and synthetic rutile.
Tronox Limited (TROX): Global; 3,400 employees across 'nearly 20' locations. Titanium ore, zircon, other minerals, titanium dioxide pigments
Lynas Corp (LYC.AX): Australia and Malaysia. Rare earths.

Source: Company data

Path to market established

- The large-scale pilot plant, market segmentation studies, and customer engagement enabled Black Rock to identify and target key 'high-spec', premium-priced, markets
- Phases 1 and 2 are already sold-out; offtake agreements have been signed for 205,000 tonnes of graphite (year 3); based on demand, the project could be accelerated, and perhaps expanded
- Fire retardants, graphite foils, high-end refractories, and battery pre-cursor, are all target markets

Target markets

A combination of market segmentation studies, customer targeting, pilot plant production, and logistics testing, have established an effective path to market. The building of a large-scale pilot plant not only allowed Black Rock to thoroughly test the process, it also threw off sample product that could be analysed and tested by potential customers. By creating samples in the pilot plant, Black Rock was able to identify the product grades it could produce, have those samples analysed and certified, and delivered to targeted customers. Black Rock defines these products as:

- Mahenge Standard Flake – 95% LOI
- Mahenge Premium Flake – 97.5% LOI
- Mahenge ULTRA PURITY-FP™ Flake – 99%+ LOI.

Black Rock has two distinct signature resources; Ulanzi and Cascades. The Ulanzi deposit possesses specific chemical and metallurgical qualities that make it suitable for applications in foils, fire retardants, engineered products, lubricants, secondary (rechargeable) batteries and thermal drilling fluids. Ore from Ulanzi, can be processed into 99.3%+ LOI at coarse flake fractions of +80, +50, and +32 (limited) mesh using three stages of polishing and flotation.

The company segmented the graphite market into five main groups, each with specific target applications. Each of these groups has demand from value-added industries, with good growth prospects. These groups are:

Thermal management: Thermal management applications use graphite as an insulator or a conductor of heat. Graphite is used in refractories, foundries, and crucibles as an insulating or conductive additive to increase refractivity, and as a geothermal additive. Natural graphite used in refractories is high purity, typically 85% to 98% LOI, and of standard flake size, usually -150 to +80 mesh. Black Rock is targeting the high-end refractory market.

Engineered products: The main target market for Black Rock is graphite foils. Typically, standard and high-purity flakes (97% to 99.9% LOI) with sizes of +100, +80, +50, and +32 mesh sizes are used in these applications. There is research going on into potential new applications for foils using flakes as large as +25, and +20 mesh, but availability of these mesh sizes is extremely limited. Black Rock is still testing whether it can produce sufficient yield for commercial needs.

Lubricants: This includes grease and drilling fluids where graphite is used to improve or manage friction characteristics. Graphite retains its lubricating properties under high temperatures and pressure, making it ideal in industrial settings.

Energy storage: The battery market is a segment of significant growth. Black Rock has already conducted successful initial tests.

Plastics, polymers and rubber: Polymer-based fire retardants are a fast-growing segment with applications in automotive, aerospace, consumer goods, and residential and commercial property. This sector has become critical after a number of significant fires over the past few years.

The thing about the EV sector

Many budding graphite producers highlight the long-term potential of the EV and energy storage system sectors, apparently in the hope that anything they produce will be scooped by grateful battery makers. Investors should not overlook two facts. First, outside of China, EV penetration remains low. Tesla's total sales in the United States only reached 200,000 EVs by June 2018. The sector is expected to grow rapidly, but as of today, the market is small. Second, as with most aspects of the car market, the qualification process is slow. It takes about three years to qualify as a supplier to producers of EV batteries.

Whilst waiting for the market to grow, and their products to be qualified, graphite producers will still have to stay in business. That presumably means generating cash flow by selling graphite to other customers. Given this, it is perhaps rather shocking that more companies are not building reasonable scale pilot plants, and undertaking detailed markets analysis. **The best, perhaps only, way to target high-end markets, is to allow sample product to be subjected to rigorous chemical and metallurgical testing.** Black Rock has done this.

In all, Black Rock provided 12 different specifications of product to customers, with 7 of these being on customer request. Commercial production will focus on the standard mesh sizes of +50, +80, +100, and -100, with limited availability of +32 mesh. Black Rock will be able to produce other mesh sizes, according to customer requirements and applications.

Samples, the largest being 1,000 kg, were sent to 24 customers. As a direct result, Black Rock has signed offtake agreements for 205,000 tpa (85% of planned production), with further discussions under way. Current indications are that demand may soon exceed the full 3-Phase planned production of 240,000 tpa.

Customer comments on Mahenge graphite include:

Ulanzi flake exhibits uniform coarse flake

- It contains lower than average volatile matter compared to other suppliers
- It demonstrates excellent expansion rates
- It has excellent metallurgical performance during the spheronization process
- It contains lower than average iron oxide, aluminium oxides, and sulphur content

Figure 16: Ulanzi graphite mesh size fractions

Specification	Base Mesh Fraction	Particle Size (mesh)	Particle Size (µm)
Mesh Size 1	Limited Availability	32	500
Mesh Size 2	Customer Request	-32	-500
Mesh Size 3	Yes	50	300
Mesh Size 4	Customer Request	-50	-300
Mesh Size 5	Yes	80	180
Mesh Size 6	Customer Request	-80	-180
Mesh Size 7	Yes	100	150
Mesh Size 8	Yes	-100	-150
Mesh Size 9	Customer Request	150	105
Mesh Size 10	Customer Request	-150	-105
Mesh Size 11	Customer Request	200	75
Mesh Size 12	Customer Request	-200	-75

Source: Black Rock Mining, DFS, October 2018

Ultimately, Black Rock's aim is to supply consistent and high-quality graphite products that meet customers' demand for both their flake size, and chemical signature. The metallurgical and chemical properties of the Mahenge deposit make it suitable for foils, fire retardants, engineered products, lubricants, secondary batteries and thermal drilling fluids. Pilot plant tests have demonstrated that Ulanzi graphite can be processed using standard flotation techniques (and no acid leaching) to achieve 99% LOI, together with larger than average flake fractions of +80, +50, and +32 mesh sizes.

Commercial production will be focused on the standard flake sizes of +50, +80, +100, and -100 mesh, with limited availability of +32 mesh. The balance of customer requirements will be met with additional screening and blending. This way, Black Rock will be able to simplify its plant operations, yet still provide for diversified product specifications and sales. Black Rock plans to offer a base range of carbon purities – 95%, 97.5% and 99%+ – with additional processing enabling the company to meet a wide range of customer specifications.

Mesh size is defined as the number of openings per square inch (sq. inch). A 32-mesh screen will have 32 openings per sq. inch, whereas a 100-mesh screen will have 100 openings per sq. inch. The higher the mesh number, the smaller the particle that will pass through the mesh. Sometimes the mesh size is noted with either a minus (-) or plus (+) sign. These signs indicate that the particles are smaller than (-) or larger than (+) the mesh size. So, a product described as -100 mesh would contain particles that passed through a 100-mesh screen. A product described as +100 mesh, would contain particles that did not pass through a 100-mesh screen.

Mesh sizes do not correspond directly to the fractional sizes of an inch. This means that 4-mesh is not 0.25 sq. inches (it is actually 0.187 sq. inches) and 10-mesh is not 0.1 sq. inches (it is actually 0.0787 sq. inches). This is because the width of the wires forming the mesh have to be taken into account. There are different definitions of mesh size; the American, British and International Sieve Series are all slightly different.

Phases 1 and 2 already sold out

Black Rock has signed three offtake agreements since October, 2018. The first of these, was with Heilongjiang Bohao Graphite Co Ltd to supply up to 90,000 tpa of graphite. The second was with Qingdao Fujin Graphite Co Ltd, an anode producer. **This second deal is important because Qingdao Fujin produces anodes for small and medium sized batteries.** In January 2019, Black Rock signed a third offtake agreement, this time with Chinese group Taihe Soar, a trading house, based in the industrial heartland of Dalian.

The agreements with Heilongjiang Bohao and Taihe Soar are believed to be the two largest offtake agreements signed by any graphite company in development.

Together, these three offtake agreements, in the third year, represent 85% of Black Rock's planned production. Further supply agreements are likely once commercial production starts. Management is firmly of the few that these agreements would not have possible without customers having had access to product from Black Rock's pilot plant.

Figure 17: Summary of Black Rock offtake agreements

	Year 1	Year 2	Year 3
Heilongjiang Bohao	30,000	50,000	90,000
Qingdao Fujin	15,000	15,000	15,000
Taihe Soar	37,500	80,000	100,000
Total	**82,500**	**145,000**	**205,000**

Source: Black Rock Mining

Heilongjiang Bohao Graphite Co Ltd

In October, 2018, Black Rock signed an offtake agreement with Heilongjiang Bohao Graphite. Under the terms of the agreement, Black Rock will supply 30,000 tonnes in year 1, 50,000 tonnes in year 2, and up to 90,000 tonnes in year 3. By year 3, this represents 37.5% of Black Rock's proposed full production of 240,000 tpa. The contract came as a direct result of Black Rock's pilot plant, and customer testing.

Heilongjiang Bohao Graphite was established in 2011, and is located in Mudanjiang, Heilongjiang Province, in north-eastern China. It is one of the largest integrated graphite producers in China, mining graphite in Heilongjiang, producing a range of graphite products including graphite paper, expandable graphite and spherical graphite, and supplying the battery sector. The company exports into North America, Japan, Korea, Taiwan and the European Union.

Qingdao Fujin Graphite Co Ltd

Also in October 2018, Black Rock signed an agreement with Qingdao Fujin Graphite Co Ltd to supply 15,000 tpa of sized graphite concentrate for up to three years. Established in 2002, Qingdao Fujin Graphite Company Limited is located in Nanshu Town, Laixi, Shandong Province. The agreement is significant because Qingdao Fujin produces anodes for small and medium sized batteries that are used in a variety of applications including automotive, consumer electronics, and energy storage, in China and Asia.

Taihe Soar (Dalian) Supply Chain Management Co Ltd

In January 2019, Black Rock signed a third offtake agreement, this time with Taihe Soar. Taihe is based in Dalian. It acts as an import/export house, and provides trade credit to smaller Chinese entities that would otherwise find it hard to operate in international markets. Effectively this gives Black Rock access to a distributor able to serve smaller volume customers.

Scope to expand the project

Demand for Mahenge graphite has been so strong that management is now considering an optimised DFS for a 4-Phase project, boosting production to more than 300,000 tpa. This highlights customers' confidence in the Mahenge project. It points to huge pent-up demand in China for high-grade product. It also suggests that customers in China are concerned about being able to continue to secure supplies from their domestic market.

In addition to these agreements, Black Rock signed two MOUs in 2017:

Meiwa Corporation

In April 2017, Black Rock signed an MOU with Meiwa Corporation, of Japan. Meiwa is a major trading house that is active in chemicals, plastics, construction materials, fuel, machinery and metals. In 2010, it became a joint venture partner in a spherical graphite production facility in Shandong Province, China. The MOU essentially allows Black Rock and Meiwa to explore the commercial viability of a long-term relationship.

Yingkou Botian Material Technology Co Ltd

In June, 2017 Black Rock signed an MOU with Chinese company, Yingkou Botian Material Technology Co Ltd. Botian is based in Liaoning province, China. It has more than 8,000 tpa of spherical graphite capacity, making it of the top ten processors in China. It supplies some of the largest battery manufacturers in China. Botian currently purchases 25,000 tpa for its spherical graphite operations. This amount is expected to grow significantly over the next few years. The company has expressed interest in purchasing 50,000 tpa of graphite concentrates from Black Rock.

Battery tests

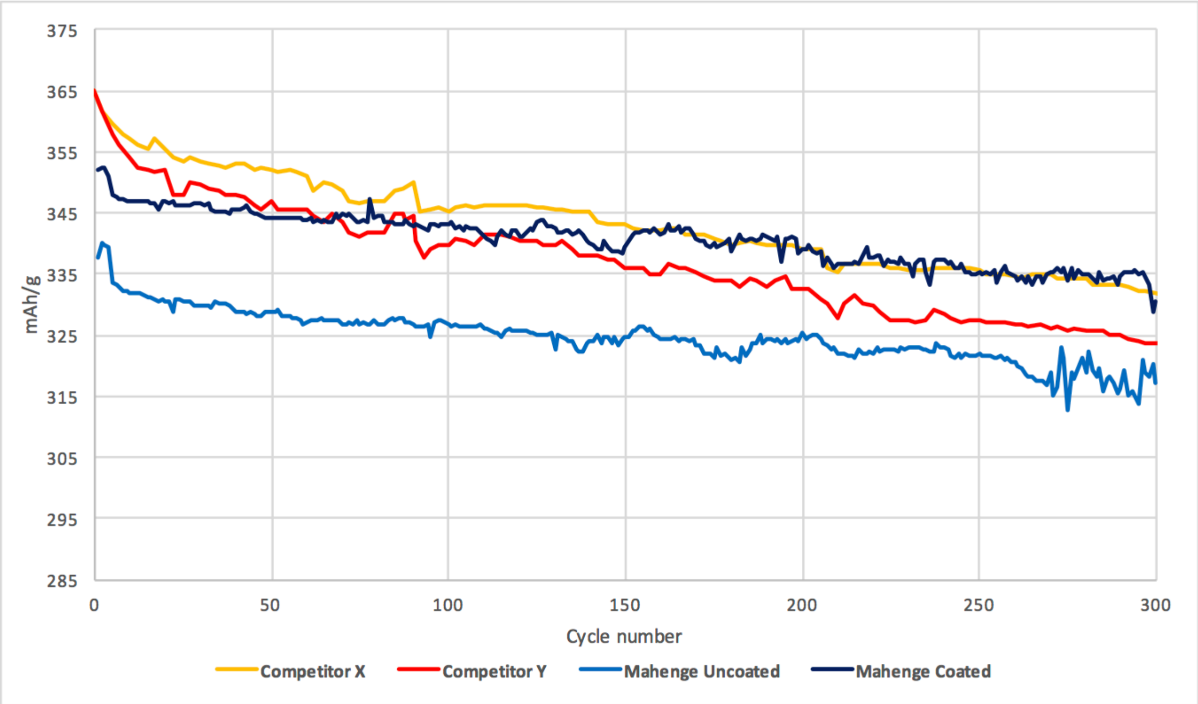
In 2016, Black Rock engaged a US based, ISO-compliant laboratory to conduct a series of spherical graphite and purification tests, designed to assess the suitability of Mahenge Ulanzi concentrate for the battery sector. The lab produced spherical graphite, both coated and uncoated, which was used to produce battery anodes. Industry standard CR2016 cells were assembled using these anodes. Several different combinations of anode, binder, additives and electrolyte were tested in 2016 and 2017. **The key result is that battery cells produced using surface coated, spheronized natural flake from Ulanzi, could exceed 300 cycles, with a 94% recharge rate.** The cells also had flatter performance curves than an existing commercial battery, indicating potential for longer battery life.

The 300 cycles benchmark is important because it essentially represents a full charge-discharge cycle every other day, and thus represents a two-year product life for consumer electronics products. To achieve these results on a first test is very encouraging. Black Rock believes it is the only company to have demonstrated such excellent battery test performance.

The other important metric is the spheronization yield. The higher the yield the better, because this means less graphite is used in producing battery anodes. Industry yields are in the range of 30-50%, meaning that typically 2-3 tonnes of graphite are used to produce one tonne of anode material. Black Rock achieved a 65% spheronization yield.

Given the strength of these results, Black Rock intends to submit product for further testing once Phase 1 is up and running.

Figure 18: Early results from battery testing were excellent



Source: Black Rock Mining

Mahenge's natural advantages

- The Mahenge graphite project has substantial and sustainable natural advantages that are reflected in the high NPV, and long project life
- Geologically, Mahenge boasts world-scale resources, a large flake size distribution, a lack of deleterious elements, and easy mining and processing
- Geographically, the project is located close to the TAZARA railway, which feeds directly into the Port of Dar es Salaam and grid power will be available

Geology

A substantial resource…

The Mahenge graphite resource amounts to 211.9m tonnes at an average grade of 7.8% for a total graphite content (TGC) of 16.6m tonnes. The resource is held under 519.8 km^2 of license area. There is a high-grade portion within the resource measuring 46.6m tonnes at 10.6% TGC. The resource contains a JORC compliant ore reserve of 5.9m tonnes.

The importance of having a large resource cannot be underestimated. As the lithium-ion battery and energy storage markets expand, battery makers will need to feed their plants with graphite that can demonstrate chemical and metallurgical consistency over a long period. Companies with small resources are unlikely to be able to penetrate the battery sector for this reason.

Mahenge has the potential to be mined from multiple zones at low strip ratios, high-graded to enhance returns in the early years, and has the potential for capacity expansion to take advantage of the substantial scale of the resource. Note that in the DFS, less than half of the current resource will be mined; there seems to be plenty of scope to boost annual capacity.

…With larger flake sizes

In addition to its large scale, Mahenge has a bias towards larger flake sizes. Roughly 59% of the expected product is of +80 mesh size or bigger. The company's ULTRA product has the highest concentrate grade of any known natural flake graphite flotation concentrate. Large flakes are used in a wide range of specialised industrial applications. Also, Chinese large flake supply is dwindling leading to attractive demand-supply dynamics for large flakes.

Easy mining…

Mining at Mahenge should be straightforward. The resource is shallow, and has a low strip ratio. The life-of-mine average strip ratio is just 0.6, though it varies between 0.5 and 1.0 throughout the mine life. This means that only a modest 1.6m tpa of rock will have to be moved for each 1.0m tpa phase of the project. Small scale equipment such as 40-tonne excavators and 20-tonne trucks can be used, both of which are available in Tanzania. This should simplify training, parts availability and support. Given the expected simplicity, Black Rock plans to run its own mining operations, allowing for increased flexibility in the mine schedule, lower operating costs, and boosting employment.

Black Rock intends to mine ores above the cut-off grade only. The company will reclaim additional material from the ROM stockpiles. This will lower the strip ratio, simplify the grade control strategy, defer waste stripping and reduce the short-term variation in mill feed.

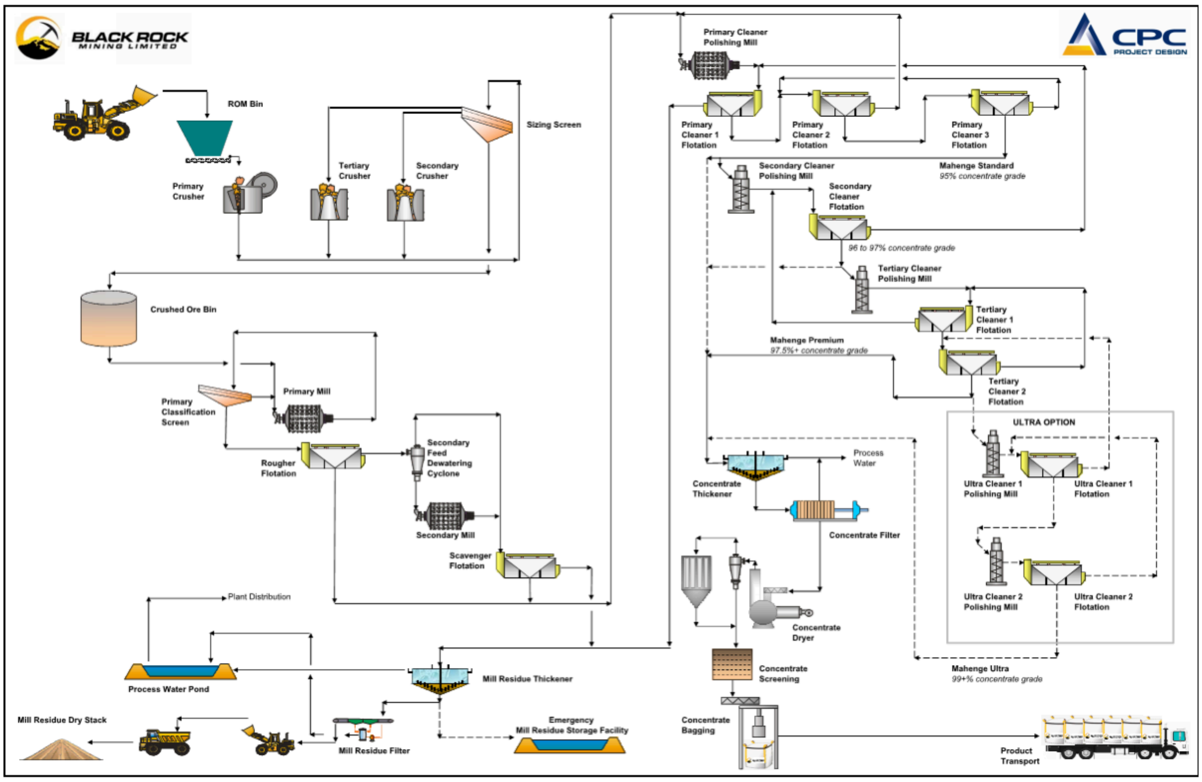
…and a simple plant

A big advantage of the Mahenge deposit is that high-grade graphite products can be produced using a relatively simple plant layout. Black Rock can produce 99%+ LOI material using only flotation and polishing. That is, without acid leaching. This is believed to be unique among global graphite operations. Most commonly, acid leaching is used to get rid of impurities in the graphite. A range of different acids (or sometimes alkalis) are used, with hydrofluoric acid being common. The use of acid adds cost, complexity and environmental risks to a project. (See Appendix 2 for further discussion on graphite processing).

A large part of this final plant simplicity came about because Black Rock built a large-scale pilot plant. The 90-tonne pilot plant was substantially – an order of magnitude – larger than other pilot plants. Black Rock's final plant layout is the result of testing 15 different pilot plant iterations.

For example, Black Rock has settled on the use of a single circuit, that eliminates intermediate screening. At first it was thought better to separate larger and smaller flakes in flotation and process them separately. Optimisation in the pilot plant demonstrated that this is not necessary. As a result, technical risk, capital and operating costs will be lower. The plant is modular, and will be pre-assembled in sizes that enable transportation in containers to minimise logistics costs.

Figure 19: Simplified process diagram



Source: Black Rock Mining, DFS, October 2018

Geography

Mahenge's geographical advantages essentially comprise, close access to the TAZARA railway, direct (rail) access to the international port of Dar es Salaam, and an available grid power supply. This infrastructure is largely in place. Together, railway, port and power access, mean cost and time savings, and a more efficient business.

Logistics

Graphite products will be bagged into 1-tonne bags on site and transported by truck to a loading area in Ifakara train station. The truck journey from plant to Ifakara is about 70km. At first, trucks will haul 15 tonnes of bagged product, 7 days a week, for 12 hours each day, allowing two return trips per day. Trucks will travel in conveys, and be accompanied by a lead vehicle. Daytime travel, in conveys, with a lead vehicle is aimed at eliminating accidents. Phase 1 of the project will require 8 trucks. There is availability of good quality trucking fleets in Tanzania, and sourcing trucks, and repair and maintenance services is not thought to pose any challenges.

Bagged product will be consolidated into shipments, loaded into 20-feet shipping containers, and onto railcars in Ifakara. The product will clear customs in Ifakara; shipping containers will be sealed for transportation. From Ifakara, the product will be transported on the TAZARA railway line to the port at Dar es Salaam. The total road and rail journey is approximately 450 km.

The Tazara Railway

The TAZARA railway was built by the governments of Tanzania, Zambia and China from 1970 to 1975. The railway provided the only route from Zambia's copper belt to a coastal port without having to transverse South Africa and Rhodesia (now Zimbabwe), both of which were under white-minority rule at the time. TAZARA was financed by China; at a cost of ~US$400m it was China's largest foreign-aid project at the time.

The railway is 1,860 km long, and runs from Dar es Salaam in Tanzania, to Kapiri Mposhi in central Zambia. Starting at sea level, it reaches its highest point of 1,789m at Uyole, before ending at 1,275m at Kapiri Mposhi. TAZARA was built using Cape Guage, which is 3 ft 6 in (1,067mm), a common gauge in southern Africa. More modern railways in Tanzania owned by Tanzania Railways Limited, have a gauge of 1,000mm. A transhipments station was built in Kidatu in 1998 to facilitate switching between lines.

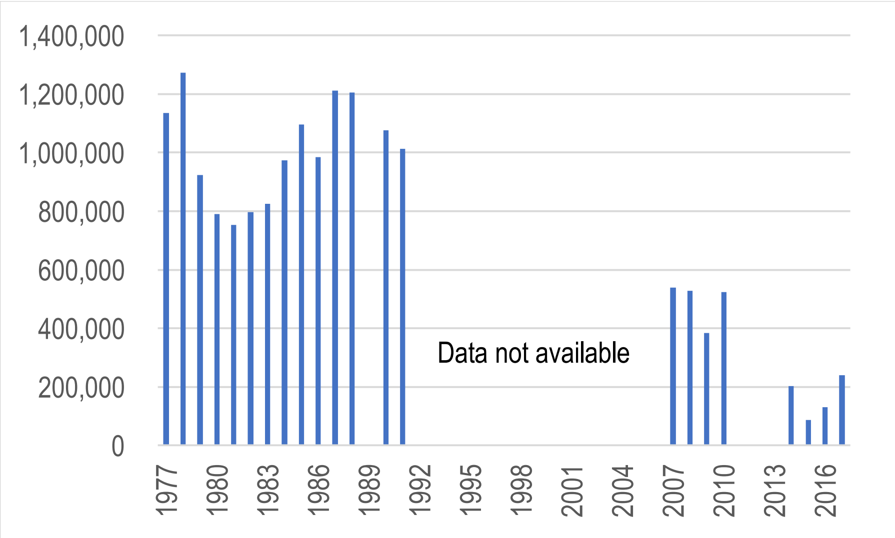
TAZARA was built for the future, but faced early challenges. It has a design capacity of 5.0m tpa freight, and carried 1.1m tonnes in 1977 and 1.3m tonnes in 1978, before volumes declined. In 2017, freight volumes were 240,000 tonnes. Part of this reflected rolling stock issues, including a lack of repairs and maintenance, and part related to staffing problems. Freight schedules had become so slow, that in 1978, Zambia re-opened links with Rhodesia to be able to efficiently import fertilisers and export copper.

Nowadays, even though there has been limited investment in the railway, capacity utilisation is so low, that there is plenty of spare capacity. Visiting TAZARA in October 2018, two things were clear. First, the tracks need tamping; simple maintenance could lift average speeds by perhaps 20 km/h. Second, TAZARA is a service in need of customers.

TAZARA offers advantages to Black Rock:

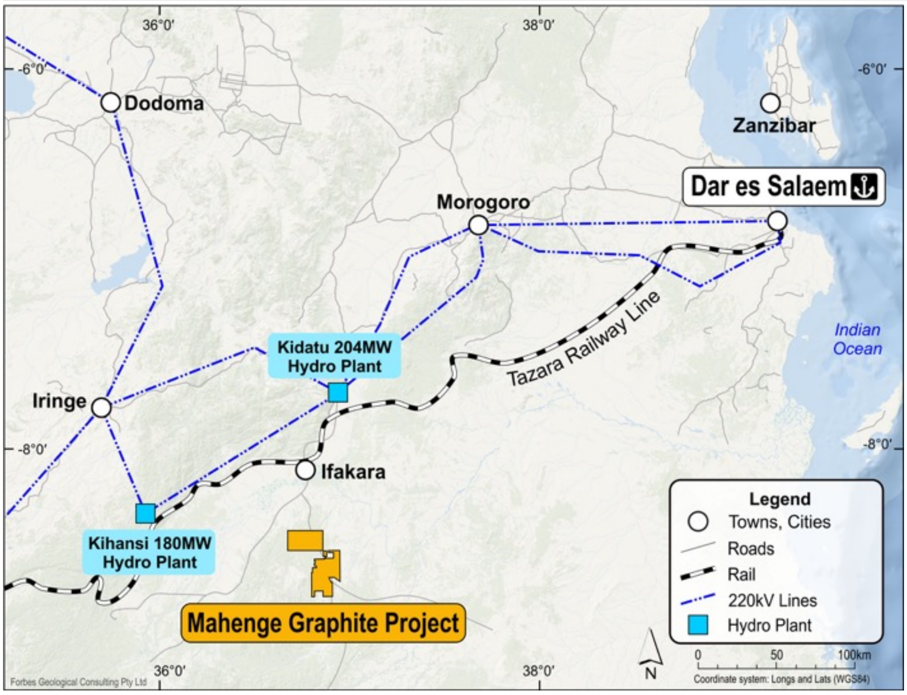
- The railway line runs to the Port of Dar es Salaam, from which Black Rock will ship graphite.
- There is plenty of excess capacity. TAZARA has offered engines and rolling stock to Black Rock.
- Unused land adjacent to the tracks at Ifakara will be used to load product onto the trains.
- Tanzania will put a customs office at Ifakara, so that graphite product can be customs cleared at Ifakara, and locked into containers for shipping.
- In Tanzania, railway transportation is both cheaper and safer than road transportation.

Figure 20: TAZARA railway freight cargo, tonnes



Source: Wikipedia (various sources), Black Rock Mining, Orior Capital

Figure 21: Map with project site, and key infrastructure



Source: Black Rock Mining, DFS, October 2018

Figure 22: Looking west from the south platform at Ifakara

Source: Simon Francis

Port of Dar es Salaam

The Port of Dar es Salaam is Tanzania's principal port, designed to handle cargoes of more than 10m tpa. This includes liquid bulk cargos of 6.0m tpa, general cargoes of 3.1m tpa, and container cargoes of 1.0m tpa (which according to the Tanzanian Ports Authority is the equivalent of 9,619,876 TEUs (twenty-foot equivalent units)). The Port has a total quay length of about 2,600m metres, with eleven deep-water berths. It is a vital international port that in addition to Tanzania, serves the landlocked countries of Burundi, Democratic Republic of Congo, Malawi, Rwanda, Uganda and Zambia. **According to the Tanzanian Ports Authority, the Port of Dar es Salaam handles about 95% of Tanzania's international trade.** The port is currently being expanded to enable it to handle larger vessels and cargoes of 28m tpa by 2020.

A local logistics company will unload product containers from the railway line, deliver them onto the ships, and return empty containers back to the trains for transportation back to Ifakara. The port has excess capacity, frequent shipping to Asia, and thus a large number of empty returning containers.

According to the TAZARA train timetable, two trains, one ordinary and one 'express' travel the entire length of the track twice a week in each direction with departures, from Dar es Salaam on Tuesdays and Fridays. According to the timetable, the Mukuba Express takes about 44 hours, suggesting an average speed of ~42 km/h. The Kilimanjaro Ordinary takes about 50 hours. Although slow, trains are considered safer, and cheaper than road transportation. The TAZARA railway timetables are available at the following links;

https://tazarasite.com/express-train-time-table-effective-february-2016

https://tazarasite.com/ordinary-train-time-table-summarised-effective-february-2016

For railway buffs, Jamie Monson's book, Africa's Freedom Railway, provides an excellent history of the TAZARA railway. ISBN: 978-0-253-22322-7.

Figure 23: Port of Dar es Salaam, bird's eye view

Source: Wikimedia, Prof. Chen Hualin

Figure 24: Port of Dar es Salaam, satellite view

Source: Google Earth

The ports of Mtwara (Tanzania), Pemba (Mozambique) and Ncala (Mozambique) were thought to be either too far from Mahenge, or to have poorer logistics connections, lower container availability, or a less frequent shipping schedule. For example, Mtwara port has a quay length of 385m, can accommodate two vessels, and is a regional port for oil & gas exploration and cashew exports.

Figure 25: Port of Mtwara, 2018

Source: Google Earth

Power supply

The Tanzania Electric Supply Company Limited (TANESCO) proposes to upgrade the local power network to meet the loads of the Mahenge graphite plant and other related increased consumer demand. This upgrade includes running a 220kV powerline from Ifakara to Ndororo (Mahenge). A 220/33 kV step down substation is proposed at Ndororo. The proposed substation includes provision of two transformer bays, with one 60 MVA transformer planned initially. The TANESCO proposal also includes running a 33kV powerline for 6 km from Ndororo to the project site. Black Rock is currently negotiating this upgrading with TANESCO. At this stage, it looks like this could cost US$10m, which Black Rock will recover in the form of reduced tariffs through the project lifetime.

Roads

Road transportation accounts for more than 90% of passengers, and about 75% of the freight traffic, according to TanzaniaInvest.com. The road network comprises more than 86,000 km of roads, of which 34,000 km are managed by Tanzania's National Road Agency, with the rest managed by regional and local administrations. TanzaniaInvest.com states that as of 2013, 19% of the national roads (about 6,400 km) and 2% of district roads (about 1,100 km) are paved, suggesting that less than 10% of Tanzania's roads are paved.

Tanzania has a clear geographical advantage as a regional trade hub, situated on the east African coast and being able to serve six land-locked countries. In 2014, the African Development Bank (AfDB) said that inadequate transport infrastructure was hampering economic growth, and competitiveness. In 2013, the World Economic Forum's Global Competitiveness Report ranked Tanzania 134th in the quality of its infrastructure, out of 148 countries. Uganda was 133rd. Since then, AfDB has looked to invest heavily. At the end of 2015, the bank approved US$346m to improve 500 km of roads in Tanzania over five years. In November, 2018, AfDB approved a further US$322m in loans and grants to Tanzania and Burundi to upgrade a further 300 km of roads. **For Black Rock, this highlights the value of being able to use rail. In Tanzania, rail is both cheaper and safer.**

Graphite market increasingly tightening

- Increasing tightness in the graphite market is being driven by exponential demand growth in new industries, and challenged supply from China.
- China already imports +50 mesh material from East Africa, and appears to have an insatiable appetite for new supply; increasing Chinese imports can have a dramatic impact on prices, as seen iron ore and coal in the mid-2000s
- Prices for large flake graphite, have already leapt, and are likely to rise further. Prices for battery grade materials look set to follow as EV penetration takes off.

Demand growth and supply tightness driving prices

Demand for 3-4 Mahenge's over the next decade

The global graphite market was ~2.45m tonnes in 2017. Of this amount, about 900,000 tonnes was natural graphite (flake, amorphous and vein), and the rest synthetic material. Historically, demand for graphite, mainly used in the steel industry, had stagnated, as global steel output peaked. Up until 2017, there had been no new graphite suppliers in the world ex-China for several years; new supplies were not needed.

Recent developments in lithium-ion battery technology, and in some industrial applications, have changed this, effectively transforming the graphite market from a mature one, into a high-growth sector, serving new, and embryonic industries. Industrial sectors that are expected to grow rapidly include thermal management products in electronics, expandable graphite for use in foils and fire retardants, and decarburising materials in electric arc furnace steelmaking. Demand for natural flake graphite is expected to grow by an average of ~8% pa over the next 10 years, driven principally by growth of 20% pa in the lithium-ion battery sector. **Flake graphite demand is expected to more than double over the next decade, from ~630,000 tonnes in 2017 to ~1.4m tonnes by 2027.**

This increase in annual demand of ~750,000 tonnes in 2017-2027, would equate to more than two of Syrah's Balama plant (nameplate capacity of 350,000 tpa) or three of Black Rock's Mahenge project (240,000 tpa). Given the rate at which Chinese resources of large flake graphite are being depleted, and government efforts there to consolidate the industry, required capacity could be more than this. It is a realistic proposition that **the world could need the equivalent of three "Balamas" or four "Mahenges" to satisfy demand over the next decade.**

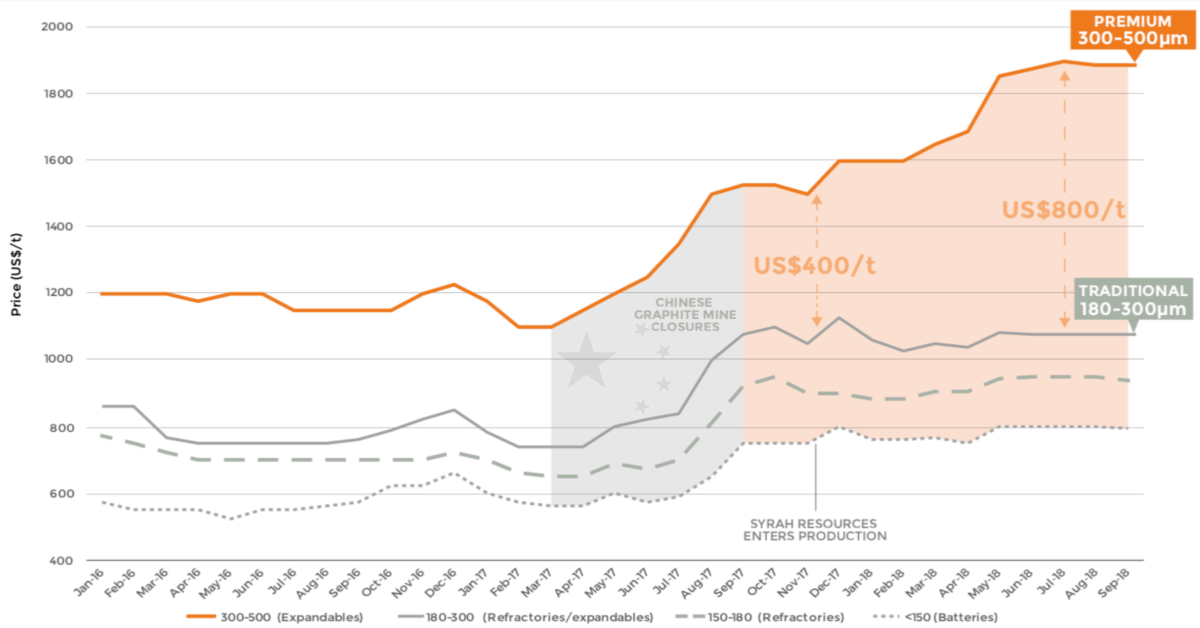
Chinese supply under pressure

Historically, the world has relied heavily on China for graphite supply. China produces about 70% of the world's graphite, and virtually all of the battery anode material. Chinese supplies are now under pressure. Chinese resources of large flake graphite are dwindling, and increasingly strict environmental controls have hampered production. China has now started to import some larger flake material, a trend that is set to continue.

Significant potential for supply shortfalls

Given the above, and even if Syrah's Balama achieves nameplate capacity, there is significant potential for supply deficits over the next couple of years. This would be expected to drive higher graphite prices. Prices for larger flake graphite have already moved. Over the past two years, prices for +32 and +50 mesh material have risen by about US$700/t. In the same period, the price for battery grade material, has risen by about US$200/t. Premiums for higher-grade products have risen significantly. Prices for battery grade material are likely to pick up substantially over the next few years as the penetration rates for electric vehicles take-off.

Figure 26: Pent-up demand and Chinese supply issues being reflected in large flake prices

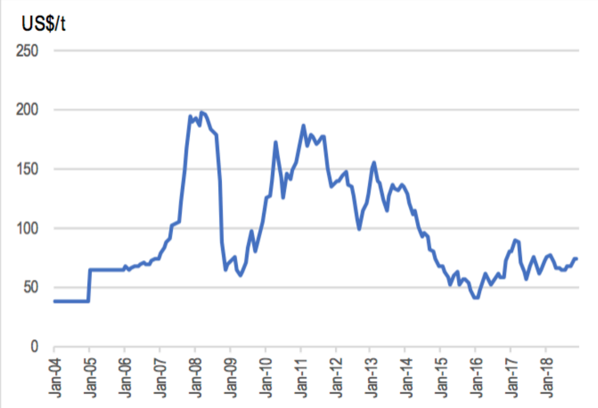


Source: Graphex Mining, October 2018

Increasing Chinese imports can have a significant impact on prices

One lesson from the iron ore and coal markets in the mid-2000s, is that increasing Chinese imports (or lower exports) can have a dramatic impact on market prices. In iron ore, in particular, prices took off as China increasingly imported higher-grade material than was available domestically. In that sense, with Chinese supply of large flake graphite dwindling, and Chinese imports poised to increase, the current graphite market resembles the iron ore market of the mid-2000s.

Figure 27: Iron ore prices



Source: Indexmundi.com

Figure 28: Thermal coal prices

Source: Indexmundi.com

Pricing in the high-end market is opaque

The prices that are more widely available in public markets are generally for refractory grade material. This is because of the large amount of commodity-grade material used in the steel industry. These prices are not representative of the prices in the more specialised flake markets, and the steel industry is not a target segment for Black Rock. Instead, Black Rock will focus on supplying markets where purities of 98% LOI are needed, and where requirements for particular chemical and metallurgical signatures are met by the company's products.

The main factors determining price are purity (carbon content), flake size, particle size distribution, and the absence or otherwise of deleterious elements (Si, Fe, Al, Ni, V, S and Ca are all contaminants in a graphite resource). Resources described as 'graphite-plus-other mineral' may simply be contaminated graphite resources, at least until metallurgical testing proves otherwise.

As the market for premium grade graphite products develops, the market is likely to bifurcate into two tiers, one supplying high-quality materials into the battery sector and select industrial applications such as expandable graphite, and another supplying refractory-grade material. The outlook for prices in the premium market is seen as excellent.

Demand: new technologies driving rapid growth

- Huge pent-up demand for expandable graphite, used in foils and fire retardants, underpins Mahenge's market position
- Demand for electric vehicles and energy storage systems is set to further propel the market as penetration rates increase
- Demand for natural flake graphite could reach ~1.4m tpa by 2027, more than double the size of the current market

Demand growth driven by rapidly growing, embryonic industries

Graphite market dominated by China

Total world graphite consumption was ~2.45m tonnes in 2017. This includes ~1.55m tonnes synthetic graphite, and ~900,000 tonnes natural graphite. The natural graphite market can be further divided into three main categories. Flake graphite accounts for almost 70% of natural graphite demand, and was ~630,000 tonnes in 2017. The remaining 30% is mostly amorphous graphite, with a small (<1%) amount of vein graphite.

Figure 29: Graphite demand by type, 2017

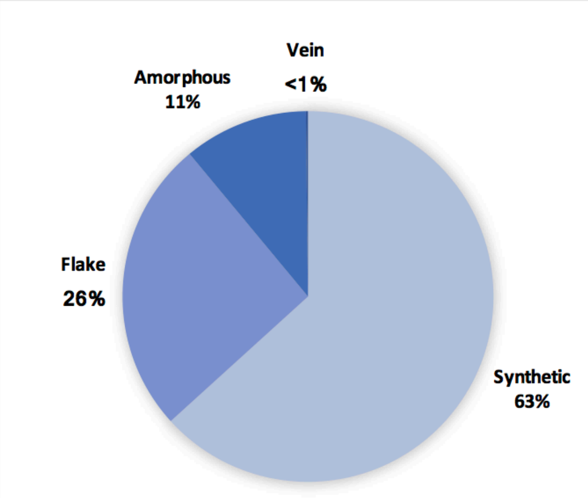
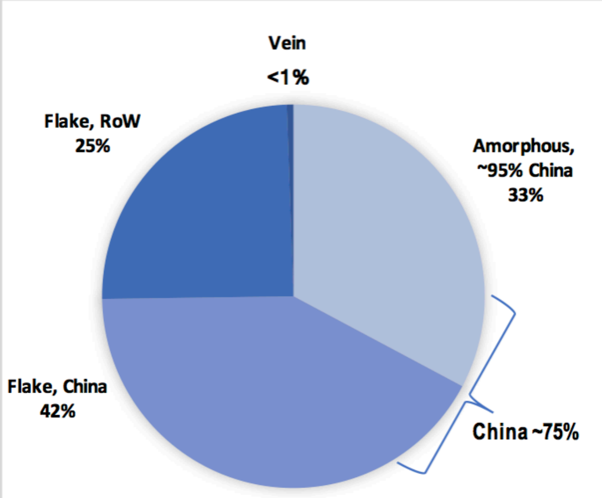


Figure 30: Natural graphite market, 2017



Sources: Various companies' data, Orior Capital estimates

Traditional versus 'new industry' demand

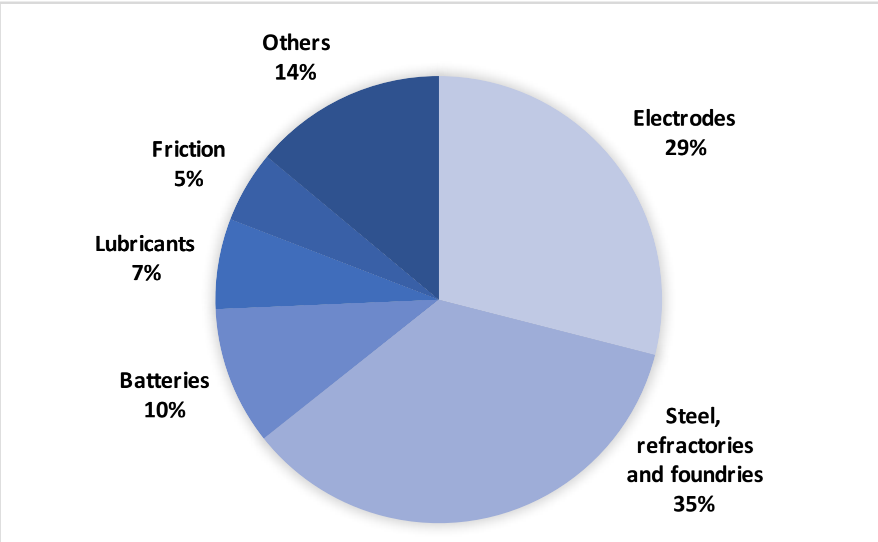
Traditional demand for both synthetic and natural graphite has been driven by the steel industry. Natural graphite is used in steelmaking in refractory bricks that line blast furnaces, to line ladles and crucibles, and directly as an agent to raise the proportion of carbon in the steel mix (in a process called recarburising). Refractories account for about half of demand for natural graphite. Demand from refractories, foundries, and other metallurgical processes together, account for about 60% of natural graphite demand. Synthetic graphite electrodes used in electric arc furnace (EAF) steelmaking account for about half of synthetic graphite demand. Generally speaking, graphite demand from traditional industries is growing slowly.

In contrast, demand from the lithium-ion battery sector is growing rapidly, albeit from a small base. This is driven by increasing take up of consumer electronics products such as smartphones, cameras, laptops, power tools and other devices. Graphite is used as the anode material in batteries, and importantly, there are no substitutes. Over the next few years, two important sectors, electric and hybrid vehicles, and energy storage, are expected to propel graphite demand. Both industries use larger batteries than consumer electronics products, and both are still in their infancy.

In 2017, the battery sector consumed around 180,000 tonnes of graphite, of which 130,000 tonnes was natural graphite (virtually all of which was flake graphite). That is, batteries accounted for ~7% of total graphite demand, and ~20% of natural flake demand. Longer-term, projections for the take-up rates of both the EV and energy storage systems sectors vary widely. Even accounting for greater efficiencies in the spherical graphite manufacturing process (meaning less graphite being used per kWh for battery capacity) graphite demand from the battery sector is expected to grow at ~20% pa. This will drive demand for both synthetic and natural graphite. Assuming this growth rate is sustained over the next decade, the battery sector will consume roughly six-times more graphite in 2027 than in 2017. How the proportions of synthetic and natural graphite change as the battery market develops is uncertain, but assuming the battery sector uses similar proportions of natural and synthetic graphite as now, the increase in annual demand for flake graphite could be more than 600,000 tonnes.

There is also huge pent up demand for expandable graphite used in producing graphite foils, and fire retardants. Fire safety has become an important sector; demand for fire retardants is being driven by technological developments and more stringent safety standards in automotive, aerospace, and in building and construction. Chinese building standards now make it compulsory to use flame retardant building materials. China has banned the use of traditional brominate retardants. China National Building Materials has estimated that China will need 40m tpa of flame retardant building materials, of which 5% is expected to be graphite. This equates to 2.0m tpa of new graphite demand. This is a huge amount, and the market will take time to develop, but it is a striking estimate given global graphite demand for this segment was around 20,000-25,000 tonnes in 2017.

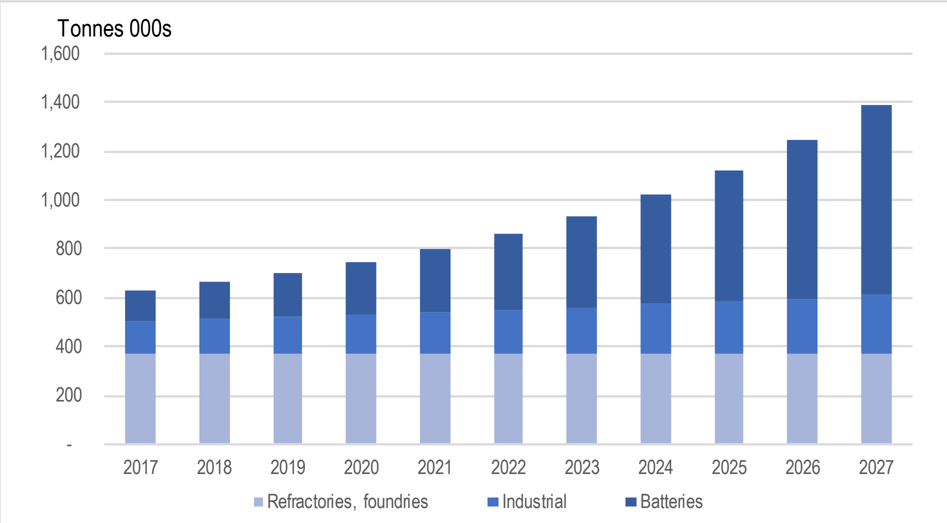
Figure 31: Graphite demand by sector



Source: Various companies' reports, Orior Capital estimates

Assuming that graphite demand for refractories remains flat at 2017 levels over the next decade, that battery demand grows by 20% pa, and industrial demand grows by 6% pa, demand for flake graphite will more than double over the next decade. There is upside potential to these forecasts for both the battery sector and for industrial demand. In particular, the forecast for industrial demand equates to incremental demand of just 10,000 tpa. Given the massive pent-up demand in the expandable market, this does not seem like very much. **There is a risk that demand growth is being hugely under-estimated.**

Figure 32: Natural flake graphite demand to be driven by battery demand



Source: Orior Capital estimates

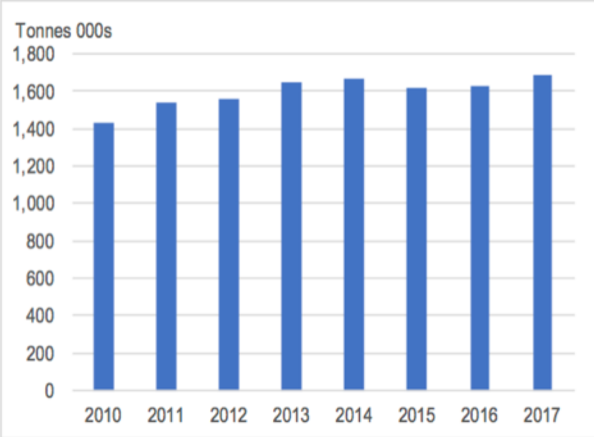
Steel

Refractories account for about 20% of total global graphite demand, and are the second largest application of all graphite after synthetic graphite electrodes. Refractories are the largest application for natural graphite, accounting for ~50% natural graphite demand. Historically, refractories have been the driving force behind graphite demand but as the market for batteries continues to take off, graphite's reliance on refractory demand will begin to decline.

Global crude steel production reached 1.7bn tonnes in 2017. Since 2010, crude steel production has risen by an average of 2% pa. The rapid growth of the previous decade was fuelled by China. As China matures, global steel production will plateau, before beginning to decline. Chinese production appears to have already peaked. In its Short-Range Outlook, published in October 2018, the World Steel Association said it expects global steel demand to increase by 3.9% y-o-y in 2018, and by a further 1.4% y-o-y in 2019.

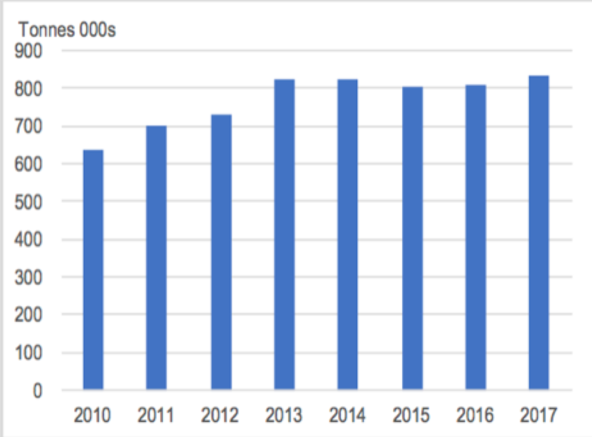
Although overall steel production growth is sluggish, the prospects for electric arc furnace steelmaking are relatively good. The EAF method recycles iron scrap by melting it in an electric arc furnace. It is the synthetic graphite electrodes inside the furnace that actually melt the iron. Graphite has high thermal conductivity and is very resistant to heat and impact. It also has low electrical resistance, which means it can conduct the large electrical currents needed to melt iron.

Figure 33: Global crude steel production



Source: World Steel Association

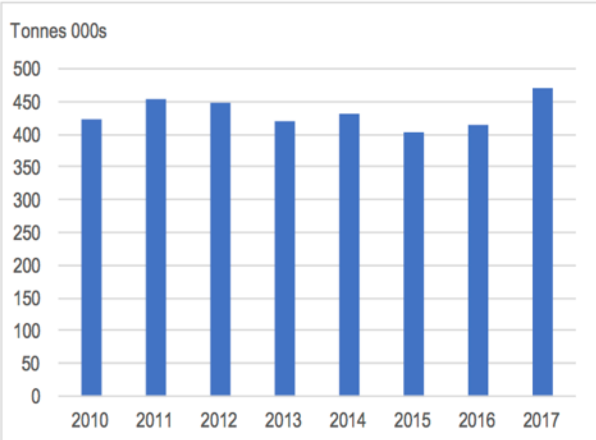
Figure 34: China crude steel production



Source: World Steel Association

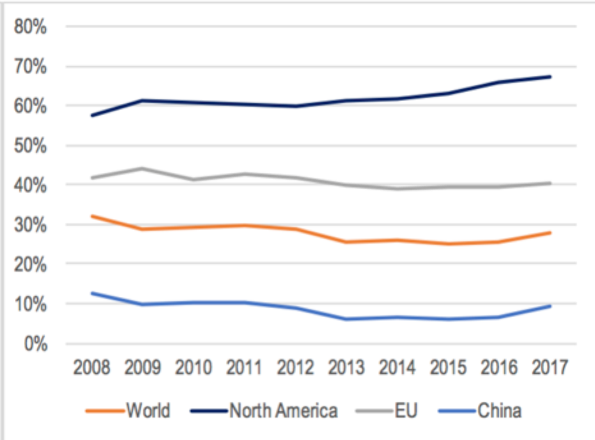
Over the past 15 years or so, Chinese steel output has mainly come from blast furnaces. As the Chinese economy matures, and the availability of steel scrap increases, it is inevitable that China will shift towards EAF-based steel production. EAF production accounted for just 9% of Chinese steel output in 2017. This compares to 67% in North America, and 40% in the European Union.

Figure 35: Global EAF steel production



Source: World Steel Association

Figure 36: Proportion of EAF steel production



Source: World Steel Association

Recarburising – an area of growth

Carburisation is a heat treatment process in which iron or steel is heated, in the presence of a carbon bearing material, and absorbs carbon. Adding carbon can make the steel harder. Typically, the carbon addictive will include a mixture of different carbon-bearing materials including synthetic graphite, natural graphite, metallurgical coke, anthracite and petroleum coke. Each of these have different properties, and the choice of which is employed will come down to chemical performance, the level of impurities and cost. Typically, metallurgical coke and anthracite are lower cost but have higher levels of impurities, whereas synthetic graphite and petroleum coke have more pure carbon contents, but are expensive. Synthetic graphite, usually recycled from electric arc furnace electrodes, has accounted for much of the supply of carbon for recarburising.

The largest use of recarburisers is in EAF steel making. As a result, their use is greatest in North

America and the EU, where EAF penetration rates are high. As EAF use increases in China, the use of graphite in recarburisers will increase as well. In terms of graphite consumption, the recarburiser market is fairly opaque, but has been estimated at about 3m tonnes in 2017. Of this amount, about 10% is graphite (petroleum coke is the largest portion at about 300,000 tonnes) of which about 30,000 tonnes is believed to be natural graphite (and mostly amorphous graphite). Over the next decade, graphite demand for recarburising is expected to grow at about 6% pa, meaning an increase in demand of ~80% over the next ten years. Assuming this growth comes from flake graphite, it would add around 24,000 tpa to annual graphite demand.

Engineering

Engineering captures a broad range of uses including foils, fire retardants, fiction applications, powder metallurgy, ceramics, pencils, inks, agriculture (graphite is used in soil remediation), military specific applications, composites, catalysts, nuclear reactor fuel spheres and others.

Fire safety

Fire safety has become a key focus for preventing loss of life, not least because of several large fires including the Lacrosse Melbourne Docklands fire in 2014, the Grenfell Tower tragedy in London in June 2017, and the Zen Tower fire in Dubai, in May 2018. Fire retardants use ‘expandable graphite’. This has the ability to expand to several hundred times its original volume when it is heated. Usually, expandable graphite is produced from +150, +100, +80, +50, and +32 mesh sizes. The graphite is subjected to heat treatment and leaching with strong acids to weaken the bonds between the graphite layers. This high cost of heat and chemical processing has meant that most fire retardants are produced in China. Expandable graphite has advantages over other flame retardant building materials because it is halogen and heavy metal free.

Foils

Graphite foils are mainly used in gaskets, seals and valve casings, because they can withstand high temperatures and pressures. They are also used in electronics as ‘heat sinks’, and as thermal conductors in the automotive sector where the use of electronics is increasing. According to Electronics Cooling, natural graphite-based heat sinks can provide better conductivity than aluminium, whilst weighing 78% less than copper. Further, graphite is used in the chemical, petrochemical and nuclear industries where the ability to retain flexibility under high pressure and temperature, and the ability to withstand chemical attack, are valuable. Natural graphite is the main component in graphite foils. The graphite is intercalated in an acid bath and then exfoliated by heating. Upon heating, the graphite expands, and can be rolled into sheets, which are then cut.

Nuclear

Pebble Bed Modular Reactors are uranium-fuelled, graphite-moderated, small-scale reactors that have several advantages over traditional larger-scale reactors. Pebble Bed reactors use inert gases rather than water as a coolant, meaning there is no need for the complex water cooling systems used in conventional reactors. Being inert, the coolant gases do not carry contaminants. A Pebble Bed reactor cools naturally when it is shut down, which means there is no need for additional safety systems, and they operate at higher temperatures, which makes more efficient use of the fuel.

Pebble Bed reactors get their name from the spherical fuel elements, known as ‘pebbles’. These are balls, about the size of tennis or billiard balls, made of graphite. Each pebble contains fuel particles (usually uranium U235), that are cloaked in graphite. Thousands of these pebbles sit in the reaction chamber, forming a core, and are cooled by inert gases (such as helium or nitrogen) that do not react with the fuel elements.

China plans to build up to 300 GW of nuclear reactors, and pebble bed reactors are expected to play a major part. According to Northern Graphite, each pebble bed reactor requires 300 tonnes of graphite initially, with a further 60-100 tpa to operate. This suggests that at an average reactor capacity of 500 KWh, annual demand for graphite would be 36000 to 60,000 tonnes.

Lubricants

Graphite is used in grease, dry films and dispersions to manage friction. It is used as an anti-seize agent in railroad and steel mill applications, and as an anti-thread compound in oil fields. Graphite's greasy texture, caused by its flakes being able to slide over one another, makes it an effective industrial lubricant. At a household level, this is why rubbing a key with a pencil can prevent the key jamming in the lock, and why a pencil can be used to unjam a stuck zip. In 2017, ~160,000 tonnes of graphite were consumed in various lubricants. Of this amount, ~30% was from natural graphite, and the rest from synthetic graphite.

Plastics, polymers and rubbers

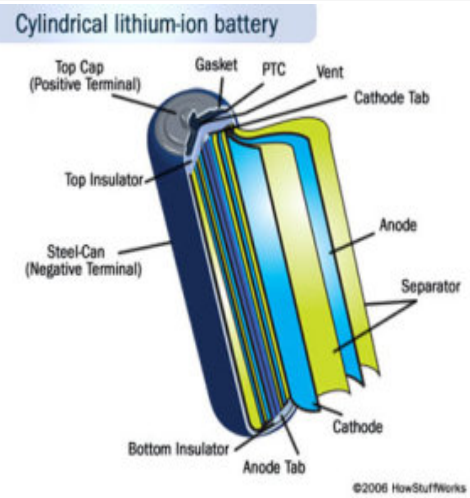
Graphite powders can be added into plastics and polymers to improve their electrical and thermal properties, and to improve their resistance to friction wear. Usually, polytetrafluoroethylene (PTFE) and polyethylene are blended with graphite. In 2017, demand from this segment was about 12,000 tonnes. According to CPC, graphite powders are used in power generation cables, electrical wire bundles, anti-static flooring, anti-static packaging, and conductive coatings. In paints and coatings, graphite is added for conductivity, lubrication, as a thermal enhancer or as a surface protection modifier. Uses include heat exchanger coatings, automotive plastic parts coatings, and engine block coatings. Synthetic and high-purity natural graphite are used in these applications.

Lithium-ion batteries

Lithium-ion batteries are smaller and lighter than traditional batteries. They have a relatively flat voltage profile, meaning they provide close to full power until they are discharged, and they discharge slowly when not in use. They are used in small consumer electronic items such as hand-phones and laptops, and are increasingly seen in larger items such as power tools, and other devices. Over the next few years, graphite demand will be driven by increasing uptake in EVs and energy storage. Both these industries use bigger batteries than consumer electronics products.

The anode in lithium-ion batteries is made of graphite. Graphite is the second largest component in lithium-ion batteries by weight. In fact, a typical battery may contain 10-15x as much graphite as lithium. Once losses in manufacturing are accounted for, a lithium-ion battery may use as much as 30 times more graphite than lithium.

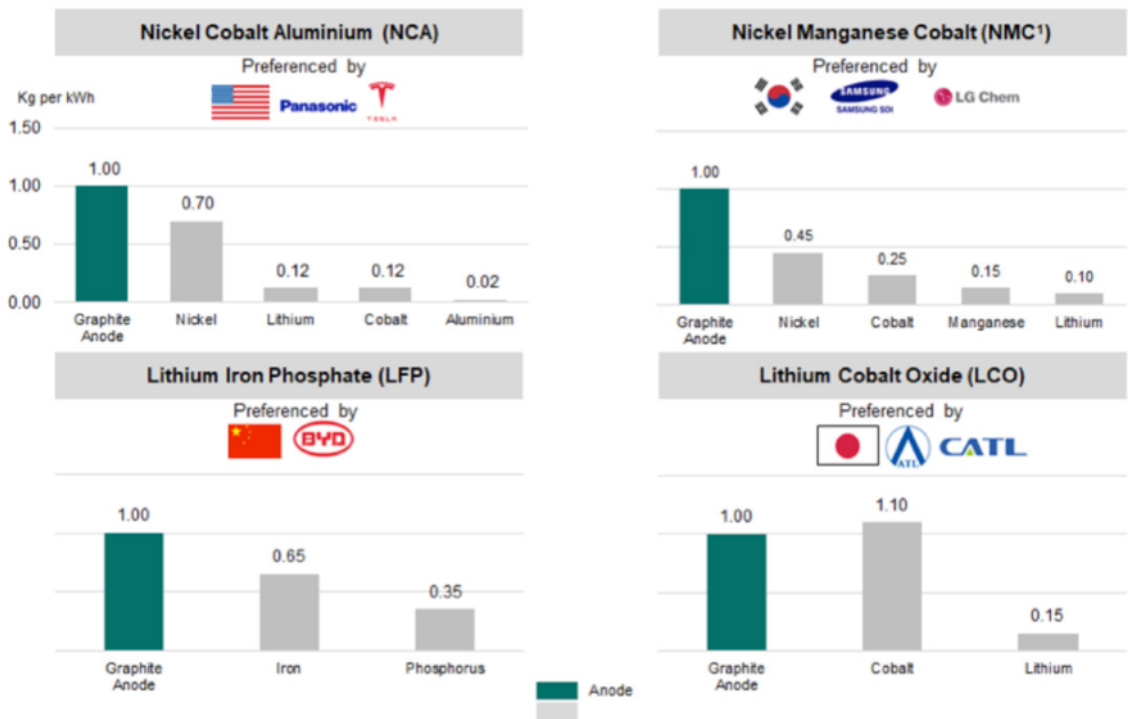
Figure 37: Construction of a cylindrical lithium-ion battery



Source: How Stuff Works

Batteries are classified into two types. Primary batteries are single use. Lithium, alkali and zinc-carbon batteries are primary batteries. Secondary batteries are rechargeable. Lead-acid and lithium-ion batteries are secondary batteries.

Figure 38: Graphite intensity for different battery technologies

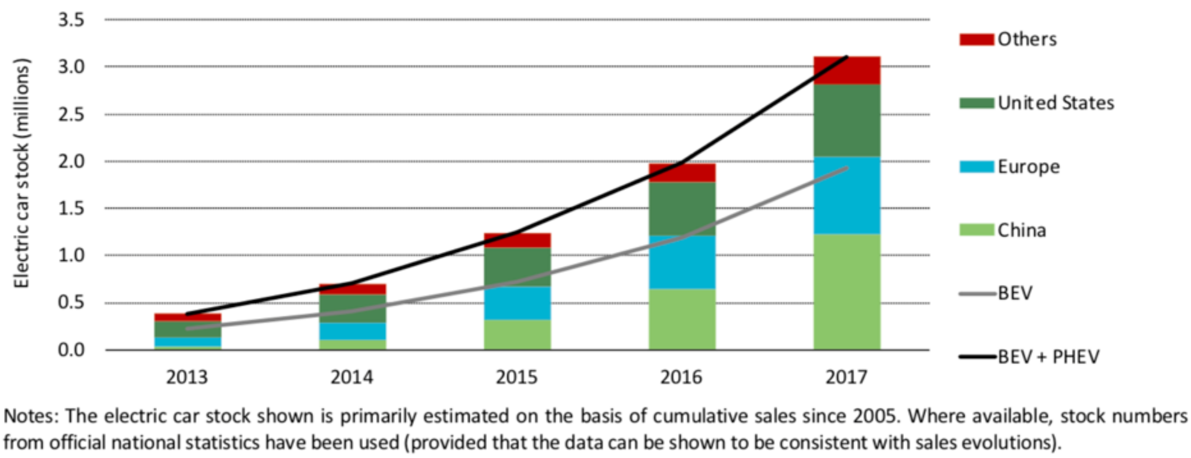


Source: Syrah Resources

Electric Vehicles

According to the International Energy Agency, global sales of new electric cars surpassed 1.0m vehicles in 2017. In fact, sales in 2017 were up 54% y-o-y. More than half of new vehicle sales were in China. Although global penetration of electric cars is currently low, it is growing rapidly from a low base. Even in China, by far the biggest market, electric cars still only accounted for 2.2% of new car sales in 2017. Twice as many electric cars were sold in China as the US, the second largest market. In total, the global stock of electric cars surpassed 3.0m vehicles in 2017, according to the IEA. China accounts for about 40% of the global stock.

Figure 39: Evolution of the global electric car stock, 2013-2017



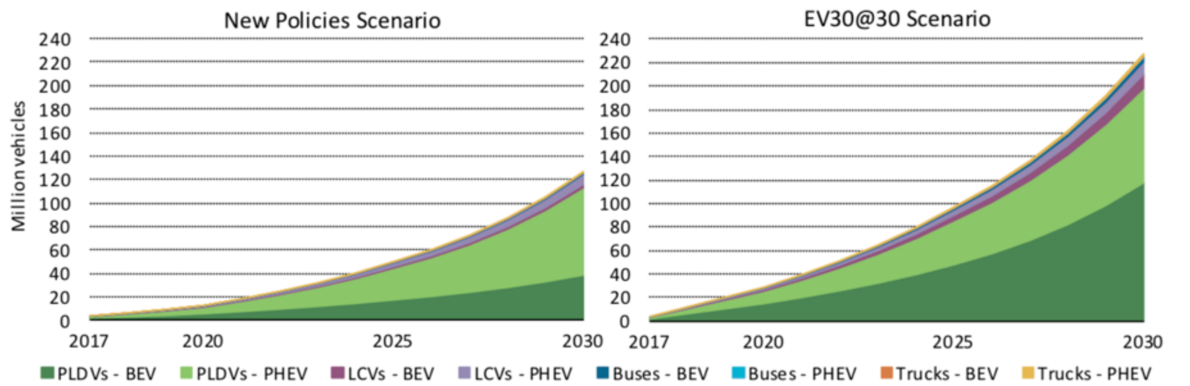
Source: International Energy Agency, Global EV Outlook, 2018

The IEA expects EV penetration to grow exponentially over the next decade or more. In its Global EV Outlook 2018, the IEA develops two scenarios for future EV demand, based on different policy outcomes. In the New Policies Scenario, which takes into account existing policy announcements by various governments, the IEA predicts that the global stock of electric vehicles will reach 13m vehicles by 2020 (up from 3.7m in 2017) and almost 130m vehicles by 2030 (excluding two- and three-wheelers). This represents an average annual growth rate of 24% pa 2017-2030.

In this scenario, sales of electric vehicles would be around 4.0m units in 2020, up from 1.4m units in 2017, and 21.5m units by 2030. The implications of this for the graphite market are significant. Assuming 100,000 tonnes of graphite per 1.0m EVs, in 2020 vehicular demand for graphite could be as much as 400,000 tonnes.

In the more ambitious ‘EV30@30’ scenario, the IEA forecasts a global stock of 228m EVs (excluding two- and three-wheelers) by 2030. This includes 220m ‘light domestic vehicles’ (130m battery vehicles and 90m plug-in hybrids) by 2030. In total, this is about 100m more vehicles than in the base case scenario. The IEA recognises that achieving this level of penetration will require rapid adoption and geographical expansion of policy commitments.

Figure 40: Global EV stock in the New Policies and EV30@30 scenarios, 2017-2030



Notes: PLDVs = passenger light duty vehicles; LCVs = light commercial vehicles; BEVs = battery electric vehicles; PHEV = plug-in hybrid electric vehicles.

Source: International Energy Agency, Global EV Outlook, 2018

According to Northern Graphite, an average electric vehicle uses up to 70 kg of graphite, and an average hybrid vehicle up to 10 kg of graphite. Every one million new EVs could require around 100,000 tonnes of graphite. This represents ~4% of the graphite market in 2017, and yet represents only 1.1% of the global new vehicle market. Even modest adoption of electric and hybrid vehicles is likely to have a significant impact on demand for graphite.

According to a research paper by Olsen et al, the Chevy Volt battery pack contains ~30 kg of graphite, the Nissan Leaf battery pack contains ~40 kg graphite, and the battery pack in the Tesla Roadster contains ~100kg graphite. The Tesla Model S battery pack (85 kWh) contains ~50 kg graphite. Assuming Tesla's Giga factory has capacity to produce 50 GWh per annum, it could supply batteries for ~500,000 EVs, each with 65-85 kWh batteries. USGS estimates that when the plant is complete, it will require 93,000 tons of flake graphite to produce 35,200 tons of spherical graphite for use as anode material for lithium-ion batteries.

Spherical graphite is made from flake graphite in a process that involves crushing, mechanical separation, grinding, purification, flotation and pelletizing. In this process, 50-70% of the flake graphite can be lost (yields are typically 30-50%), meaning that one tonne of spherical graphite may require two to three tonnes of flake graphite. (Tests of graphite from Black Rock's Ulanzi deposit demonstrated much better performance than this).

The growth in the electric vehicle (EV) and hybrid electrical vehicle (HEV) markets is a significant area of demand growth for both synthetic and natural graphite. Traditionally, synthetic graphite has been used in batteries because of its greater consistency in terms of grade and impurities, and its higher carbon content. Developments in natural graphite mean that processed flake graphite can now compete with synthetic graphite. Typically, a battery maker will use a mix of inputs – synthetic and spherical graphite, as well as other carbon materials – to achieve the specifications required.

Reference: The Geological Society of America Special Paper 520, 2016; Natural graphite demand and supply—Implications for electric vehicle battery requirements, Donald W. Olson, Robert L. Virta, Mahbood Mahdavi, Elizabeth S. Sangine, Steven M. Fortier.

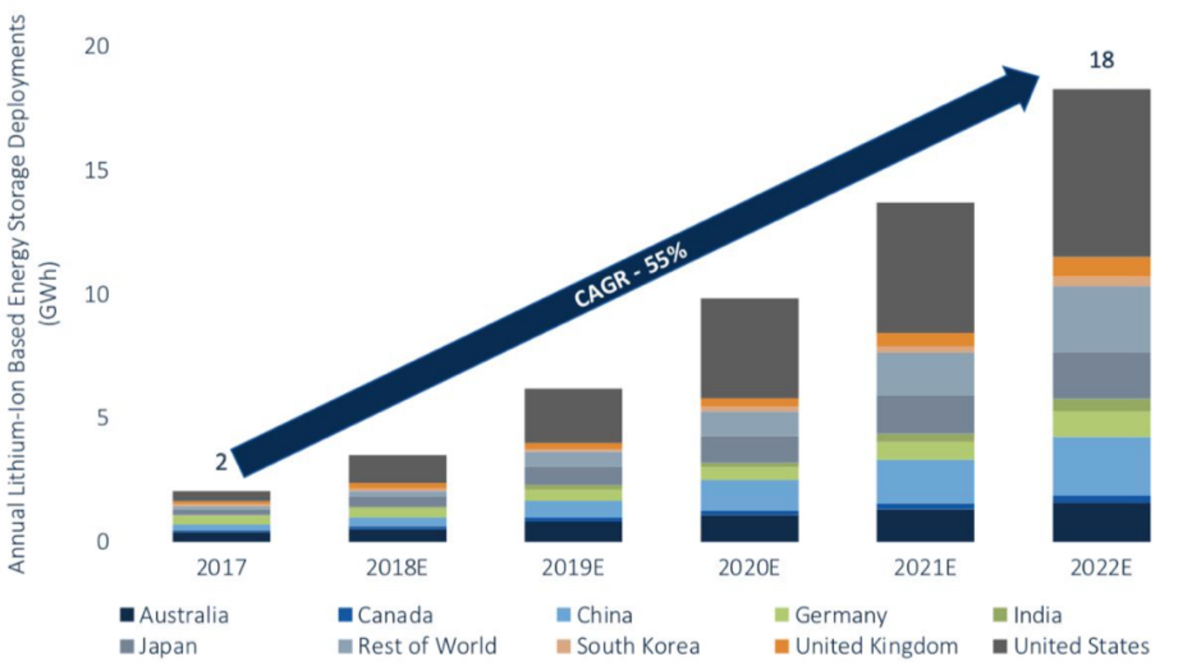
Energy storage systems

The other new and rapidly growing market is the energy storage market. In August 2018, GTM Research (Green Tech Media) estimated that global lithium-ion battery deployments will grow by 55% pa from just 2 GWh in 2017 to 18 GWh in 2022. Energy storage capacity is still small; in 2017, battery capacity for EVs was ~126 GWh. Most energy storage capacity being developed is in the US, China, Japan and Australia.

Small capacity and high costs, have so far limited the adoption of lithium-ion batteries for energy storage solutions. As more factories are built, and costs come down, integrating battery capacity into electricity grids becomes more realistic. GTM Research estimate that battery pack prices will fall from US$219/KWh in 2017 to US$39/KWh by 2040.

These lower costs will have a significant impact on the market. California has considered completely phasing out fossil-fuel power by 2045. In Australia, batteries could displace new and existing gas plants for peak power as early as 2025, and begin challenging for bulk power a decade later.

Figure 41: Annual lithium-ion energy storage deployment forecast, 2017-2030 (GWh)



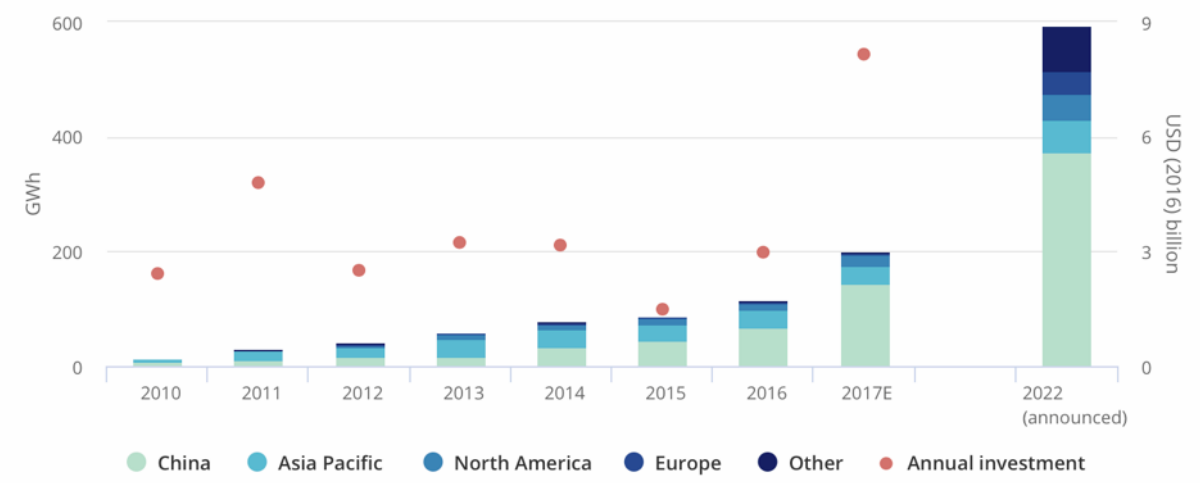
Source: Greentechmedia.com

Cost and performance are key to wider adoption

Governments around the world have put in place various targets and incentives – 'push factors' – to drive the adoption of electric vehicles. 'Pull factors' are battery performance, and cost. Lithium-ion battery costs have fallen dramatically over the past few years, and are expected to fall further. According to IEA estimates (2017), for each doubling in lithium-ion battery output, costs fall by 19%. Two factors are driving this; improving battery technology, and larger-scale manufacturing.

According to IEA, battery manufacturing capacity has grown rapidly, from very little in 2010 to around 200 GWh of EV and energy storage lithium-ion battery capacity in 2017. Investment in the sector was expected to have reached almost US$8.0bn last year. There are more than 200 factories around the world, most of them in China, though other regions are growing quickly. Tesla, which is ramping up its Gigafactory 1 in California, is the obvious non-China example. Tesla has also proposed to build a European plant, though a location has not yet been decided. Tesla has considered the Czech Republic, and Portugal, both of which have significant lithium deposits, as well as Poland and Hungary. Others including Panasonic Samsung in Hungary, LG Chem in Poland and Daimler in Germany. Battery plants are being built by a variety of companies in automotive, chemicals, electronics (Panasonic) and as well as battery specialists such as Contemporary Amperex Technology Co. Limited (CATL) (a Chinese technology company) and Guoxuan High-Tech.

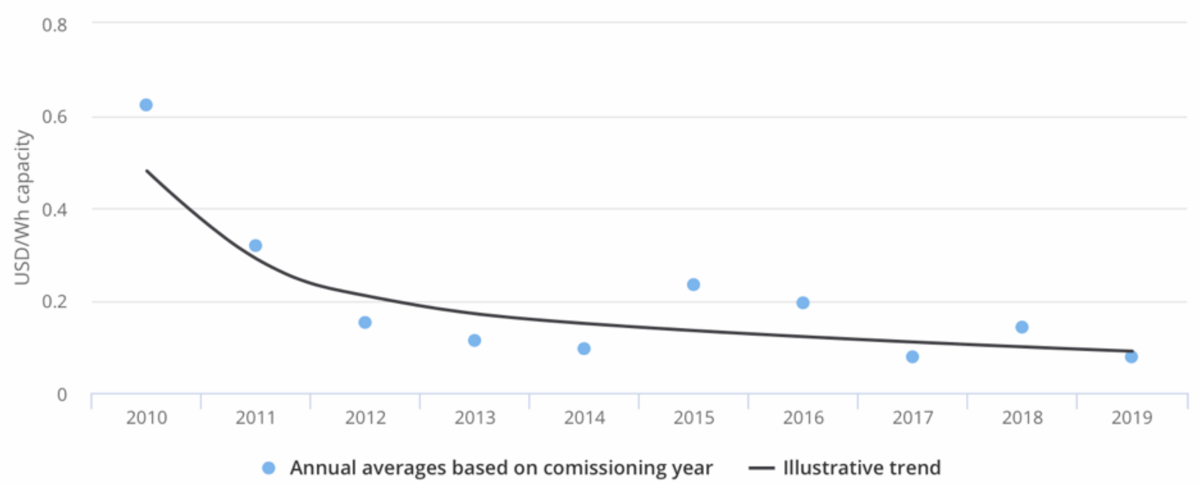
Figure 42: Commissioned EV and energy storage lithium-ion battery cell production by region, and associated annual investment



Source: IEA, 2017

Factory capacity has grown tenfold since 2006, from an average capacity of 500 MWh/year in 2006-2010, to ~5 GWh/year (post-2016). These larger scale plants, together with greater sophistication in manufacturing techniques, and maturing supply chains are bringing down costs.

Figure 43: Capital costs per unit of new EV and energy storage battery manufacturing capacity



Source: IEA, 2017

Supply: challenged in China, ramping in Africa

- Supply from China, the world's largest producer, is being hampered by dwindling grades, and tougher environmental controls
- Several African projects are looking to ramp up; financing is likely to be challenging for projects at the pre-DFS stage
- The Mahenge project looks compelling; supply growth over the next few years may come down to two large players, in Syrah and Black Rock, with a number of smaller players serving niche markets

Global dependence on China

China is the world's largest producer of both synthetic and natural graphite. In 2017, China produced ~50% of the world's synthetic graphite, and ~75% of the world's natural graphite. China accounts for nearly all (>95%) of the world's amorphous graphite output, and ~60-65% of the world's flake graphite output.

China dominates the graphite supply for battery anodes. China is the largest producer of fine to medium flake graphite, which is used to produce spherical graphite. As a result, China produces virtually all of the natural graphite that is used in lithium-ion batteries. It also has a ready supply of comparatively low-value synthetic graphite, including recycled anode material. In Japan, a higher proportion of spherical graphite is used to make anodes, with this spherical graphite also sourced from China.

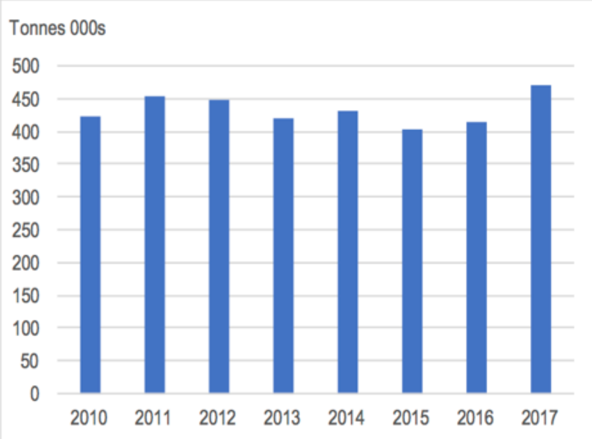
In 2017, non-Chinese production of flake graphite was around 235,000 tonnes. Brazil is the second largest producer, accounting for about 10% of natural graphite production.

Situation critical

It is this dependence on China for supplies, and a lack of other new sources, that has prompted both the US, and the EU, to classify graphite as a critical raw material. The European Commission classifies critical raw materials by a series of measures including an import reliance, and a substitutability index. Currently the EU relies on imports for 99% of its graphite demand, with 63% of imports coming from China, and a further 13% from Brazil. The EU ranks substitutability on a scale of 0 to 1, with 1 being the least substitutable materials. The EU ranks graphite 0.95 on this index.

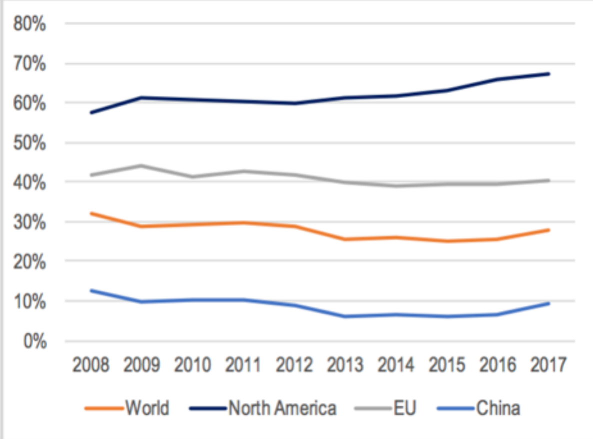
Given the current reliance on China, the expectation for penetration of electric vehicles to advance quickly, the potential for huge demand from the energy storage systems space, and developments in industries such as fire safety and others, **there is a clear strategic need for secure, sustainable and cost effective supplies to be developed from non-Chinese sources.**

Figure 44: Global production of natural graphite



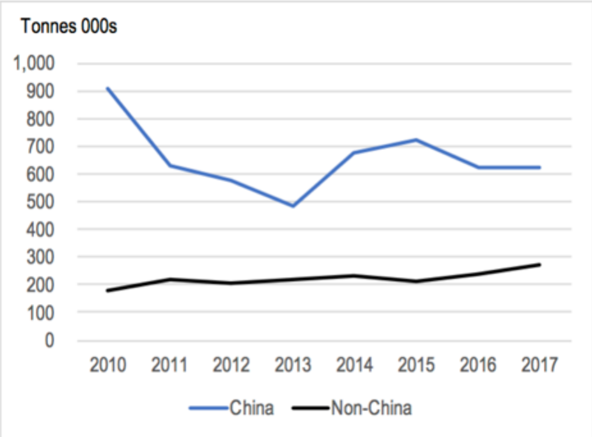
Source: Roskill

Figure 45: Natural graphite production by type



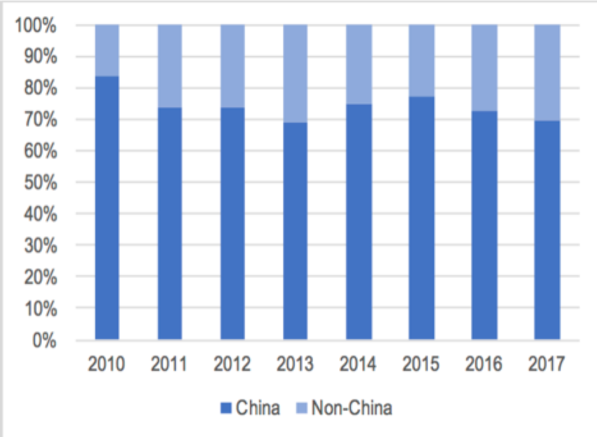
Source: Roskill

Figure 46: Natural graphite output, China and RoW



Source: Roskill

Figure 47: Natural graphite supply by type



Source: Roskill

China mines graphite in two main regions; Shandong and Heilongjiang. Production in Shandong is mainly large flakes. Various reports suggest that this supply of large flakes is now declining, either because the reserves are being depleted or because of stricter Chinese environmental regulations. This bodes well for Black Rock, and is probably a reason the company has so readily found offtake partners in China.

Production in Heilongjiang is mainly of smaller flakes. In 2014, Mining Weekly reported that Heilongjiang accounted for ~45% of Chinese natural graphite production and ~29% of global production. The majority of its flake graphite production is very small, in the +200 mesh range. There has been excess capacity in small flakes in Heilongjiang – established to serve the lithium-ion battery market – and this will continue to restrict upside in prices of small flake graphite, at least until battery penetration rates increase and this excess capacity in China is absorbed.

China's environmental crackdown

Over the past few years, China has introduced stricter environmental controls that have impacted a number of industries, including graphite, and has enforced its environmental code more strenuously. Jurisdiction for plant inspections, a common tool used to restrict output in China, have moved from local authorities to the national government, and they have become more frequent. Penalties for flouting the rules are harsher. China's new Environmental Protection Tax Law came into effect on 1 January 2018.

Plant closures are not new. The Chinese government started a concerted campaign to reduce air pollution in Beijing ahead of the 2008 Olympics, closing more than 450 mining operations, including graphite mines. In 2013, the government suspended the operations of 55 amorphous graphite producers in Shandong, which at the time accounted for 10% of Chinese graphite production. Since 2016, the government has stepped up its efforts. Typically, the government targets plants that use the most acid in producing spherical graphite for the battery industry, or expandable graphite. The current focus appears to be on forcing consolidation in Heilongjiang, where there are about 50 producers. In 2014, the China Graphite Industry Association warned that as a result of the highly fragmented nature of the industry, and often essentially unregulated mining practices, China's graphite resources could be largely depleted within 20 years.

According to Northern Graphite, Chinese domestic demand for expandable graphite is ~70,000 tpa. China produces about 25,000 tpa of +50 mesh flake, and meets remaining demand with +80 mesh flake. Expandable graphite with very high expansion rates requires +32 mesh flakes. There is a shortage of +32 and +50 mesh material, and China now imports +50 mesh flake from Africa.

Immediate opportunity; new projects abound

The upshot of all this is clear; there is an immediate opportunity in large flake graphite. New suppliers of high-quality materials should be able to supply into a rapidly growing sector that is currently seeing shortages and which the governments of the US and the EU see as being critical.

As a result, there is no shortage of budding new supply. There are more than 30 projects outside of China that are in various stages of development. The combined capacity of these projects is around 2.0m tpa, though relatively few are likely to come on stream anytime soon, and have some already been halted.

Over the past few years, only two new flake graphite producers have commenced operations. Demand has been driven by the traditional steel-related industries, and as a result, demand growth has been slow. China had substantial overcapacity in graphite, and Chinese exports tended to keep world prices low. As a result, supply has been broadly flat. Two projects, the Woxna project in Sweden and the Uley project in Australia, came on stream in 2014, and were closed again in 2015. In fact, in the western world, the only major projects to come on stream over the past few years have been Imerys' Okanjande project in Namibia, and Syrah's Balama project in Mozambique, both of which started in 2017. In 2017, flake production in the world ex-China was only about 100,000 tonnes more than in 2010.

There are plenty of budding projects in East Africa, and some in the US and Canada, hoping to fill the expected supply gap. These are at various stages of development. Ultimately, the more thoroughly engineered a project is, the more likely it will attract financing. This means, it is likely that companies will have to undertake DFS studies before they are likely to attract financing; at least, financing at a palatable cost.

Syrah Resources' ramp up issues at Balama have not helped market perceptions of the sector. Syrah reported, 2 February, 2018, an issue in its' fines graphite circuit. Repairs were completed in April 2018. On 4 October, 2018, a fire occurred in the primary classifier (the part that classifies and distributes milled material from the scrubber before flotation). Production resumed in November. While frustrating for management and investors alike, these things are perhaps not surprising. Syrah did not complete a DFS study, deciding instead to go straight to production from the PFS stage. This might have made sense from a "grab the market" perspective. From an engineering perspective, it made it hard to know whether the plant was optimally suited to the deposit (it was not). Also, there was no operational readiness study, something that Black Rock has focused on.

Figure 48: Some development stage graphite projects

Company	Code	Project	Capacity Tonnes pa	Latest study	NPV US$ m	Initial capex, US$ m	Comments
Australia							
Lincoln Minerals	LML.AX	Kookaburra Gully	35,000	FS, Nov 2017	59	32	NPV is pre-tax
Renascor Resources	RNU.AX	Siviour	142,000	PFS, March 2018	500	99	NPV is post-tax
Canada							
Focus Graphite	VMS.V	Lac Knife	44,300	FS, 2014	124	125	NPV is post-tax
Mason Graphite	LLG.V	Lac Guéret	51,900	FS, updated Dec 2018	209	194	NPV is post-tax
Nouveau Monde Graphite	NOU.V	Matawinie	100,000	FS, Oct 2018	575	211	NPV stated at 8%
Madagascar							
Next Source Materials	NEXT.V	Molo	51,000	FS, updated 2017	26	18	NPV, capex for Phase 1 only. Phase 2 is 34,000 tpa
Malawi							
Sovereign Minerals	SVM.AX	Malingunde	52,000	PFS, Nov 2018	201	49	NPV is pre-tax
Mozambique							
Battery Minerals	BAT.AX	Montepuez	50,000	VES, Oct 2017	n.d.	51	NPV not disclosed
		Balama Central	58,000	FS, Dec 2018	n.d.	69	NPV not disclosed
Triton Minerals	TON.AX	Ancuabe	60,000	DFS, Dec 2017	298	99	NPV is pre-tax
Tanzania							
Black Rock Mining	BKT.AX	Mahenge	240,000	DFS, Oct 2018	895	115	NPV post tax, and net of government stake
Graphex Mining	GPX.AX	Chilalo	108,000	PFS, updated Sept 2018	273	44	NPV is post-tax, but excludes government's 16% stake
Kibaran	KNL.AX	Epanko	60,000	FS, June 2017	211	89	NPV is pre-tax. Also looking at downstream production
Magnis Emergy Technologies	MNS.AX	Nachu	240,000	BFS, March 2016	1,690	269	NPV is post-tax, graphite only
Volt Resources	VRC.AX	Bunyu	23,700	FS, Phase 1, July 2018	15	32	NPV, capex for Phase 1 only. Phase 2 is 170,000 tpa
Walkabout Resources	WKT.AX	Lindi Jumbo	40,000	DFS, February 2017	180	30	NPV post tax, and net of government stake

Source: Company data, Orior Capital estimates

Appendix 1 – The Mahenge graphite project

Location

Mahenge sits towards the south-western end of the Eastern Arc Mountains, a mountain chain that runs northeast to southwest, with the northeast end of the chain in Kenya, and the other ranges in Tanzania. The climate is temperate, with average monthly temperatures ranging from 17°C to 33°C. Average annual humidity is 70%. Average annual rainfall is approximately 1,870mm, with average evaporation of 1,170mm; there is a positive water balance through the course of the year. Typically, there are long rainy spells during March and April (the wettest months), and shorter rains in November to January. The dry season is May to October.

The Mahenge graphite project is located at the edge of the Mahenge Mountains which rise to ~1,500m above sea level. The area is mountainous with north-south oriented steeply-dipping hills and scarps. There is good natural drainage on mountain slopes. The mountains typically have linear slope gradients of 70% to 85%, while the U-shaped valleys are flatter with average slope gradient of 18%. The plant will be located 600m north of the Ulanzi pit at an elevation of 487m above sea level.

The Mbaha River crosses the area of the proposed Ulanzi pit and mill dry stack area. It joins the Luri River, one of only 5 permanent rivers in the area. Management believes it will be straightforward to re-route the Mbaha River at the project site.

Vegetation in the region is diverse, though in the project area, much of the forest has been degraded by local people, probably in order to develop subsistence farming, though now, only a small proportion is actually farmed.

Permitting

The Mahenge Graphite Project is held under 4 prospecting licenses, that surround the town of Mahenge. The entire Mineral Resource lies within one of these licenses. All 4 licenses are held 100% by Black Rock through its subsidiary, Mahenge Resources Limited. The licenses were granted under the Tanzanian Mining Act 2010 by the United Republic of Tanzanian Ministry of Energy and Minerals. Black Rock acquired the licenses in 2014.

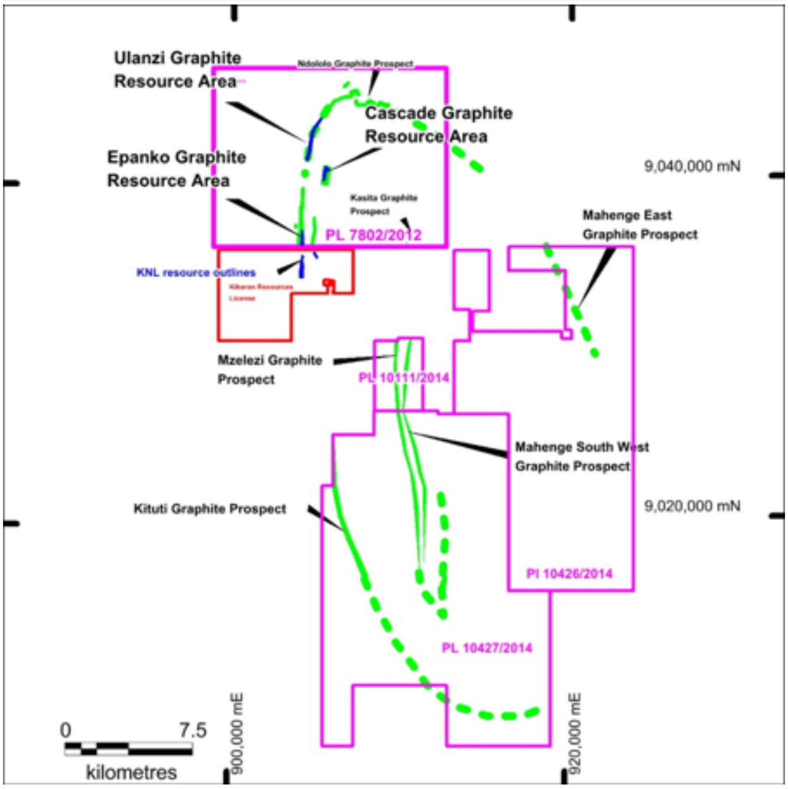
Under Tanzanian law, a prospecting license allows a company to explore for a period of 4 years. The licenses can be extended twice for a total of a further 5 years. That is, a company can explore for a total of 9 years. Upon the presentation of a suitable feasibility study, a Special Mining License (SML) can be applied for that will cover an area of 35 sq. km (for projects costing more than US$100m) with a 25-year duration. A SML has the advantage of extended tenure, but contains provisions for a 30% local listing on the Dar es Salam Stock Exchange. This is a consequence of the recent Mining Code reset. As a result, financiers no longer consider SML licenses as strong instruments. Black Rock has opted to apply for two contiguous Mining Licences (ML) to cover the project area. While a ML has a reduced footprint of 10 sq. km, and a reduced life of 10 years, it avoids the 30% local listing rule, and provides for future flexibility, particularly in regards to any future relaxation of the Mining Code as Tanzania seeks to attract inbound investment.

Figure 49: Black Rock license area, Mahenge

License type	License Number	Area (km²)	Date Granted	Expiry Date	Stake
PL	7802/2012	144	3/4/2012	2/4/2019	100%
PL	10111/2014	13	13/8/2014	12/8/2020	100%
PL	10426/2014	155	2/12/2014	1/12/2018	100%
PL	10427/2014	209	2/12/2014	1/12/2018	100%
Total		**520**			

Source: Black Rock Mining, DFS October 2018

Figure 50: Mahenge license area



Source: Black Rock Mining, DFS October 2018

Geology

The project sits within the Proterozoic Mozambique Orogenic Belt. The Belt comprises high-grade mid-crustal rocks with a Neoproterozoic (1,000 Ma to 541 Ma; 'neo' meaning 'new') metamorphic overlay. The belt is divided into eastern and western portions. The western portion comprises upper amphibolite-grade gneisses with emplacement ages predominantly between 2,970 to 2,648 Ma (Johnson et al., 2003) but also as young as 1,837 Ma. The eastern portion comprises high-grade, arc-derived lithologies with Pan-African-aged emplacement ages ranging between 841 Ma and 632 Ma.

In **'Techtonic Evolution of the Mozambique Belt, Eastern Africa', 2006, Cutten, Johnson and De Waele** suggest the different geologies in the western and eastern basins arise from the eastern basin being thrust over the western basin, during the closure of the Mozambique Ocean, 585 Ma to 550

Ma. The belt as a whole has undergone granulite phase metamorphism (under high-temperature and moderate pressure) and the Mahenge region has undergone intense deformation to form a tight poly-phase sequence of marble, mafic and felsic gneises and graphitic schists as part of the Mahenge Synform (a concave formation). The Mineral Resources are located on the western side of this concave formation.

Resources

The Mahenge Graphite Project comprises the Ulanzi, Epanko and Cascades resources areas. Total Mineral Resources across the three sites amount to 211.9m tonnes at an average grade of 7.8% TGC. There is a high-grade portion within the resource measuring 46.6m tonnes at 10.6% TGC. The Mahenge Mineral Resource is the 4th largest JORC-compliant graphite resource globally. It was delineated from the results of 175 RC holes totalling 15,167m and 34 diamond holes totalling 3,911m.

The Cascades resource contains a higher-grade zone from surface of 12.9m tonnes @12.5% TGC (included in the 46.6m tonnes global high-grade resource). This is substantially higher-grade than immediately available at Ulanzi. It offers the potential to enhance mining grade in the early years (though the current intention is for Cascades to supply Phase 3), thus enabling Black Rock to achieve significantly lower operating costs.

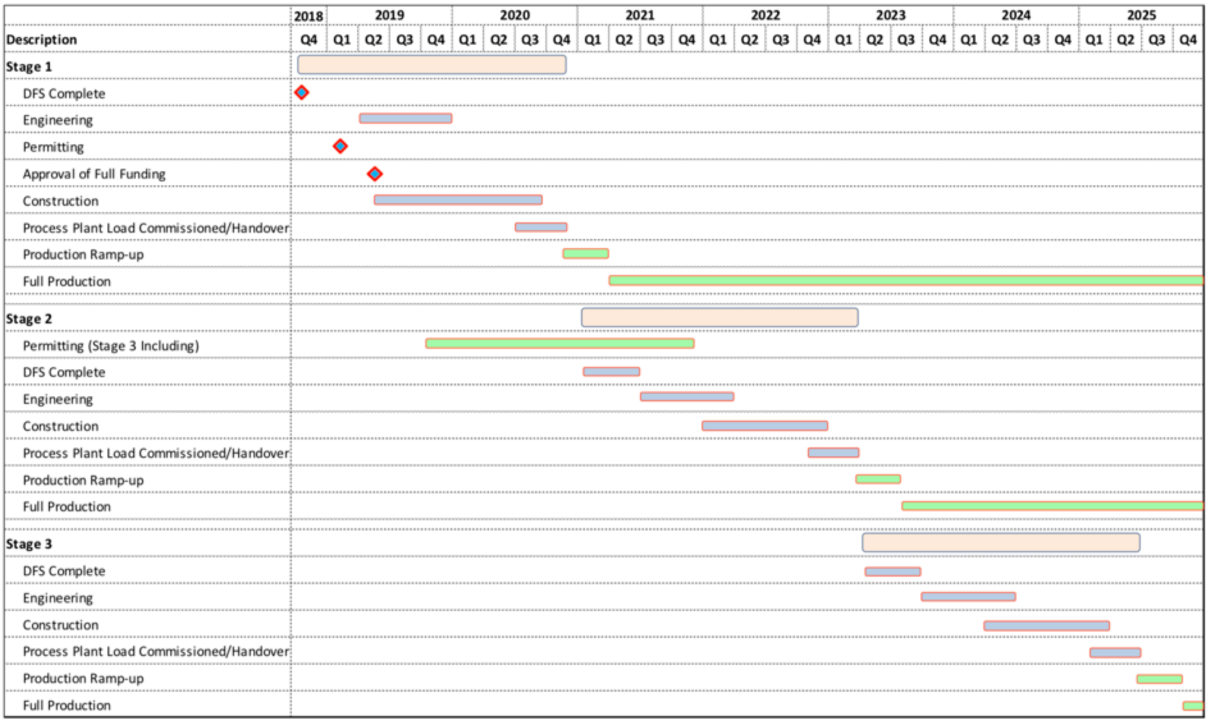
The mineralised zone, as modelled, for Ulanzi is 2,500m long (traced at surface at a bearing of 020°) with four zones measuring 50-60m thick, and ranging from 400m and 760m RL above mean sea level (AMSL). The mineralised zone, as modelled, for Epanko is 1,025m long (traced at surface at a bearing of 000°) averaging between 55-80m thick, and ranging from 640m and 1,025m RL (AMSL). The mineralised zone, as modelled, for Cascades is 900m long (surface trace at 020°) averaging 70m thick, and ranging from 560m and 900m RL (AMSL).

‘Proterozoic’ comes from Greek, with ‘protero’ meaning ‘former’ or ‘earlier’, and ‘zoic’ coming from ‘zoe’ meaning ‘life’. The Proterozoic Eon extends from 2,500 Ma (million years ago) to 541 Ma, and spans the time from the appearance of oxygen in the Earth’s atmosphere, to just before the beginnings of life. It is the longest eon on Earth’s geological time scale. ‘Orogeny’ also comes from Greek with ‘óros’ meaning mountain and ‘genesis’ meaning ‘creation’ or ‘origin’. An orogenic belt is formed when a continental plate crumples and is pushed upward to form mountain ranges. Orogeny is the primary mechanism by which mountains are formed on continents.

Project execution

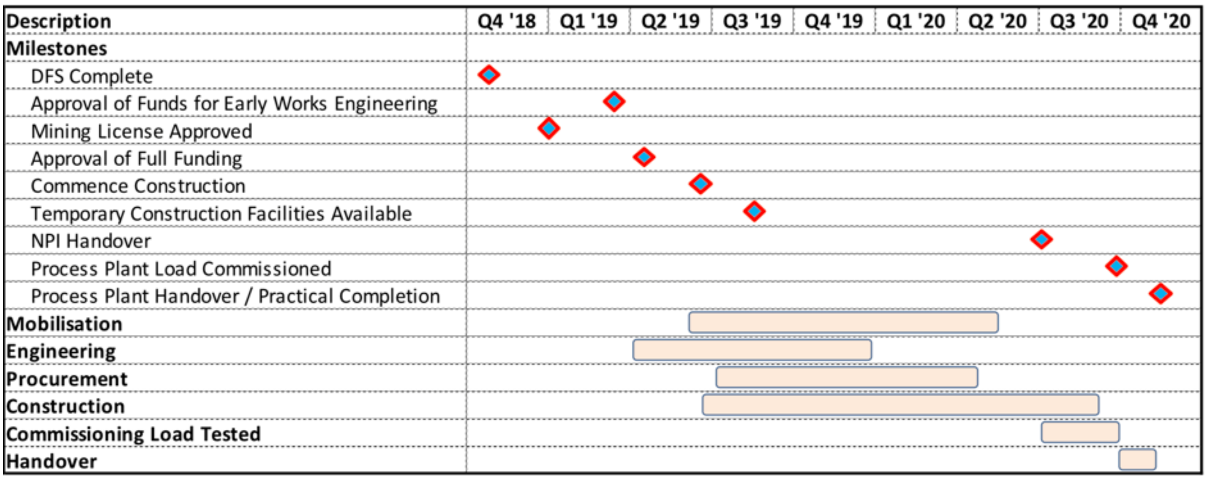
The following figures set out the project timetable as described in the DFS. Given the strong demand for offtake, it seems likely that this timetable will be accelerated.

Figure 51: Implementation schedule



Source: Black Rock Mining, DFS October 2018

Figure 52: Implementation schedule for Phase 1



Source: Black Rock Mining, DFS October 2018

Metallurgy

Black Rock will adopt a single flotation–filtration–drying train. At first it was considered prudent to separate larger and finer flakes in flotation, and process them separately, but optimisation testing and the pilot plant have demonstrated this is not necessary. Test work has demonstrated that Black Rock can achieve 95%, 97.5% and 99% TGC products by varying the number of stages of flotation and polishing. It is rare to be able to achieve these higher grades through a basic mechanical process, and without acid interference, and this represents a significant advantage for Black Rock.

Tests also show that graphite particle size distribution is generally weighted towards coarse fractions (as defined by the market), as opposed to medium flake fractions. This is another advantage. The DFS states that in testing, there was good consistency between particle size distributions achieved in lab testing, and in the Pilot Plant.

Proposed product categories have been determined by marketing feedback. The flowsheet to 95% and 97.5% concentrations was determined in lab scale work, and confirmed in a 40-tonnes pilot plant test. Samples of the final product exceeding 99% TGC were generated both in laboratory, and in un-optimised pilot plant scale equipment.

Process plant

The proposed process plant is remarkably simple. It comprises the following stages:

- Three stage crushing of ROM
- Primary milling in a rod mill and rougher flotation, including a ball mill regrind-scavenger flotation circuit
- Primary polishing in a ball mill and three stage cleaner flotation (Standard Flake)
- Secondary polishing in a stirred mill and one stage cleaner flotation
- Tertiary polishing in a stirred mill and two stage cleaner flotation (Premium Flake)
- Two stages of ultra-polishing in stirred mills, each followed by one stage cleaner flotation (ULTRA PURITY-FP Flake)
- Concentrate dewatering using a thickener and pressure filter, followed by a dryer
- Product classification using screens
- Product bagging
- Process plant mill residue is thickened, vacuum filtered and dry stacked.

The location for the process plant was chosen in a clearing sufficiently large to accommodate Phases 1 and 2, whilst also minimising earthworks. With the project situated amongst hilly terrain, some areas were deemed unsuitable. Phase 2 and 3 are essentially duplicates of Phase 1. (In management speak, ‘it is modular’). Phase 2 will share the bagging plant and building with Phase 1, but otherwise there is little overlap. Phase 3 will require the same footprint as Phase 1.

Site layout and access

The Phase 1 and Phase 2 plants will be located close to the Ulanzi deposit, which is expected to provide the initial feedstock. Most of the necessary infrastructure will also be in this area. Phase 3 will be located close to the Cascades open pit, which is about 5 km from Ulanzi, though it will utilise most of the infrastructure from Phase 1.

Figure 53: Mahenge site layout

Source: Black Rock Mining, DFS October 2018

Road access

The current road into Mahenge is narrow and has steep winding inclines in some places. Access to the project site is via a single lane track leading off from the Ifakara to Mahenge road. This single lane track will be upgraded, using locally available marble, to a two-lane unsealed road.

During discussions with local villagers, an alternative road was identified that follows a currently unused colonial-area access track. This is ~7 km long, relatively flat and avoids the steep inclines of the existing road. Black Rock has held discussions with the Tanzania Rural and Urban Road Agency (TARURA) about this alternative route. TARURA will document and gazette the road (publish that it is a public road). This rediscovered route will become the main public access road into the town of Mahenge. Opening the road, will open new areas for resettlement and farming. In addition, Black Rock will create a plant site and mine services area road, and a magazine access road.

Explosives magazine

An explosives magazine will be located northwest of the Ulanzi deposit and east of the Phase 1 and Phase 2 processing plants. The location of the magazine has been established to achieve required safe working distances with a blast radius of 500m. The magazine will consist of sea containers and adhere to both Tanzanian and Australian safety standards.

Accommodation village

An accommodation village will be built to house up to 120 residents in single rooms with en-suite bathrooms (Phase 1) with an additional 20 rooms for each of Phase 2 and Phase 3. This will provide sufficient living quarters for Black Rock personnel during operations. It is expected that most required labour will be sourced from the local community. The camp will be independent from the main plant and managed by an independent camp village management company.

Fuel storage

Black Rock will build a fuel farm with sufficient capacity for 201m^3 of diesel fuel, sufficient for approximately two weeks' operations. Diesel is required for the mining fleet, light vehicles, the dryer, running the reagents collector, and for raw materials bore pumps. An automatic vehicle recognition system will be used to prevent pilfering and to measure fuel usage by vehicle and by driver.

Dry stacking of mill residue

One of the biggest changes in thinking towards the project over the past year or so, has been in the use of dry stacking. In 2017, a mine surface water and groundwater management study was completed to investigate the potential methods of mill residue disposal. The study concluded that as many as eight storage dams would be required over the life of the project raising environmental and social risks, and economic questions of the project. With these results, a further study was undertaken in late-2017/early-2018 that resulted in the wet residue mill dams being replaced with dry stacking. A risk assessment carried out in April 2018 confirmed this preference. Dry stacking has several advantages:

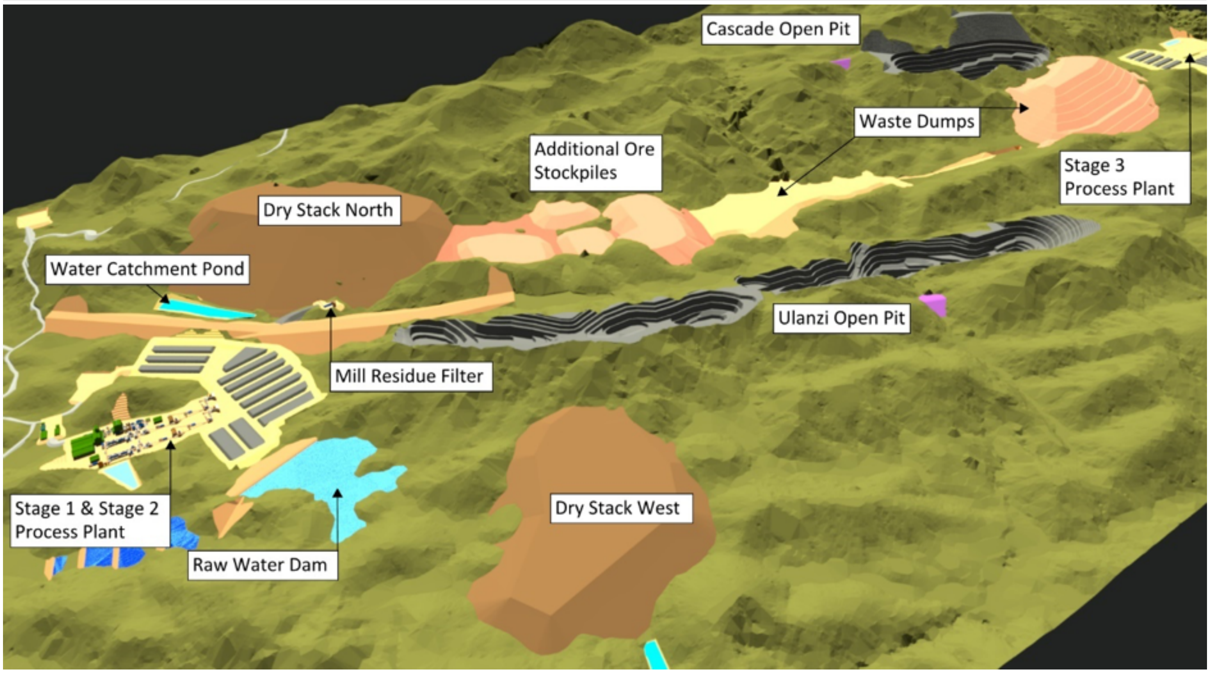
- Significantly reduces water management risks; the complexities of wet tailings storage are substantially reduced
- A smaller plant footprint, and one located close to Ulanzi
- Reduced infrastructure requirement

Black Rock proposes to stack the mill residue after filtering and screening in a hillside standing structure. The mill residue will be thickened in the processing plant, pumped to the filtering and screening plant, where it will be processed to reduce its moisture content before being trucked to the storage area. The stored residue is expected to have a maximum water content of 20%.

There are two proposed sites. The northern facility will be built first and will have a life of approximately 20 years. The western facility will be built later in the projects' lifetime.

During the dry season, evaporation will readily remove moisture during transportation and stacking of the mill residue. The risks of instability will be lower during the dry season. During the wet season, rainfall may result in ponding of the water on the surface of the residue stack. This will be managed through a combination of sloping the top surface of the stack to internal drains, the use of internal drains down the sides of the valley, the use of temporary covers such as low-density polyethylene sheeting. During the wet season, stacking operations will need to be confined to smaller working fronts and may need to cease for during storm events. An emergency stacking location will be available in case of these events.

Figure 54: Mahenge, dry-stack locations



Source: Black Rock Mining, DFS October 2018

Socio-economic

Mahenge, population about 10,000, is located 10 km southeast of the project and is the nearest town to the project site. The village of Mdindo is situated within the Ulanzi area and has a population of around 1,500 people. The village of Kiswwe is located 1.3 km from the Cascade pit area and has a population of around 990 people. Two other villages, Kwiro and Nawenge, are located 1.5 km southeast of the Cascade pit area, and are contiguous with the Mahenge township.

The population is predominantly Tanzanian of the Pogoro ethnic group, though there are a small number of people from other tribes, including the Sukuma tribe from the Mwanza Region that came to the area for mining. The languages spoken are mainly Kiswahili and Kipogoro, with English and Kiswahili taught in local schools.

The main source of income comes from agriculture, with most households undertaking subsistence farming. Maize, rice, cassava, bananas and vegetables are farmed in the area. The little involvement in waged labour is mostly focused on artisanal and small-scale mining. There is no industrial activity in the project area. Young people tend to seek employment in the towns of Mahenge, Morogoro and Dar es Salaam.

About 80% of the project area has been cleared for farmland, though only about 15% of the area is being actively farmed, with much land laying abandoned or fallow.

As a result of the project, some 180 households will be relocated (at a total cost of ~US$2.5m), with local people keen for their dwellings to be upgraded (from dirt to concrete floors for example).

Figure 55: Local accommodation is basic; mud bricks, and mud ‘cement’

Source: Simon Francis

Appendix 2 – Graphite basics

There are two forms of naturally occurring pure carbon. One is graphite, the other is diamonds. Graphite has a planar molecular structure (i.e., it is two-dimensional), whereas diamonds have a crystalline structure (three-dimensional). Graphene is a one-atom thick plane of carbon atoms arranged in a hexagonal honeycomb shape. According to Northern Graphite, it has been estimated that there are three million layers of graphene in a one millimetre thick piece of graphite.

Graphite forms in layers. Within each layer, the carbon atoms are held together by strong covalent bonds. The layers themselves, are held together by a weak electrical force known as van der Waals bonds. This structure means that the physical properties of graphite, parallel to the layers are very different from those normal to the layers. The fact that these layers can be easily disrupted gives graphite its softness, makes it somewhat greasy to the touch, and means it may come off onto a finger when wiped.

Graphite forms through the metamorphism of carbon rich materials. Graphite is non-metallic, but exhibits many metallic type properties. For example, graphite is an excellent conductor of electricity, and heat. It has the highest natural strength and stiffness of any material. Its strength and stability and maintained at extreme temperature, and it is resistant to chemical attack.

Different forms of graphite

Natural graphite resources are classified according to a variety of properties including grade (the amount of impurities remaining in the graphite after processing), crystallinity (the degree of structural order within the graphite), flake size, and shape.

Synthetic Graphite

Synthetic graphite is manufactured from various hydrocarbons including petroleum coke, anthracite, natural graphite, or recycled synthetic material. The main material for lithium-ion batteries is petroleum coke. These materials are crushed, sorted for particle size and type depending on the desired properties of the synthetic graphite, blended with binders, including some amorphous graphite, and compressed. This compressed mixture is then baked at 800 to 1,000 °C, before being converted into graphite at 3,000 °C. Being a manufactured product, the chemical properties of synthetic graphite can be controlled, and it can be produced consistently. The price is that synthetic graphite can cost 2-10 times more than natural graphite.

There are three types of natural graphite known as flake, amorphous, and vein (also called lump) and each has its own characteristics.

Amorphous Graphite

Amorphous graphite is the lowest quality natural graphite, and has a very small crystal size. Nearly all amorphous graphite comes from China. It is also the lowest-priced graphite. Amorphous graphite is used in refractory products, lubricants, paint, rubber composites, drilling muds, and pencils.

Vein or Lump Graphite

Vein or lump graphite is the rarest, most valuable, and highest-quality form of natural graphite. It accounts for less than 1% of the graphite market and is only mined in Sri Lanka. Vein graphite is used in electrical applications, friction products, lubricants, plastics, and powder metallurgy.

Crystalline or Flake Graphite

Flake graphite has larger crystals than amorphous graphite and this enables it to be used in higher-end applications. For example, flake graphite competes with synthetic graphite in the lithium-ion battery market where, with modern processing, the purity and particle size is sufficient for anode production.

Figure 56: Graphite properties

	Flake	Amorphous	Vein	Synthetic
Description	Crystaline structure Typically 80%-98% TGC Flaky morphology	Non-crystaline structure Typically 70%-75% TGC Seam mineral, high as	Rare (<1% supply) Expensive Typically >98% TGC	
Main sources	China Mozambique Brazil Tanzania - soon.	China	Sri Lanka	China USA Europe India
Advantages	Low cost Low impurities Crystalline structure Porosity	Lowest cost	Very high graphite content	Consistent quality Very low impurities
Disadvantages	Inconsistent quality	High impuritie, such as ast	Small resources High cost	Highest pollution Highest cost
Metallurgical	√	√	√	x
Batteries	√	x	x	√
Technical	√	x	x	√
Other	√	√	√	√

Metallurgical: Refractories, crucibles, moulds, castings. Batteries: Lithium ion
Batteries: Lithium-ion
Technical: Electrodes for steel and aluminium production, expandable, brakes, flame retardants.
Other: Pencils, lubricants, paints

Source: Syrah Resources

Graphite beneficiation

The size of the graphite flakes is an important consideration in determining selling price. Graphite is soft, and a balance has to be achieved between reducing impurities and retaining flake size. The methods used to reduce impurities depend on what the impurities are, and how they are attached to the graphite. The process of froth flotation is well-known, and widely employed. Common reagents used in the process are kerosene as a collector, methyl isobutyl carbinol (MIBC) as a frother, and sodium silicate as a depressant. Sometimes, impurities need to be removed using chemical methods (leaching, caustic roasting). These techniques can produce very high grades, but are expensive, and create environmental concerns. Microwave irradiation is a possible alternative to these techniques.

Impurities (gangue materials) in graphite are typically feldspar, quartz, mica, and carbonate. These impurities can be deposited between the layers or stacks of layers, or between clusters of flakes. Impurities can be attached to the surface of the graphite flakes, or trapped in-between flakes (called 'intercalated'). This is important, because how the impurities are attached to the graphite may largely determine how the graphite will be beneficiated. Milling has to be applied carefully to avoid damaging the flake size.

In some plants, attrition mills are used as a final cleaning process – typically when gangue materials are still attached to graphite flakes – to shear off the gangue, without stressing the graphite. This process can be applied before or after flotation. During the attrition process, individual particles are rubbed against each other. This is usually considered an effective way of removing clay minerals.

Flotation

Graphite is hydrophobic, meaning it is not attracted to water. As a result, froth flotation is a common technique used in beneficiation. Hydrophobic molecules are usually non-polar, and prefer other neutral or non-polar solvents. Water molecules are polar. Fats and oils, and in fact, greasy substances in general, are hydrophobic. Hydrophobic molecules often cluster together in water. These properties enable hydrophobic substances to be used in chemical separation processes, including for example, the management of oil spills. Froth flotation is a common technique used in the beneficiation of graphite.

The basic flotation process is simple. Essentially, the mineral is mixed with a reagent (the 'frother'), and put into a cell where air is pumped in, to form bubbles. Hydrophobic articles attach to the air bubbles, and rise to the top of the cell, where they can be skimmed off. Hydrophilic materials are collected at the bottom. Frothers are an important element of the process and several different chemicals are used depending on the exact process and chemical elements being separated.

Graphite flotation, aimed at separating impurities, is usually improved with the use of surfactants and depressants. Surfactants are compounds that lower the surface tension, for example between a liquid and a solid. The surfactants have to impart hydrophobicity selectively, to the desired particles, for successful separation. Depressants increase the efficiency of the flotation process by selectively inhibiting the interaction of the mineral with the collector.

Chelgani, Rudolph et al (2016) claim that fine graphite can be upgraded to about 95% carbon by flotation, but that further upgrading using physical methods is challenging. This demonstrates the strength of the Mahenge deposit. **Black Rock achieved in access of 99% carbon contents using polishing and flotation.** After flotation, the main impurities are usually compounds of silica, potassium, sodium, calcium, magnesium, iron, and aluminium.

Refining

Acid leaching

After flotation, acid leaching is the most common process used to purify graphite concentrates. Depending on which impurities remain, different acids including hydrochloric acid (HCl), hydrofluoric acid (HF), sulphuric acid (H_2SO_4) and nitric acid (HNO_3) are used, either separately or in a mixture. Generally speaking, hydrofluoric acid can dissolve both impurities and organic material and its use can result in substantial weight loss. Acid leaching is an effective way of removing silicate impurities. Hydrofluoric acid is effective in leaching clay materials, but does not remove pyrite, gives rise to insoluble fluoride compounds (e.g. CaF), and has environmental issues making it hard to dispose of. **One of the great benefits of the Mahenge deposit is that high-grade graphite products can be produced without the need for acid leaching.**

Roasting

Roasting can get rid of both silicates and sulphides in graphite concentrates. Usually, the process involves roasting, water washing and then acid leaching. This combination enables the sulphur content of the final product to be reduced to less than 0.05% by weight. It is possible to directly roast the concentrates at high temperatures (often 500 to 900 °C), but this is expensive, and widely restricted by environment legislation.

The flotation product can also be treated with an alkali reagent such as caustic soda (sodium hydroxide, NaOH). This allows roasting to be carried out at temperatures below 500 °C. In China, most high-grade graphite production uses a combination process involving caustic roasting and leaching. Whilst this has the advantage of using less acid compared to a single leach process, it does consume a large amount of caustic soda. Typically, one tonne of graphite concentrate requires 450-500 kg caustic soda, which causes environmental issues, especially in waste water.

Microwave treatment

One relatively new method of beneficiating minerals is with treatment by microwaves. Microwave irradiation has several advantages including that it allows for rapid and selective heating, it can be turned on and off quickly, is highly energy efficient, and environmentally benign. Graphite is a weak absorber of microwave energy. In contrast, pyrite, for example, readily absorbs microwave energy. This means that pyrite can be selectively heated until it decomposes into pyrrhotite (iron sulphide) or iron sulphate. In addition, microwave energy can break the sulphur-carbon bonds in organic sulphur compounds, allowing the sulphur to be released as a gas. Experiments demonstrate that a combination of leaching with hydrochloric acid or nitric acid and microwave irradiation can increase graphite grades to 95% to 99.4% without altering the morphology (shape) of the graphite flakes.

Gravity separation

In addition to the above methods, it is possible to use gravity separation to separate gangue materials from the graphite. Dense media separation is widely employed in the coal sector, and is an efficient gravity-based technique. For graphite, the graphite with the least impurities (and the highest carbon content) will tend to be the least dense, and thus tend to float in dense media separation.

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Ashbury Carbons, https://asbury.com/

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Appendix 3 – Tanzania: rapid industrialisation

Tanzania is situated on the east coast of Africa. It comprises the mainland of Tanzania, and the Zanzibar islands. It covers an area of 945,000 sq. km. Tanzania is bordered by Kenya and Uganda to the north; Rwanda, Burundi, and the Democratic Republic of the Congo to the west; Zambia, Malawi, and Mozambique to the south; and the Indian Ocean to the east. The terrain is one of the most varied in the world with mountainous areas in the north-east, plateaus in the centre, and plains along the coast. Dodoma, Tanzania's capital, is located in the middle of the country. The former capital, Dar es Salaam, is located along the eastern coast. The current population is about 55 million.

Tanzania was formed as a result of the combination of two former British territories. Tanganyika, a British military outpost during the Second World War, and now the mainland, gained independence in 1961. Zanzibar gained independence in 1964. Tanganyika and Zanzibar combined to form the United Republic of Tanzania in 1964.

Tanzania is governed as a democratic presidential republic in which the President of Tanzania is the head of government and of a multi-party system. The party system is dominated by the Chama Cha Mapinduzi (Revolutionary State Party). The country holds elections for the president and vice president every five years that are based on a simple majority popular vote, and are done through ballots. The first multi-party democratic elections were held in 1995. The judiciary is independent of the executive and the legislature. Tanzania's legal system is based upon English common law.

Nowadays, Tanzania has a vibrant, fast-growing economy, that benefits from a young and educated workforce. The country is seeing rapid infrastructure development, aided by organisations such as the Africa Development Bank (AfDB). The government's vision is for Tanzania to be semi-industrialised (where manufacturing represents 40% of GDP) by 2025, something that will require increased foreign investment.

The official language of Tanzania is Kiswahili. English is the second official language and the language of commerce, administration, and higher education.

Political overlay

President Magufuli was elected in 2015. Since the election, he has led a significant overhaul of the mining sector. Some changes have been applied retrospectively, leading to a loss of confidence in the sector, in 2017. As a result of the changes, many companies were essentially forced to delay projects while they, and their financiers, tried to understand the new situation. Despite the uncertainties of mid-2017, Tanzania very much remains 'open for business'. Companies report that engagement with the government is positive. Typically, they note that the government is focused on ensuring projects include meaningful local content, work towards Tanzania's economic growth and industrialisation, ensure that Tanzanians are employed, and that projects are generally 'inclusive'.

Although President Magufuli has been criticised for his crackdown on opposition groups and media freedoms, the country's anti-corruption drive has been well received by both the private sector and public sector. Since 2016, the crackdown on corruption, including the removal of more than 10,000 'ghost' workers within the government, has managed to attract foreign investment. Over the past year, there appears to have been a greater level of engagement between the highest levels of the government and the private sector.

A vibrant economy…

Tanzania has seen significant economic growth, averaging around 6-7% per year over the past decade. Real GDP grew by 7.1% in 2017, and this growth rate is expected to be maintained until 2022. Tanzania is urbanising quickly. In 2017, about 33% of the people lived in urban areas, up from about 26% a decade earlier.

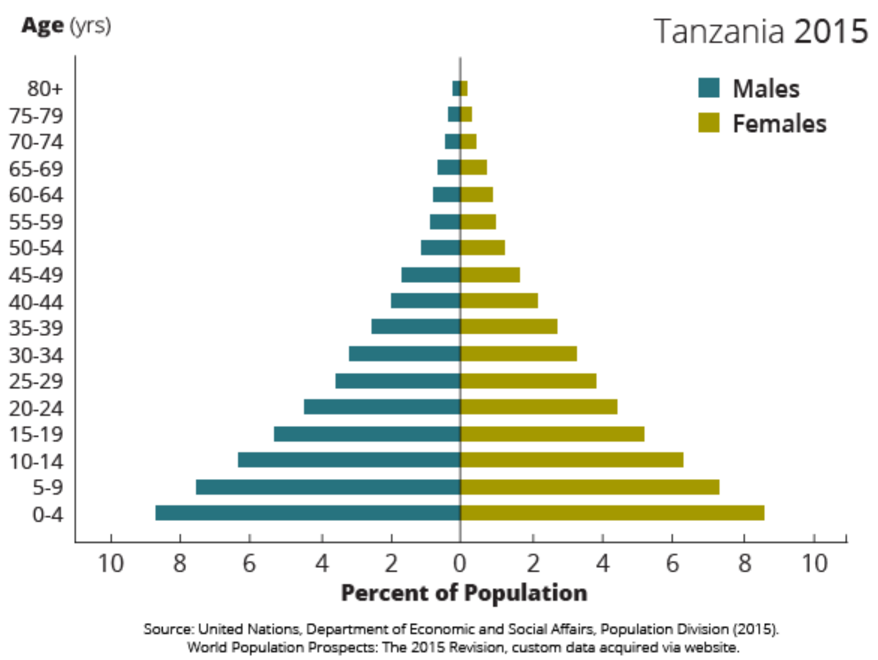
The country is still heavily focused on the agriculture sector, which contributes about 30% of GDP and 67% of total employment, but Tanzania is industrialising rapidly. Industry accounts for about 26% of the economy, with services accounting for about 43%. The government plans to invest heavily into rail, port, and road infrastructure between 2017 and 2026.

The Dar es Salaam Stock Exchange was founded in 1996. There are currently 28 listed companies, 12 of which are banking or finance related. Currently, total market capitalization is ~TZS20,000 billion (~US$8.7bn). The three largest companies by market capitalization are Tanzania Breweries Limited (US$1.7bn), East African Breweries Limited (US$1.5bn), and the KCB Group (US$1.1bn). Other notable companies include Acacia Mining, Tanzania Cigarette Company, and Vodacom Tanzania.

…And a bright young workforce

Tanzania has a young population, with about 22% of the population under the age of 15, and about 32% under the age of 25. A young population can provide a ready workforce for investors, and a large tax-base for governments, though it can also put pressure on education systems, and resources. Tanzania has a number of universities, the top three of which are probably the University of Dar es Salaam, Muhimbili University of Health and Allied Sciences, and Sokoine University of Agriculture.

Figure 57: Tanzania Population Pyramid



Source: United Nations Department of Economic and Social Affairs

Figure 58: Tanzania map

Source: CIA World Factbook

The author

Simon Francis is a UK qualified chartered accountant with significant experience in the natural resources and minerals sector. Simon led research in the sector in various roles at major financial institutions including Macquarie, Samsung and HSBC, in a career spanning more than 20 years. He has been involved in approximately US$4bn of capital raising, for a number of natural resources companies. Simon has been engaged in the financing of early stage companies using production agreements, and has privately funded exploration companies in various metals and jurisdictions. Simon seeks to deploy capital in undervalued mining and resources opportunities that have been missed by the market.