Colts

A research initiative by Canaccord Genuity

Talga Resources (ASX:TLG)

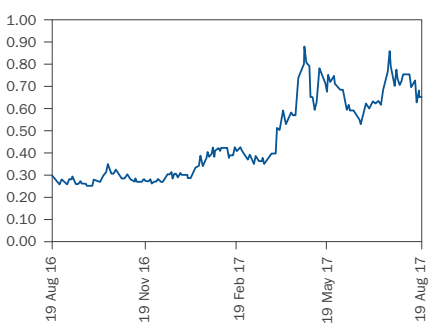
Leading the charge on the commercialisation of graphene

Key Facts	
Company Code	TLG.ASX
Closing Price (21/8/17)	$0.65
Date of Report	22/8/17
Company Website	talgaresources.com.au
Analyst	Tim McCormack

Company Statistics	
12-Month High	0.87
12-Month Low	0.24
Market Cap (A$Mil)	A$130m
Issued Shares	202m
Issued Options (ITM)	75m
Cash (est.)	A$16m

Major Shareholders	%
Smedvig	12.6%
Mark Thomson	7%

Share Price Performance



Canaccord Genuity (Australia) Limited has received a fee as the Lead Manager to the Talga Resources Ltd capital raising announced in June 2017

Canaccord Colts provide research coverage on a select group of early-stage ASX-listed microcap companies that our institutional research team believes have strong development trajectories.

If you have received this indirectly, please click **here** to receive future research on TLG and other Colt companies.

Investment highlights

TLG has continued to advance upstream, midstream and downstream aspects of its European graphene and micro-graphite operations since our last update. In our view, the company is now well placed to become a vertically integrated provider of not only raw graphene and micro-graphite materials, but also a wide range of commercially viable, functionalised graphene related products. TLG's test processing facility has allowed the company to refine flowsheet parameters and establish in-house commercialisation capabilities, while providing ample product distribution capacity to end users, resulting in a number of collaborative development agreements being executed. During the next 18 months, we expect TLG to continue scaling up its current operation, complete a PFS and DFS and be at a decision to construct a commercial scale processing facility by early 2019. We have derived an indicative project level valuation of A$234m (A$1.15/sh), which assumes production of raw graphene and micro-graphite materials. We note that as TLG continues to demonstrate commercial scale applications for functionalised graphene products, our base case may ultimately prove to be conservative.

Unique orebody and processing gives TLG the edge. TLG's Nunasvaara graphite deposit in Sweden (part of its Vittangi project), is the highest grade orebody (JORC) of its ASX listed peers, at 12.3Mt at 25.5% graphite. Mineralisation begins at surface and is wide and uniform, but its key point of difference is the unique combination of conductivity, morphology and high grades which support an electrochemical exfoliation processing method. Ore is cut into blocks and used as an electrode in an electrochemical cell, liberating graphene and micro-graphite in a fast, efficient and flexible manner. TLG is still optimising the flowsheet as it scales up through the test processing phases, but initial results have been highly encouraging, with the Phase 2 plant able to convert up to ~76% of ore graphitic carbon to graphene with the remainder useful in micro-graphite products.

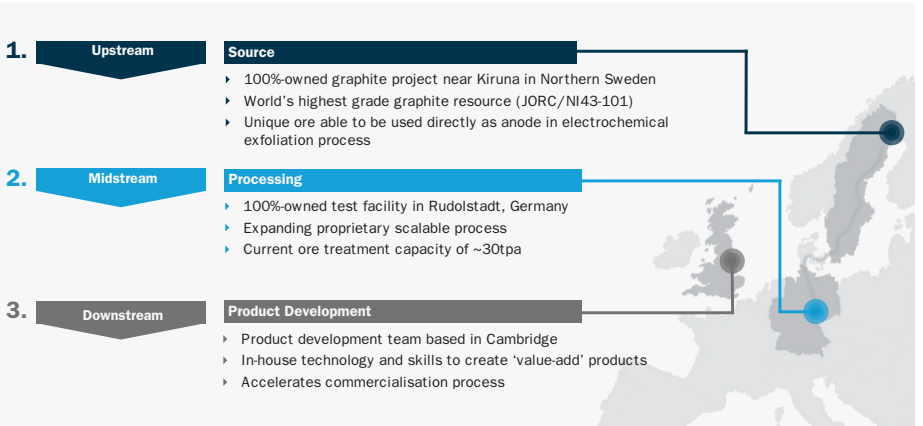
List of commercial partners growing. TLG has signed a number of agreements with commercialisation partners to accelerate the development of graphene related products. Key partners where TLG has formal collaboration agreements include Haydale (July 2015) which is focusing on graphene composites and ink products, Tata Steel (November 2015) which is focusing on developing graphene additives for the paint and coating market, Jena Batteries (September 2016) which is focused on utilising graphene in patented polymer flow battery for commercial and grid, Zinergy (March 2017) which is focused on the development of ultra-thin, flexible printed batteries, Chemetall (March 2017) which is focusing on graphene additives to improve anti-corrosion properties in coatings and Heidelberg Cement (MoU July 2017) which is focused on applications of graphene and graphite to enhance strength and conductivity in concrete. TLG has also established its own in-house team, which is working to develop value added graphene and micro-graphite products for end-user markets. Products developed by TLG could result in enhanced margins, as distinct from supplying raw micro-graphite and graphene to customers. The company has developed and trademarked Talphene, as a brand for its graphene, where it is targeting applications in the coatings and anti-corrosion sector.

Valuation. We have made a number of assumptions, based partly on the 2014 Scoping Study and partly on the outcomes from the latest test processing results. Our NPV12% project valuation of A$234m assumes a 50ktpa processing rate, with first commercial production by mid-2020.

Overview

TLG (TLG.ASX) is a technology minerals company, developing and commercialising its flagship Vittangi graphite project to mass-produce graphene, micro-graphite and carbon derivatives. The company is European focused, with its high grade orebodies in Sweden, test processing facility in Germany and numerous R&D centres across Europe. TLG has made a number of impressive advancements on the mining, processing and product development fronts, and in our view, it is well positioned to become a vertically integrated producer of graphene and micro-graphite products.

Figure 1: TLG's vertically integrated business model



Source: Company reports

> "Focus on collaborative work with end users has become an important pillar of TLG's business strategy, and one that in our view could deliver significantly better financial outcomes for the company."

During 2016, TLG (under its trial mining permit) extracted ~2,000m3 from the Nunasvaara orebody (Sweden) over two mining campaigns. The company cut blocks (approximately ~7t each) which are stored in a nearby facility and transported to the processing plant in Rudolstadt (Germany) as required. The 2016 mining campaign, utilised new mining equipment, which improved the scale and automation compared with the 2015 trail mining techniques. TLG utilised a new mine contracting team, which significantly improved mining efficiencies and there is currently a large supply of feed material for pilot test work to continue. We also note that the mining campaign gathered important data for larger scale mine planning for the future.

Following the 2016 trial mining campaign, the project site has been fully rehabilitated. The next steps involve preparation for commercial scale production, and TLG has engaged Environmental Consultants to begin hydrological modelling and stockpile management planning. Baseline environmental studies are underway as a requirement to obtaining an Exploitation Permit which will allow full scale mining. We note that TLG currently has ample stockpiles available for Phase 3, and that if additional material is required before an Exploitation Permit is granted, TLG can apply for another trial mining licence which should allow for a further ore to be extracted.

A drilling campaign at the Vittangi project in late 2016, culminated in a recent resource upgrade which now stands at 12.3Mt at 25.5% for 3.1Mt of contained graphite (17% cut-off). The latest resource represents a 25% increase on the previous estimate, which also used a lower cut-off grade of 10% graphite. We note that 80% of the current resource is the Indicted category and that a high grade domain of 2Mt at 32.6% graphite for 652kt of contained graphite extends from surface, which is favourable from a development aspect.

In the 2H'16, TLG announced the completion of the Phase 2 test-work program. Current capacity for ore treatment is ~30tpa from a single modular exfoliation platform, consisting of several Phase 1 and 2 exfoliation cells. The plant is currently configured so that 76% of the inputted graphitic carbon can be recovered as graphene products (few layer graphene – FLG and graphene nanoplatelets - GNP) with the balance reporting as micro-graphite which TLG is targeting use in the building and battery markets. As the understanding of the processing circuit evolves, TLG is refining its ability to consistently manufacture graphene and micro-graphite (from various stages of the process circuit) for a range of targeted products. As per the business strategy, TLG aims to either supply raw materials to end users, or prepare value added products such as metal pre-treatment coatings, conductive inks, cement additives, battery components and membranes. Focus on collaborative work with end users has become an important pillar of TLG's business strategy, and one that in our view could deliver significantly better financial outcomes for the company.

As the project has ramped up, TLG has appointed full-time project and plant managers who have overseen notable improvements across all aspects of the flow sheet including: exfoliation cell design, power and exfoliation, beneficiation, purification process analysis and characterisation. TLG has also made an effort to incorporate feedback for its industry partners which is improving the efficiency of developing marketable products.

TLG is currently finalising designs for Phase 3, which will increase sample production for customers and provide improved process and quality control under a steady-state processing environment. By pursuing a progressive scale up, TLG has been able to effectively access the economic and technical parameters of full scale development. Permitting for Phase 3 has also commenced in association with the relevant government departments in Germany and the state of Thuringia. Final design and cost estimates for Phase 3 are now in progress and expected to be completed for approval in the near term. Given the modular nature of the current pilot plant and relatively small scale of the operation, TLG is comfortably funded to finance the expansion with A$16m in cash reserves. An ongoing Feasibility Study is incorporating the actual consumption and operating costs from the current Phase 2 test-work. The data, together with input from numerous engineering consultancy groups is forming the basis for the Feasibility Study on the options of expanding production. We expect to see the outcomes of the Feasibility Study by mid-2018, at which point TLG will make a decision on the ultimate location and scale of the commercial scale processing facility. Sweden is naturally the preferred location given the proximity to its Nunasvaara orebody, and TLG has initiated a Location Study in parallel with the Feasibility.

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TLG’s business strategy aims to manufacture targeted ‘fit for purpose’ graphene products to complement the supply of raw graphene and graphite materials in industrial markets.

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Business strategy and avenues to commercial development

Given graphene has nearly limitless potential applications, the challenge facing TLG has been refining its business strategy to demonstrate the potential commercialisation of its products. TLG launched a graphene products business strategy in mid-2016, identifying four key industry sectors where its graphene, and micro-graphite material products have the highest potential to create long term sustainable cashflow. TLG’s business strategy aims to manufacture targeted ‘fit for purpose’ graphene products to complement the supply of raw graphene and graphite materials in industrial markets. The four key markets being targeted are:

- Construction (building materials)
- Energy (batteries and transmission)
- Coatings (anti-corrosion and other functions)
- Composites (epoxy resins).

Figure 2. TLG’s four key target markets for graphene products

Construction additives

Advantages

Improves strength, durability and impermeability

Imparts electric and thermally conductive properties

Reduces concrete used and decreases industry CO2 emissions

Enables underground power transmission cables, underfloor heating, road and bridge snow melting and de-icing

Immediate market opportunity

US$17bn specialty concrete

Energy storage (batteries)

Advantages

Enables higher performance and lower cost Li-ion, flow and alkaline batteries.

Flexible, printable batteries for ‘Internet of Things’ and ‘Wearable’ devices

Lower toxic footprint by enabling water-based battery chemistry

Lower cost fuel cells

Immediate market opportunity

US$24bn battery market

Talphene™ enhanced coatings

Advantages

Eco-friendly alternative to toxic chromium based coatings

Lower cost and superior performance with reduction in zinc, copper, phosphate, zirconia

Corrosion protection increased by up to 74% for mild steel

Eco-friendly marine anti-fouling

Immediate market opportunity

US$22bn corrosion protection sector within global US$120bn

Carbon fibre composites/resins

Advantages

Stronger and lighter epoxy resin systems for carbon fibre and polymer composites

Enables lightning strike protection and EM shielding in carbon fibre planes and EV’s

Replaces copper heating elements/wires to reduce weight of EV’s

Immediate market opportunity

US$18bn composites sector

Source: Company Reports

Construction additives

- Large volume applications for graphene, micro-graphite and graphite products are a key target market for TLG. In our view, the construction sector is a major consumer of materials that can be improved with the addition of graphene and its derivatives. TLG has completed a number of trials on concrete, where the addition of graphene and micro-graphite has demonstrated new functionality and higher performance to cope with the demands of growing urbanisation. Initial work has been completed, with impressive results relating to thermal conductivity and increase strength.
  - Thermal Conductivity: Initial testwork completed by TLG has demonstrated ~30% gains in the thermal conductivity of cement against the current market leading product and a 300% conductivity increase over untreated concrete. We highlight, that the results were achieved using extremely low loadings of graphene, blended with raw Nunasvaara graphite ore. Most likely applications for commercial use include: underground power cable installations (for heat dispersion), underfloor heating, domestic geothermal installations and emerging applications such as snow and ice-free roads, runways and paths.
  - Increased strength: Recent tests completed on TLG graphene and graphite showed significant increases in strength over the existing high performance concrete. Strength (compression and flexural) improvement, with the incorporation of graphene and graphite in cement represents a huge opportunity for TLG, and test work on this remains ongoing.
- The company recently signed an MoU with Heidelberg Cement (a German based multinational building materials producer and world leader in concrete products) to jointly explore business opportunities associated with TLG's graphite and graphene materials to enhance concrete applications in the building sector. The MoU will provide TLG the opportunity to work with Heidelbergs engineering and innovation departments, exploring ways to enhance cements/concretes by improving conductivity, strength and longevity of products. In our view, this is another clear demonstration that TLG's commercialisation strategy is being effective. Heidelberg can produce ~200Mt cement p.a, and should a graphene additive be adopted, this represents a considerable opportunity for TLG.

> "In our view, the construction sector is a major consumer of materials that can be improved with the addition of graphene and its derivatives."

Energy products

- TLG is progressing the testwork on the potential applications of graphene in the energy storage market on a number of fronts. Ongoing development work with industry partners Zinergy UK Limited (flexible printed batteries) and Jena Batteries GmbH (redox flow batteries) has demonstrated encouraging potential applications, however, in our view, the recent outcomes demonstrated by TLG's lithium ion anode program are genuinely exciting.
- TLG is currently exploring the potential applications of graphene nanoplatelets (GNP) as the active material of lithium-ion battery anodes. Testing at the Warwick Manufacturing Groups Energy and Innovation Centre (University of Warwick in the UK) has been encouraging, with preliminary results (where commercially available graphite anodes are replaced by graphene) have demonstrated improved electrochemical performance, delivering up to ~27% more energy density. As a result of the increased battery energy density, benefits in an application could include increased range for an electric vehicle or additional usage time for a mobile devices. While further work needs to be completed to validate the cycle times, batch to batch consistency and endurance performance, the initial results present an exciting opportunity for TLG. Ongoing work will focus on number of opportunities within the lithium-ion battery space and include:
  - Replacement for spherical graphite in anodes
  - Conductivity enhancing additive for current anodes and cathodes
  - Testwork on next generation silicon-graphene anodes
  - Anti-corrosion and conductive coatings for cell, case and battery pack components.
- We see potential for TLG product to be economically competitive with current flake and synthetic graphite anode materials, noting that costly shaping and coating steps that are required before use in the downstream battery supply chain, can largely be bypassed in the case of TLG's product. Should ongoing testing prove to be economically viable, exposure to this growing market segment would be a key positive catalyst for TLG.

Coatings

- TLG has completed significant test work, including delivery of its first value added graphene product (metal pre-treatment coating), which has demonstrated that when graphene is added to coatings such as paint and metal pre-treatments, corrosion resistance is significantly improved.
- The control of steel corrosion typically requires galvanisation (zinc coating) or chromatising (hexavalent chromium). With zinc coatings requiring high weight and high loadings required for effectiveness (up to 90% loading in metal corrosion coatings) and the toxic impact of hexavalent chromium on human health (known carcinogen) and the environment resulting in restricted usage, we see good potential for graphene to replace (disrupt) the current market place.
- TLG has completed a number of trials demonstrating the superior anti-corrosive performance of functionalised graphene coating against zinc and hexavalent chromium versions under various real world scenarios. Through a Joint Development Agreement with Chemetall (business unit of BASF), work continues to advance, with the aim of delivering eco-friendly, high performance, corrosion resistant surface treatments, which today are used in an addressable market of ~US$10bn.

“TLG has completed a number of trials demonstrating the superior anti-corrosive performance of functionalised graphene coating against zinc and hexavalent chromium versions under various real world scenarios.”

Composites

- Testwork has shown that graphene additives allow epoxy resin systems to become stronger, lighter and more functional (conductive). The key use of epoxy resin, is used to make carbon fibre composites, a lightweight material widely used in aerospace, automotive, marine and wind turbine sectors.
- While this is realistically TLG’s least advanced product stream, we see good potential applications in the weight reduction in aeroplanes, epoxy based anti-fouling marine coatings and emerging markets including textiles, wearable technology and 3-D printing.

Development blueprint for commercialisation in place

In targeting these four industrial sectors for its product streams, TLG has executed a number of collaboration agreements with relevant industry players. Alignment with multinational companies is important in validating TLG’s product, but also expedites potential development routes for many graphene products. TLG has a number of targeted products (dispersed, functionalised and/or formulated) under development already, and we expect this facet of the business to continue expanding as the team, facilities and capabilities continue to grow. Some of TLG’s key development partners are shown in Figure 3.

Figure 3: TLG collaborative partners

TATA STEEL	haydale	Chemetall expect more	JENA BATTERIES
Collaboration underway to develop coatings products	**Focused on epoxy composites and inks**	**Anti-corrosion product agreement with world’s largest manufacturer**	**Focused on flow batteries and clean grid power applications**
Multinational industrial conglomerate with over 100 operating companies, operations in >100 countries and 580,000 staff worldwide	Nanomaterials company based in the United Kingdom	World leader in surface treatment manufacturing	German-based private technology company
The second largest steel producer in Europe	Owns a proprietary process to functionalise graphene at its purpose built facilities in South Wales	Part of the BASF Group (US$87BN market capitalisation)	Currently commercialising its globally patented metal-free redox flow battery
Formal Collaboration Agreement with UK steel arm in Nov 2015	AIM-listed with market capitalisation A$47m	Headquartered in Frankfurt with 21 production centres	Supported by Wirthwein AG, a leading international plastic components manufacturer
Focus to develop graphene additives for the global paint & coatings market (> 40 Mtpa)	**Formal Collaboration Agreement established in July 2015**	**Joint Development Agreement includes initial 2 years of product development/5 years of exclusive supply**	**Formal Collaboration Agreement established in Sept 2016**
	Focus to develop finished graphene composite and ink products	**Focus to develop metal protective treatment coatings (market size US$10.4bn)**	**Focus to utilise Talga graphene in patented polymer flow battery for commercial and grid**

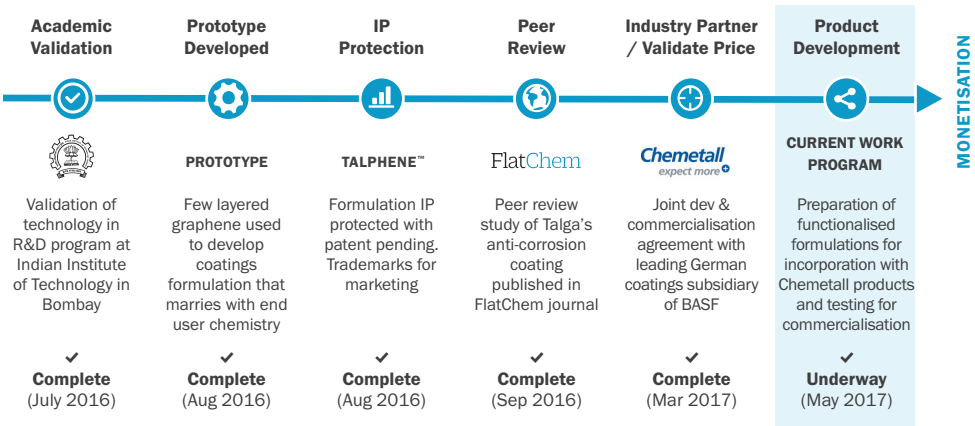
Source: Company Reports

An example of the product development roadmap is outlined in Figure 4. This demonstrates TLG's most advanced product development initiative, which is now only one step away from receiving initial revenue. While the quantum of the revenue stream will take a while to become material, this blue-print is currently being replicated for a number of potential product markets. In this case, TLG has a patented Talphene, then subsequently entered into a two year product development phase where graphene test samples and products will be sold to Chemetall. A further agreement is also in place for a five year exclusive graphene supply arrangement, where Chemetall shall purchase graphene solely and exclusively from TLG in the event that jointly developed products are commercialised.

TLG aims to use this product development model to progress product and commercialisation developments in its other three target markets (energy/batteries, construction/building materials and polymer composites). TLG has demonstrated early prototype successes and we understand there is mature dialogues and product testing collaborations with number of potential partners/customers.

"TLG aims to use this product development model to progress product and commercialisation developments in its other three target markets (energy/batteries, construction/building materials and polymer composites)."

Figure 4: Product development blueprint

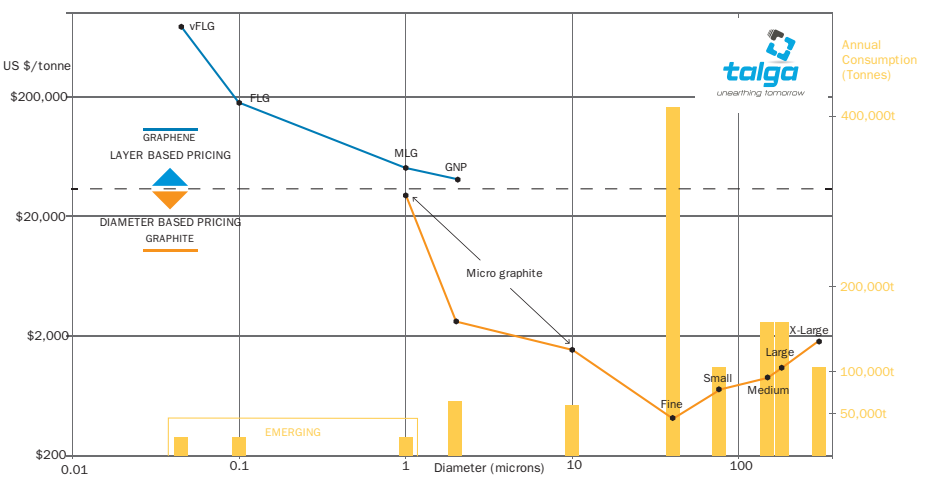


Source: Company reports

What could TLG be worth?

In developing a valuation for TLG, we have based our pricing assumptions on much of the publically available information for graphite, micro-graphite and graphene, which TLG has well summarised in a slide presented in the FY16 annual report presentation. As outlined, the price received escalates exponentially with the move from micro-graphite to graphene, where some very few layer graphene (vFLG) product is reaching prices >US$200,000/t (generally sold in <1kg increments). An important observation of the chart below is the current annual consumption rate for each of the graphene, micro-graphite and graphite product groups. Extreme pricing, relates to very small markets, and as a result we have taken a conservative view in the modelling of the project vs the 2014 Scoping Study. We assume a 50/50 product split of graphene and micro-graphite raw materials, with each basket receiving an assumed price of US$15,000/t and US$2,000/t respectively.

Figure 5: Graphene and micro-graphite pricing model



Source: Company Reports

While TLG has completed a Scoping Study contemplating a 250ktpa processing facility, outcomes demonstrated from the test facility over the past year have shown a marked increase in the yield of graphene materials, and in our view the quantum of the ultimate processing plant will be considerably different to what was originally contemplated (CG assume mining and processing ramping up to 50ktpa). We have utilised some of the base line cost metrics used in the Scoping Study, but essentially we have designed a pre-emptive view of how we see the PFS looking next year. We don't attempt to capture any revenue from the test plant phases and assume first commercial production in the SepQ'20, ramping up to a 50ktpa processing rate. Our key assumptions are outlined in the table below.

Figure 6: Key assumptions underpinning the project NPV

Capex	US$50m
First production	Mid-2020
Mining and processing rate	50ktpa
Assumed head grade	30% Cg
Assumed total recovery	70%
Graphene production (50% steady state)	5.2kt pa
Micrographite production (50% steady state)	5.2kt pa
Cash costs (steady state)	US$795/t
AISC (steady state)	US$1045/t
Assumed average graphene price	US$15,000/t
Assumed average micrographite price	US$2,000/t
Average FCF pa at steady state	A$70m pa
Mine life	20 years
Discount rate	12%
NPV	A$234m

Source: Canaccord Genuity estimates

> "Our initial NPV on the project of A$234m equates to A$1.15/sh (un-levered), and in our view, the assumptions behind this are conservative and achievable."

Our initial NPV on the project of A$234m equates to A$1.15/sh (un-levered), and in our view, the assumptions behind this are conservative and achievable. Given the market is still in its infantile stages, we have taken a view, that a slower production ramp up rate than that outlines in the Scoping Study is prudent. Key justifications for our assumptions are outlined below:

- Capex US$50m, sits higher than the US$30m envisaged in the Scoping Study for a 250ktpa plant. We have increased this with a view that refined engineering and automation will be incorporated in the final plant design. We also expect that processing circuits will be modular, which could see further rapid production ramp up readily achievable. Our valuation is based on an unfunded basis at this stage, but we note that future equity may be utilised to fund development of the project.
- First production by mid-2020, allows for the PFS to be completed by mid-2018, a further six months for a DFS and then an18 month window for construction and finalisation of Swedish mining permits.
- 50ktpa mining and production rate, seems achievable while not saturating the market with product in a way that would impact pricing. We highlight that based on our assumed head grade (30% graphite) and recoveries (70%), the operation would be producing 10.4ktpa of graphene and micro-graphite.
- Mined head grade of 30% sits above the current resource grade at Nunasvaara of 25.5% graphite, but we note that TLG has a good opportunity for selectively mining the deposit (CG assume only 10% of current resource is mined LOM). We also highlight that using a higher cut-off grade (30%), domains as high as 2Mt at 32.6% graphite can be delineated. LOM we only assume 1Mt of ore is mined in order to sustain a 20 year mine life.
- Our assumed recovery of 70% (split 50/50 graphene and micro-graphite product) sits against TLG's current plant configuration which can yield up to 76% of the input graphitic carbon being converted to graphene materials (CG implied is 35%). Provided TLG's current graphene yields are sustainable at commercial run rate, there is good potential upside our assumed product split, which will have a meaningful positive impact on the projects NPV (70% graphene would see the NPV increase to A$469m or A$2.32/sh).

- Total production of 10.4ktpa, assumes a 50/50 spilt of graphene and micro-graphite. We have utilised conservative product pricing in our view, assuming US$15,000/t for graphene, noting that the current price range is US$20,000-1,000,000/t depending on quality. Logically, as commercialisation occurs, prices will reduce, but in our view the assumed price used in our modelling is achievable long term, noting that TLG used a graphene price of US$55,000/t in its Scoping Study (on lower assumed yields). Micro-graphite is a larger market currently, where product is readily bought and sold. Current market prices average US$1,800-20,000/t across a broad range of uses, and we see our assumed price of US$2,000/t as reasonable.
- While pricing seems intuitively high, it's important to remember the relative loading of graphene in most applications is comparably very low. In marine coatings for example, graphene loading might be ~5% vs zinc loading at 60-70%. Simplistically, given the requirement for ~13x more zinc to be used by weight, there is an argument that a US$3,000/t zinc price could justify a ~US$40,000/t graphene price. In our view, this kind of logic, gives comfort that our assumed US$15,000/t graphene price is conservative.

Unsurprisingly, graphene pricing is the key sensitivity in our project valuation. Figure 7 demonstrates the potential impact (on a per share basis) of various graphene and micro-graphite price scenarios. While not on the table below, for illustrative purposes, if we ran US$55,000/t as used in the Scoping Study by TLG, we would get a project valuation of A$961m or A$4.80/sh.

> "Graphene, with its potential applications, has been a widely publicised breakthrough in nano-science technology since it was discovered in 2004 by professors at the University of Manchester..."

Figure 7: Sensitivity table to graphene and micro-graphite pricing

		Graphene price (US$/t)				
		$5,000	$10,000	$15,000	$20,000	$25,000
Micro-graphite price (US$/t)	$1,000	0.15	0.61	1.05	1.50	1.95
	$2,000	0.25	0.70	1.15	1.60	2.05
	$3,000	0.34	0.79	1.24	1.69	2.15

Source: Canaccord Genuity estimates

Following a recent A$12m placement, TLG has a cash position of ~A$16m (30 June 2017), with the company indicating that it is funded through to the end of 2018. We also note that the company has 44.9m in-the-money options (A$0.45/sh expiring 31 December 2018) which could see an additional A$20m raised assuming full conversion. Provided TLG maintains its momentum, the injection of funds from the options will cornerstone the financing of the commercial scale plant. We also note that TLG owns a number of traditional graphite deposits and a cobalt project in Sweden, which are non-core in our view. The company may look at divesting these assets in the future, which could present an additional avenue of funding for the main project.

Quick re-cap on graphene

Graphene, with its potential applications, has been a widely publicised breakthrough in nano-science technology since it was discovered in 2004 by professors at the University of Manchester through isolating one-carbon-atom-thick graphene sheets using the 'Scotch Tape' mechanical exfoliation method. Since this time, key attributes such as unsurpassed strength, optical, permeability and electronic conductivity properties have been identified. Literature suggests that <20t of graphene was produced in 2014.

While the graphene industry is nascent with few applications at commercial scale, the addressable market is enormous. Applications besides battery anode materials include paints, coatings, galvanics, polymers and building materials, a sector collectively worth over US$620 billion annually.

Graphene is highly abundant but economic production is the key challenge when assessing the suitability of a graphitic ore body to commercial graphene potential, a number of inherent geo-metallurgical factors are important which include: high insitu grade (TGC%), a highly crystalline structure with consistent homogeneity and the nature and ratios of the non-graphite minerals dispersed through the ore (gangue).

It is also important to understand the size of the material. About 3 million layers of graphene sheets exist in 1mm of graphite, hence developing economic separation methods is the current challenge, as is successfully keeping atomic size particles separated post exfoliation.

Graphene exists in many forms, generally determined by the method of production, source of precursor and the method used to stabilize the product.

- Single layer graphene: This is the purest and typically the most expensive form. Desirable to high-tech end-users and product markets, the graphene exists in a single-atom-thick sheet, with bonded carbon atoms adhered to a substrate or freely suspended.
- Few-layer graphene (FLG) and multi-layer graphene (MLG). This typically ranges from two to ten layers thick, either free standing or substrate bound. It is typically used in composite materials and reinforcements.
- Graphene oxide. This chemically modified graphene prepared by oxidation and exfoliation. Graphene oxide is a monolayer material with a high oxygen content. Major uses are for thin membranes that allow water to pass through but block off harmful gases.
- Graphite nanoplatelets, graphite nano-sheets, graphite nano-flakes, and 2D graphite materials with a thickness and/or lateral dimension of less than 100 nano metres. The use of nanoscale terminology here can be used to help distinguish these new ultrathin forms from conventional finely milled graphite powders, which typically have a thickness >100 nano metres. These materials are excellent for electrically conductive composites.

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Much of the hype around graphene has been in its use in hi-tech applications, however the most likely near term market for significant commercialisation is in its use as an additive.

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Methods of production

- Bottom-up approaches involve organic synthesis of carbon from small molecules via their deposition on a substrate through a reduction process. Substrate-based growth of single layer graphene can be achieved through chemical vapour deposition (CVD) or via the reduction of silicon carbide. Both of these processes are limited however by the heating requirements (+1000°C) and the high substrate cost due to removing the underlying metal layer. This impacts the ability to scale up these processes to produce commercial levels of graphene.
- Top-down approaches isolate graphene layers from the parent graphite ore under various physio-chemical conditions. Alongside mechanical exfoliation (the “Scotch Tape” approach), liquid phase exfoliation offers the most likely path to produce few layer graphene (FLG) within a one-step process.
- Liquid phase exfoliation (LPE) has been used in the production of carbon materials upon the reduction of graphene oxide since the 1950s. This shear-based method is known as the “Hummers” method and, due to the structural defects introduced by the oxidation process, results in structural defects within the graphene that degrade the conductive and morphology (dimensional) properties.

Much of the hype around graphene has been in its use in hi-tech applications, however the most likely near term market for significant commercialisation is in its use as an additive. Graphene can be added to common bulk materials (0.05-2% volume) to exponentially increase the strength. As TLG has demonstrated, additions to paint and steel coating can also impart anti-corrosive properties or conductive properties. There is also a considerable market emerging in conductive 3-D printing inks. It’s this additive market which TLG will be targeting due to the near term commercial potential and higher quantity requirements.

Given the early stage of the market, the ultimate pricing dynamics for graphene are difficult to quantify. Its scarce quantities and strong appetite over recent years has seen graphene prices trade at extraordinarily high levels and typically only transact in gram and kilogram quantities. In our view, the extent to which TLG’s production of graphene will impact the price will be governed by how dynamically end users move to utilise additional supply.

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