Graphene Production Beyond The Hype: Electrochemical Exfoliation

Summary

Graphene has many special properties and its adoption has been limited by availability and price.

Few layer graphene has similar properties to single layer graphene in certain applications.

Affordable few layer graphene production has arrived.

Talga Resources is on track to be one of the largest graphene producers in Europe by the end of 2016.

200 times stronger than steel. The most conductive material discovered. Transparent, flexible and the most expensive material on earth.

Graphene is all of these things and these unique properties have led to development of many companies focused on graphene research around the world. The EU alone has committed 5 billion euro to the development of applications for graphene.

So what is graphene? In a sense it is the simplest material known to man. A two dimensional material formed by a single layer of carbon atoms. This material had been theorised about since 1947 but the process of forming it was not documented until 2003.

The discoverers of this process were awarded the Nobel Prize for Physics in 2010. The process is surprisingly simple and it is possible to replicate in your home. Graphite is essentially made of innumerable layers of graphene and by rubbing a pencil on adhesive tape you deposit graphite onto it. By sticking another fresh piece of tape onto it before pulling them apart you get a thinner layer of graphite. After doing this repeatedly what you are eventually left with is graphene.

Obviously this is not a scalable process. The cost of producing just one micrometer of graphene in this manner was estimated in an article published in Nature at just over $1000. Hence the label of graphene being the most expensive material in the planet.

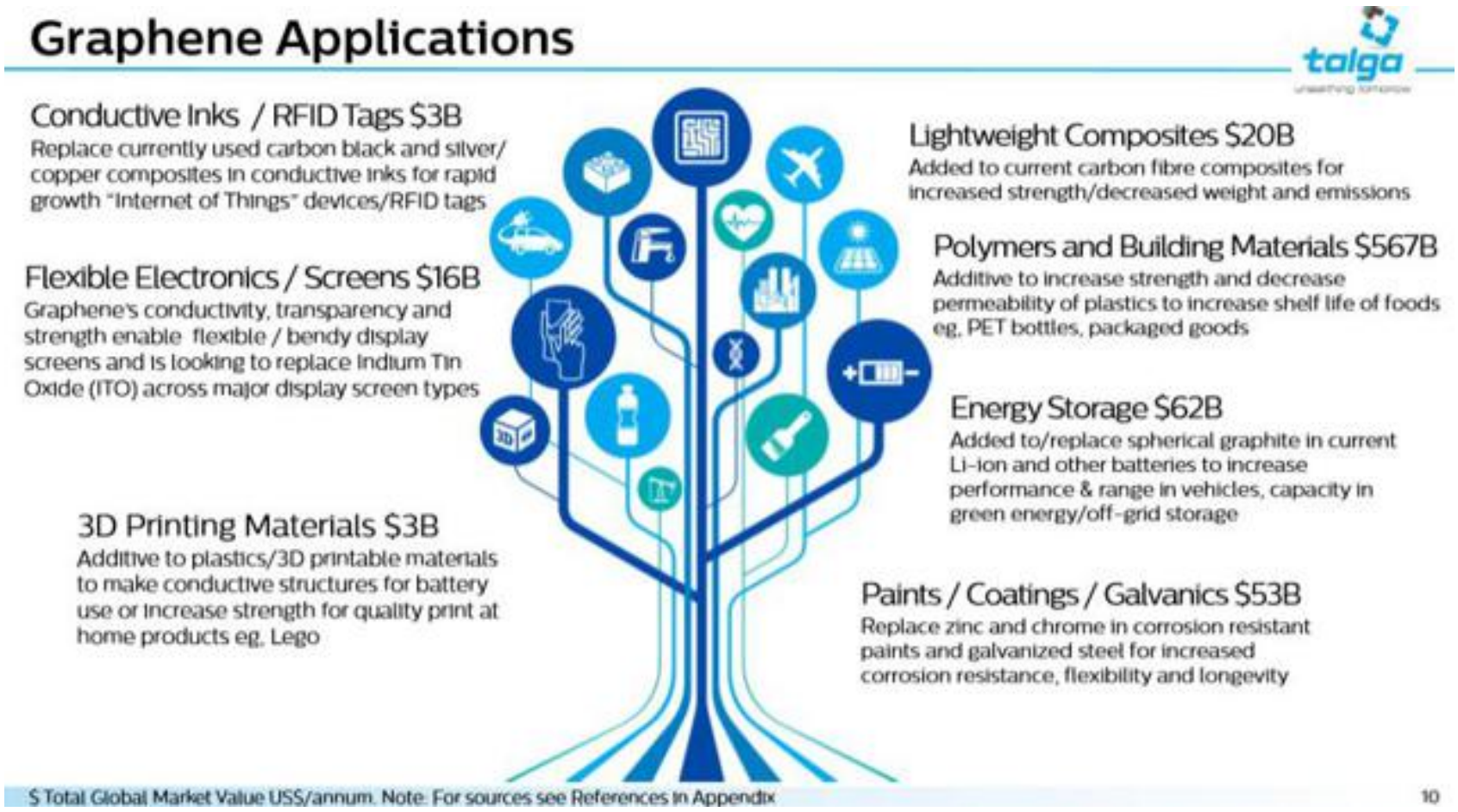
Despite the cost, some graphene enhanced products are already available. Head has developed tennis racquets used by players such as Novak Djokovic and Maria Sharapova. A lightbulb is due to hit UK markets soon and graphene enhanced bicycle tires have been developed by Vittoria. Especially good for avoiding those annoying tyre

punctures.

The market for graphene at present is minuscule and opaque but the potential for producers who can make affordable graphene is large.

Figure 1. Market Size of Future Graphene Applications. Talga Resources Presentation.

(click to enlarge)



In this series of articles I will look at the various production methods with a focus on the listed companies that are pursuing them. I have chosen electrochemical exfoliation of graphite ore as the first production method to analyse as it has the potential to unlock the factors holding back the proliferation of graphene. Quality and quantity at an affordable price.

For a more comprehensive overview of the graphene market this video by Talga Resources CEO, Mark Thompson is quite informative.

Electrochemical Exfoliation Directly from Graphite

True graphene is a single layer of carbon but increasing researchers have found that few and very few layer graphene share many of the properties of single layer graphene. Very few layer graphene is much easier to make and when added to other material greatly enhances their properties.

Mechanical exfoliation has been used to produce very few layer graphene but typically uses synthetic graphite as a feedstock due to its higher purity (99.9% carbon). At

$10,000 a tonne this is not cheap so I have focused on companies using natural graphite ore to produce graphene.

Focus Graphite and Grafoid

Focus Graphite (OTCQX:FCSMF) is listed on the TSX and owns 18% of Grafoid. The future of these two companies is deeply intertwined and share Gary Economo as CEO.

Grafoid

Grafoid is a private company and its trademarked product Mesograf is made directly from the high grade ore of Focus Graphite's Lac Knife deposit. The process they use to make this high quality few layer exfoliated graphene is purportedly scalable, does not involve the crushing or treatment of the graphite ore with harsh chemicals.

On February 20, 2015, Grafoid received C$8.1 million dollars from the Government of Canada, through Sustainable Development Technology Canada to help with the development of an automated Mesograf production system.

Grafoid CEO Gary Economo was also quoted in August 2015 as saying that he expected the company to earn C$100 million in revenue by the end of the year.

Focus Graphite

Focus Graphite's main project is its Lac Knife deposit in Quebec. It is one of the highest grade graphite deposits in the world with a mineral reserve of 7.9Mt @ 15% Cg with a proven mineral reserve of 429kt @ 23.61% Cg.

Focus Graphite also owns 7,800,000 shares of Grafoid which it values at $5 dollars a share or $39 million based on the value per share Grafoid acquired Alcereco a testing company. This measures favourably with Focus Graphite's market capitalisation of $10 million.

Figure 2. Feasibility results for Focus Graphite's Lac Knife project . Focus Graphite Presentation.

(click to enlarge)

FEASIBILTY STUDY

Filed August 8, 2014

Revenue Estimates

Annual Milling Capacity	323,670 tpy
Concentrate Production	44,300 tpy
Cost Per Tonne of Concentrate	$441/tonne
Annual Operating Costs	$20M
Annual Operating Margin	$56M
Selling Price Average	USD$1,713/tonne
Strip Ratio	
First 5 years	1.26:1
Life-of-Mine (LOM) average	1.7:1

Revenue Breakdown

Large Flake	$26M
Medium Flake	$9M
Fine Flake	$41M
Total:	$76M

Financial Results

Initial Capital Cost	$166M*
**Includes $17M contingency*	
Net Present Value (Pre-tax)	
8% discount rate	$383M
10% discount rate	$291M
Net Present Value (After-tax)	
8% discount rate	$224M
10% discount rate	$165M
Pre-Tax IRR	30.1%
After-Tax IRR	24.1%
Pre-tax Payback Period	3 years
After-tax Payback Period	3.2 years

Negatives for an investment in Focus Graphite.

1. The price of graphite has decreased since the release of Focus Graphite's feasibility study.
2. At June 30, 2015 the company had only $367,871 cash at bank with a decrease in cash of $1,658,348 for the 3 months to June 30, 2015.
3. Declining share price and low market capitalisation $10million.
4. It does not seem feasible that Focus Graphite could finance the Lac Knife project in its current form.
5. Lack of revenue despite success of Grafoid.

Positives for an investment in Focus Graphite include.

1. An offtake agreement has been signed with Grafoid covering over half of anticipated production.
2. 18% stake in Grafoid it has valued at $39 million.

Talga Resources

Talga Resources (TLG:ASX) current focus is the development of its Vittangi Graphite project in Sweden. This deposit was previously owned by Teck Cominco now Teck Resources (TCK:NYSE) and this was purchased by Talga Resources in 2012 for $478,500 and a 1% net smelter return. A further 2% net smelter return is due to Phelps Dodge now Freeport-McMoRan (FCX:NYSE).

Its Vittangi deposit in Sweden is the world's highest grade JORC compliant graphite deposit at 7.6Mt @ 24.4% Cg. There is minimal overburden with a uniform deposit which allows for ease of extraction.

More importantly the uniformity of the graphite allows Talga to make graphene directly from Vittangi ore rather than synthetic graphite. The unique nature of Talga ore can be seen most readily by looking at the raw ore itself.

Figure 3. Synthetic graphite compared with Vittangi ore. Talga Resources Presentation.

(click to enlarge)

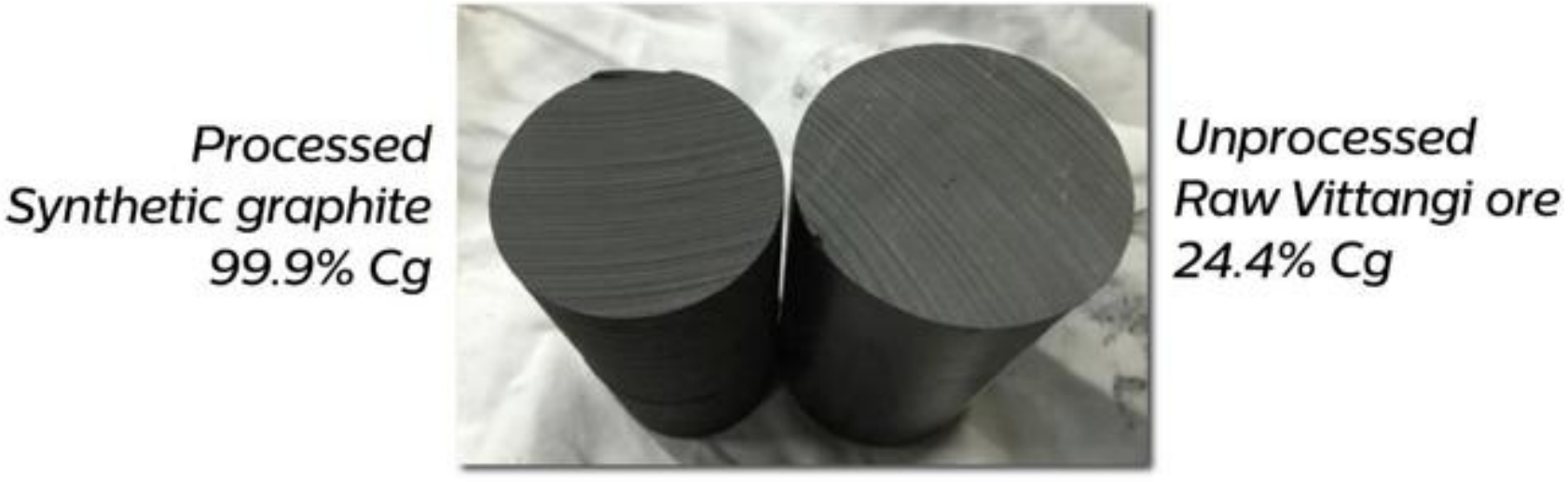


Figure 4. Trial Block Mining at Vittangi. Talga Resources Presentation.

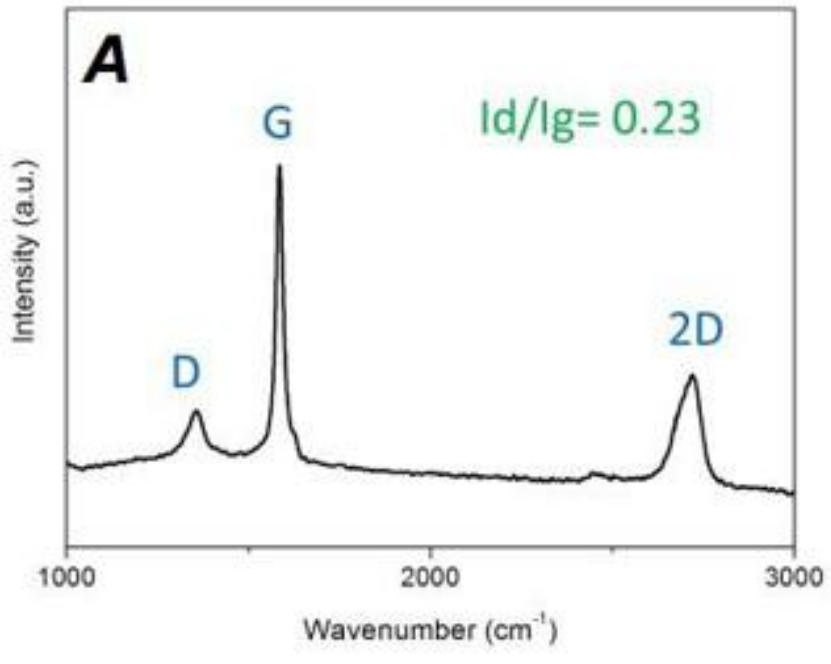
(click to enlarge)

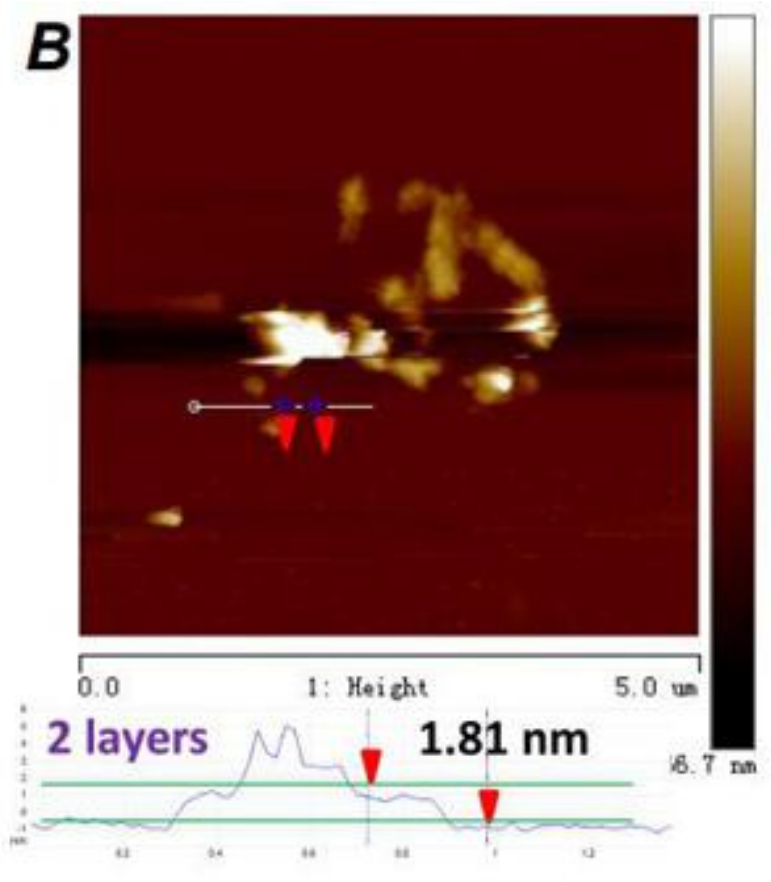
Like Grafoid, Talga has not detailed the exact mechanics involved in the production of its graphene but it appears that it may use the conductive properties of the ore to liberate the graphene. This simple process also appears to produce high quality few layer graphene with an Id/Ig of 0.23 and large particle size.

Figure 5. Talga Graphene Production Process. Talga Resources Presentation.

[Figure 6](). A) Raman Spectroscopy and B) Atomic Force Microscopy of Talga Graphene. Talga Resources ASX Press Release.

(click to enlarge)





Talga has already sold some of its graphene to a German 3D printing company and has started production at its pilot plant (capital cost A$1 million) in Germany. Production at the pilot plant is ramping up in 3 phases to a production rate of 100-200 tonnes of

graphene per annum. Talga expects to reach this production rate by the end of 2016 at which point it will be one of the largest producers of graphene in Europe.

The capacity to directly produce graphene directly from raw ore leads to low capital costs and impressive net present values in its feasibility study. Management have been deliberately conservative in their assumptions with a 12% discount rate used and a 2% graphene yield when test yield results from Vittangi drill cores have reached >10% as the numbers would not be believable.

Figure 7. Feasibility Study Results for Vittangi Project. Talga Resources ASX Press Release.

(click to enlarge)

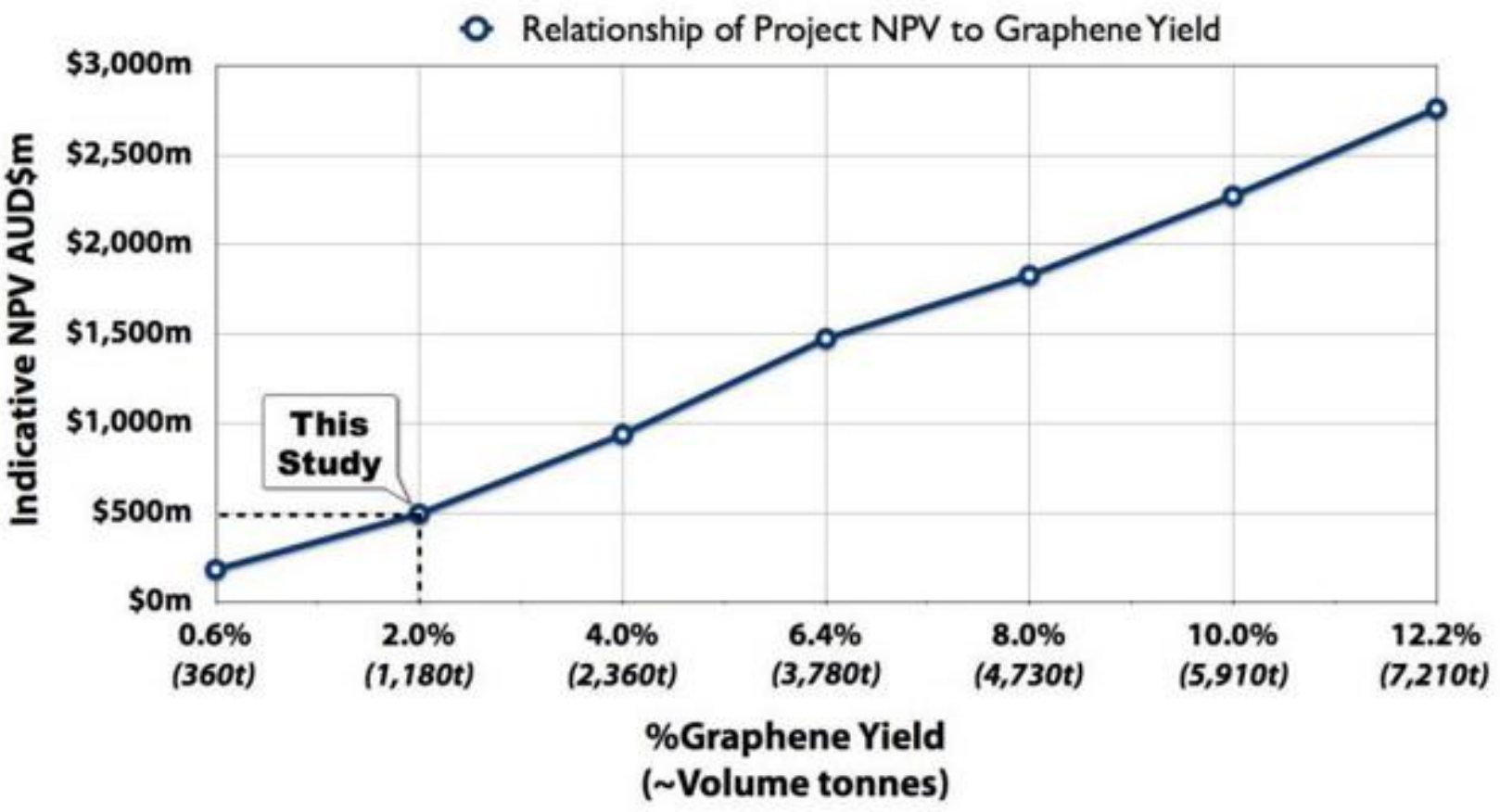
Items		Base Case
Plant throughput	(tpa)	250,000
Diluted Feed Grade	(%)	23.6*
Graphite production	(tpa)	~46,000
Graphene production	(tpa)	~1,000
Life of Mine Strip Ratio	W:O	4:1
Graphite price assumption	(USD$/t)	480
Graphene price assumption	(USD$/t)	55,000
Capital cost	(AUD$m)	29.3
Mine Life	(years)	19.7
Discount Rate	(%)	12
Pre Tax Net Present Value (NPV)**	(AUD$m)	~490
Payback from construction start	(years)	1.4

**Feed grade after mining dilution factors. ** Pre-tax and other impositions but including state and private royalties.*

Figure 8. NPV of Vittangi Project Versus Graphene Yield Results. Talga Resources ASX Press Release.

(click to enlarge)

Graph of indicative project NPV (using US$55,000t graphene price) sensitivity to graphene yield/volume.



Negatives for an investment in Talga Resources

1. Untested technology.
2. No offtake agreements.

Positives for an investment in Talga Resources

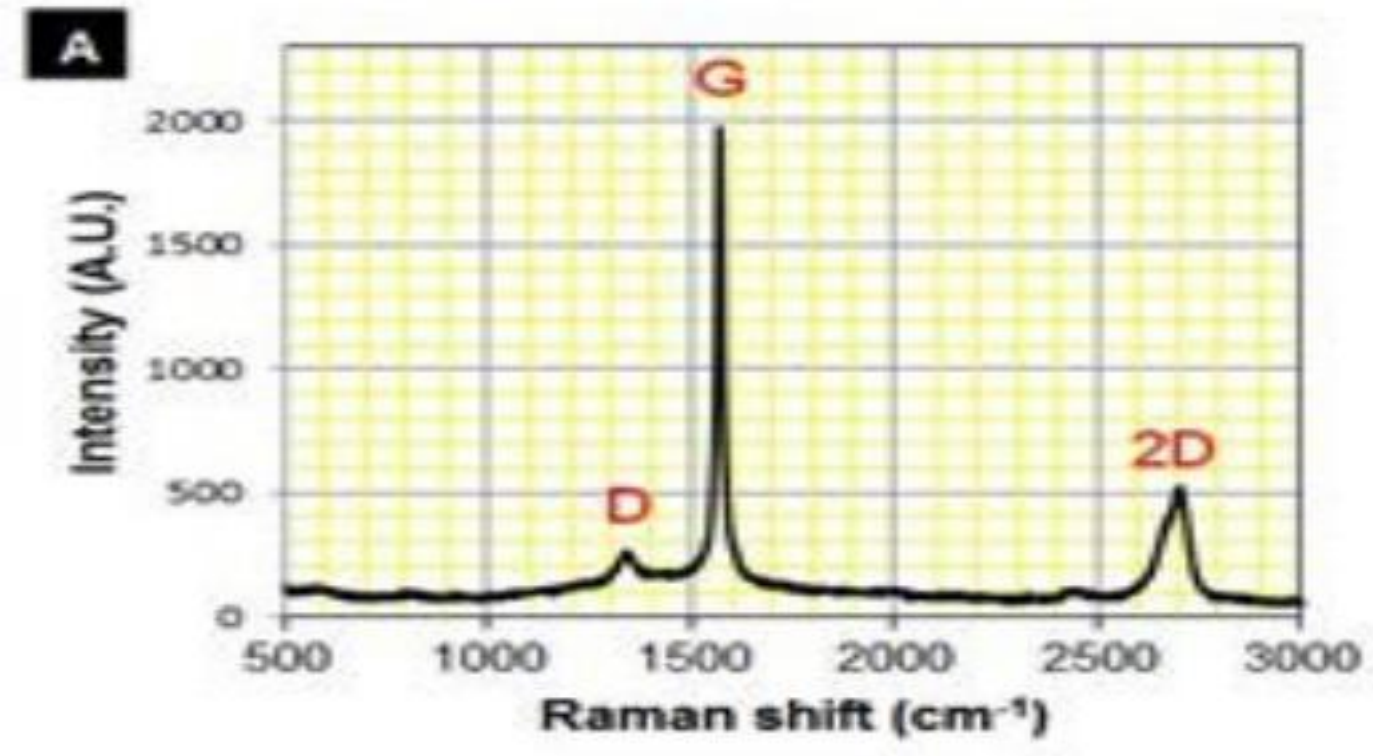
1. Will be one of the largest graphene producers in Europe by the end of 2016
2. Low market capitalisation, $40 million
3. Capital cost of Vittangi project low, $21 million.
4. Net present value of Vittangi project high, $343 million.
5. Production of few layer graphene has started at its pilot plant.
6. Capital cost of Vittangi project may be covered by revenue from pilot plant.
7. High quality few layer graphene has been produced.

MRL Corporation

MRL Corporation essentially sent their vein graphite to the same researchers that showed that Talga's ore was amenable to graphene production. MRL corporation

however was able to achieve graphene yields in excess of 90% from the exfoliation of its vein graphite compared to 2-12% for Talga resources. The quality of the graphene it produces also appears comparable to Talga but was more crystalline in nature.

Figure 9. Raman Spectroscopy Results For MRL Graphene. MRL Corporation Presentation.



Sri Lankan vein graphite has commanded a premium in the market due to its high carbon content (90-99%). Its production has always been limited by the nature of the deposits, narrow, typically only a few cm to a meter wide as the name vein implies. This characteristic means that it is not feasible to drill a JORC compliant resource for a deposit.

The civil unrest in Sri Lanka has also limited production and by 2012 production of vein graphite was down to less than 3200 tonnes with only 2 mines left in production. Production in 1916 was 33,000 tonnes.

At present MRL has identified approximately 220 old mines on its 5 separate graphite project areas. The company believes that with the application of modern mining methods they will be able to follow these deposits deeper as historically large amounts of graphite were produced from quite shallow mines.

Figure 10. Historical Sri Lankan Vein Graphite Mine. MRL Corporation Presentation.

Historical Adit

Historical Shaft

At this stage MRL corporation have yet to clarify the process by which it will achieve production and has yet to publish a feasibility study. Its market capitalisation however is only $8 million which would see incredible leverage in case of success and after its recent capital raising has at least >$1 million in cash at bank to continue operations.

Negatives for an investment in MRL Corporation

1. Geography risk in Sri Lanka.
2. No JORC compliant resource.
3. Untested technology.
4. Production of commercial quantities of graphene 2+ years away.

Positive for an investment in MRL Corporation

1. Vein graphite may have unique properties.
2. First mover advantage in Sri Lanka.
3. Leveraged graphene play due to extremely low market capitalisation.
4. High graphene yield from preliminary studies
5. High quality few layer graphene produced.

Conclusion

All of the companies discussed in this article are of a speculative nature but have the capacity to disrupt the world we live in.

Focus Graphite is particularly hard to analyse as most of its value appears to reside in the 7,800,000 shares it holds in Grafoid, a private company.

In its current form, Focus Graphite's Lac Knife project will not be developed without a large increase in the graphite price.

The only catalyst I can see for Focus Graphite is the sale of its stake in Grafoid. Management have valued this stake in Grafoid at 4 times its current market capitalisation. Management have made no indications that they will do this which makes Focus Graphite a high risk asset play.

Talga resources is a company using very low tech mining methods to produce high tech graphene. It looks set to become one of the largest graphene producers in Europe by the end of 2016 from just its pilot plant production.

The NPV of $341 million for its Vittangi project feasibility study is robust as it is able to produce graphene at the price of amorphous graphite. There is also large upside to the NPV of this project with if higher graphene yields achieved during bench top testing are replicated in the pilot plant.

Talga however has yet to announce customers for its graphene and has only sold a minor amount of graphene thus far. Investors I believe are compensated for this by its low market capitalisation of $40 million and the possibility that revenue from its pilot plant could pay for the Vittangi project.

Upcoming catalysts for Talga include the successful ramp up of pilot plant production and confirmation that the pilot plant will have a graphene yield of >2%.

The most crucial catalyst will be the announcement of the sale of commercial quantities of graphene. This is like to occur in 2016-2017. Management have indicated that they are bound by confidentiality agreements by its customers to prevent the leakage of information to their competitors. Talga's customers are doing this as they want to launch their innovative graphene enhanced products directly to the market.

MRF is following in the footsteps of Talga resources but has not made the case for its vein graphite being unique. Its graphene yield is much higher than that achieved by Talga but the geology of vein graphite means that it will likely to lose out to Talga in bulk applications. The structure of MRF's graphene appears different to Talga's and there will likely be applications where its crystalline graphene would be more suitable.

Further testing is required to determine how MRF's graphene will perform but investors are highly leveraged should it prove successful.

Upcoming catalysts will be the beginning of trial mining. A sector halo effect if Talga Resources proves to be successful and the publication of results of a feasibility study.

Editor's Note: This article covers one or more stocks trading at less than $1 per share and/or with less than a $100 million market cap. Please be aware of the risks associated with these stocks.