



UNION SECURITIES INTERNATIONAL

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**USIL : mining and materials sector strategy :
London, Monday December 14th 2020**

Graphite, graphene and the Dyson swarm

Re-visiting Kardashev and the mining super cycle

To finish the year, a festive assessment of the crumbliest flakiest version of the only non-metal conductor on the planet. A hexagonal crystal lattice, a variation of its better known structural form - diamond. It turns out there are lots of 'allotropes' to occupy a new generation of research PhD's but the 2010 Nobel Prize for the isolation of graphene in 2004 was the milestone that kickstarted a new rush of commercial interest.

[For those in a hurry, jump to [pages 5/6](#) to see the companies that make up the industry : **10 minute** read in total, preferably on a desk top]

Conclusion : amongst the listed company names, we are drawn to three :

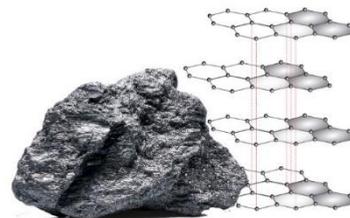
1).... **Aixtron AG**, 2) **Talga Resources** 3) **Zen Graphene**

Long term investment rationale ?

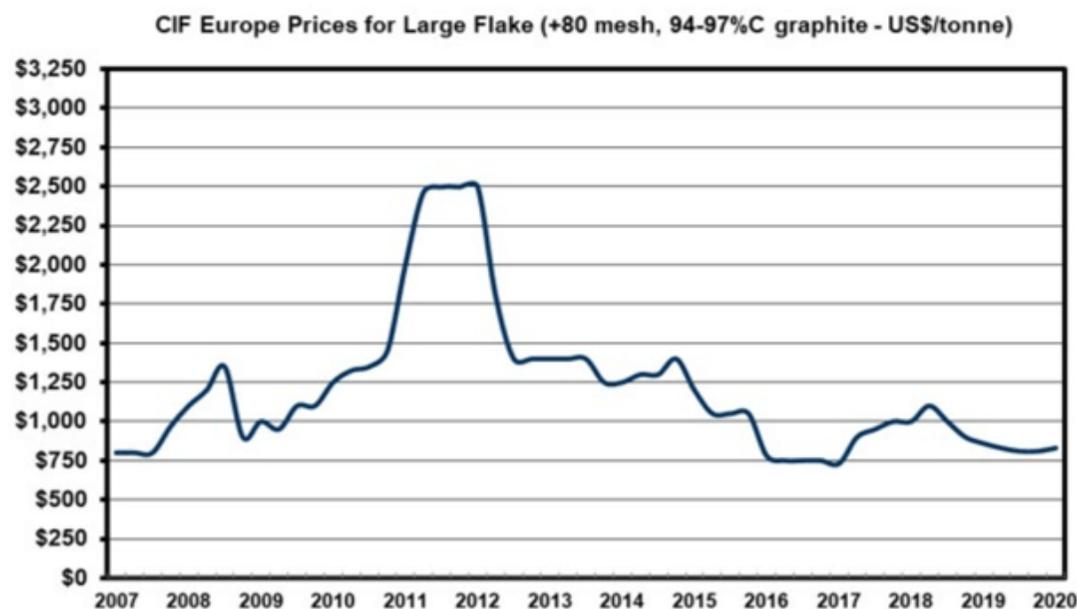
Some kind of techmageddon will provide an awkward 2021 reset for the *growth at any price* wunderkind of the COVID era. That may sound like a weak swipe at the extraordinary momentum of a cluster of trillionaire club members but it's our excuse to test the tea leaves for some new hot money beneficiaries. Can a manufacturing business or an upstream graphite specialist hope to attract the '20x sales' mystique being dished out to anything with an app? While we salute the market entrance of C3ai, DoorDash and AirBnB, three of the week's dazzling arrivals, we can invent some sci-fi valuations of our own.

To enter into the spirit of very far forward earnings, begin by choosing either the Kardashev scale of civilization, or Barrow's micro dimensional alternative. The graphite/graphene opportunity works quite well in both scenarios. The very large volumes of graphite required to complete the Dyson Swarm in a Kardashev type 2 civilization would be excellent for graphite deposit owners. John Barrow's micro-dimensional alternative, a world in which we achieve progressive control over genes, molecules, atoms and nano structures, would favour the PhD's and the (mainly privately held) graphene and nano projects. For a re-cap on escape velocity and the volumes of graphite we'll eventually need, step into the excellent [Kurzgesagt](https://www.youtube.com/watch?v=pP44EPBMb8A) video, right here :

(time needed : 7.47) <https://www.youtube.com/watch?v=pP44EPBMb8A>



Graphite : types - grades - purity - and pricing



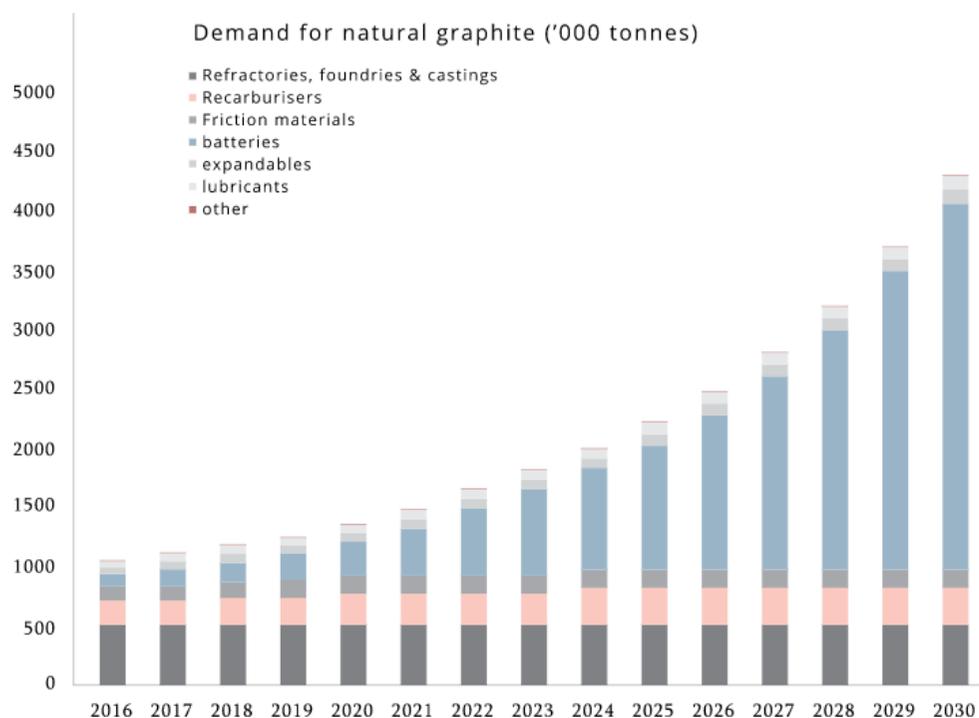
There is no spot or futures derived price for natural amorphous graphite . Terminology is confusing and casual listeners should be prepared to get muddled. *Amorphous graphite* is a contradiction in terms since all graphite is crystalline. Bluffers should suggest that 'microcrystalline graphite' is a far better description

– follow that up by asserting that amorphous graphite is a *seam mineral*, not to be confused with a *vein mineral*. Learn also that bog standard amorphous grades are only 20-40% carbon whereas what's often needed is grades of 90% and above.

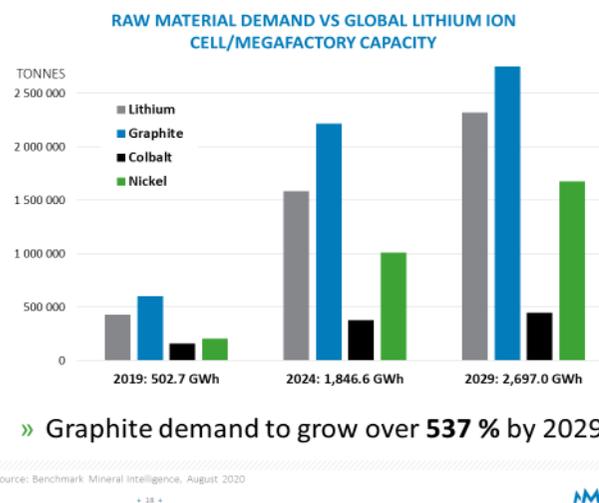
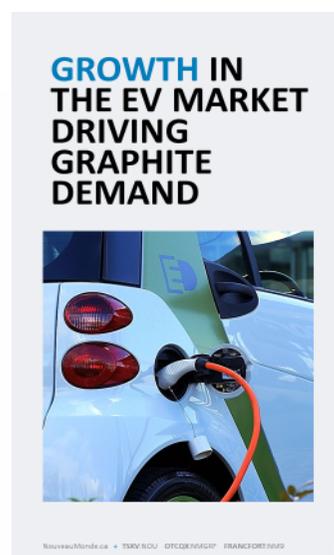
Carbon purity: Flake graphite concentrate with a greater carbon purity receive a premium price because that requires less processing to remove disruptive impurities. A carbon content of 90% and above is generally required in all refractory, foundry and crucible applications. The most common grade used in refractory applications is around 92% C, but some major producers will demand a purity of up to 96% C to ensure the integrity of their products. The price of grades greater than 94% increase at an accelerated rate as the carbon content increases, due to the greater cost involved in refining the material for top end applications.

Mesh size: Similar to high-carbon purity grades, larger mesh sizes demand a premium. Tighter supply conditions for these grades dictate that prices escalate rapidly at mesh sizes larger than +80 mesh. Larger mesh size improves the material's conductivity for higher-value applications. Clear !? For a more informed source of pricing on all the minor and industrial metals, seek out some current data from www.fastmarkets.com

NATURAL GRAPHITE demand.



Graphite's primary role in lithium ion batteries is its application as the anode. Graphite is here to stay even though we occasionally hear talk that it's one of the limiting factors of the Li-ion battery. Lithium is added to graphite when charging and removed as the battery is used. Graphite anodes are used in nearly all Li-ion batteries although it's not the only solution. With a theoretical capacity of more than 10 times that of graphite, silicon anodes can at least double the capacity of graphite-anode batteries. However, it is this ability to absorb lithium and expand during charging that is the problem: the silicon breaks down quickly. Capacity and structural stability are cited as key qualities for graphite and, as Benchmark Minerals Intelligence are often quoted, flake graphite demand is likely to increase significantly as the decade progresses. They show 170,000 tonnes of battery demand moving to 2.6mm tonnes by 2030. Thanks to Benchmark for the demand chart below.



Graphic courtesy of Benchmark Minerals

Synthetic graphite is of growing significance since it offers quite different power and speed variables. Regular graphite is associated with 'better' range and duration qualities but the physics is complicated enough to leave room for doubt as to how the market will eventually divide. Processing and production is dominated by Chinese companies and more generally these graphite purification skills are better known in Shenzhen and Heilongjiang. The West has at last begun to address these supply side risks - about time.



GRAPHENE applications

To displace current solutions, graphene will simply have to be better. Much, much better. While the number of real world commercial examples remains quite niche, there is a growing list of uses that bring dramatic performance enhancements. Some of these are real benefits that sustainability and ESG watchdogs will actually want to endorse. Success is heavily dependent on overcoming teething problems around scaling up. Equity funding takes great science to the starting gate but only with scaled production will larger lenders pay attention. Seeing those credit structures more widely established will do good things for investor confidence.

<https://www.youtube.com/watch?v=IesIsKMjB4Y> (6.25 “.....one word ‘*graphene*’”)

Which firms are out there doing interesting things and putting the best of a decade’s research to work ? Here’s some product examples that represent the big ideas at scale.

- ❖ [Advanced Material Development](#) : Guildford UK based technology platform with strong commercial partners across sensors, composites, photonics and stealth electronics. Graphene & nano materials focus includes RFID and super conductive inks.
- ❖ ‘Graphene 360’ branded [Head](#) tennis rackets, Novak Djokovic endorsed.
- ❖ [Vollebak.com](#) : wearable technology and pricey top end graphene jackets.
- ❖ [Concrene Ltd](#) and Thomas Swan & Co pushing into precast materials with graphene nano platelets: adds huge strength to concrete, lowers needed volumes and solves porosity.
- ❖ [FreeVolt Sp zo.](#) : graphene enhanced solar panel makers. Major improved efficiency hopes.

- ❖ [Huayuan Group's](#) RFID tags. One of many near field comms (NFC) groups racing to apply graphene's excellent conductive, thermal and adsorption properties to large end markets.
- ❖ [Huawei Mate '20X' model](#). Device cooling facilitation using a graphene vapour chamber.
- ❖ [Cardea Bio's](#) graphine gFET's (graphene field effect transistors). Biology meets electronics.
- ❖ [Inov-8.com's](#) high traction, super durable, low permeability running shoes
- ❖ [Spaceblue's](#) waste tyre initiative and everlasting rubber floormats.
- ❖ Canny heating mattresses by Hong Kong listed device makers, [Xiaomi](#)
- ❖ Smart graphene flooring by the Australian firm Imagine [Intelligent Materials Pty Ltd](#).
- ❖ [Ora Sound's](#) graphene GQ acoustic transducers for better headphones.

The **listed entities** follow in the next section and are a mix of pure upstream, midstream, and fully integrated businesses. Some with special manufacturing expertise and some with decent research budgets. It's that transition from the lab to affordable end products which has started to look promising. A large demand component for semi-finished B2B graphite material should encourage upstream deposit owners to look at ways of capturing some of processing margin.

(Data may be difficult to view on the move, desk top viewing advised)

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LISTED COMPANIES.

Selecting possible winners is about overcoming the usual challenges, mainly the payoff between the poor liquidity of pure upstream commodity-sensitive juniors - and much larger corporates with only a fringe interest in the main investment focus.

We referred earlier to four names that we believe have some of the ingredients likely to catch investors' attention as more of the commercial potential goes mainstream. We conclude it's likely to be a series of smaller steps forward, mostly with the product quietly creeping into everyday applications without a lot of fanfare. The four names we highlighted strike us as well equipped to catch investor imagination even if underlying graphite prices go nowhere fast.

Tier 1 names

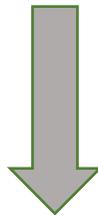
With an arbitrary line drawn at \$100mm of enterprise value, the more potentially investable names include the following :

	Exchange	Company	local price	US \$mm	EV\$	symbol	# key words
1	NYSE	Entegris	92.6	12,302.40	13,563.00	ENTG	Advanced materials handling, \$2.0bn run rate, semi conductor customer centric, 5000+ staff.
2	Euronext	Imerys Graphite	36.84	3,682.80	5,755.20	IMYSF	lotsa debt, multiproduct line, bought Bodio - a leading synthetic producer in Switzerland.
3	XETRA	Aixtron AG	12.74	1,768.80	1,465.20	AIXA	Well funded EU market leader in MOCVD and thin films deposition. Opto/power and nano electronics.
4	Nasdaq	Veeco Instruments	17.33	883.08	893.64	VECO	semiconductors, RF filters, ion beam deposition and LED markets. Orders and margins improving.
5	Euronext	AMG Advanced Met Group	23.5	806.52	1,372.80	AMG	3000 staff, specialty metals, alloys, CO2 reduction systems : Graphit Kropfmuhl division.
6	XETRA	SGL Carbon	3.85	568.92	876.48	SGL	30 production sites and 4950 staff, tough year but stayed in the black in spite of 14% 9mos sales fall.
7	tsxv	Nano Xplore	3.52	394.68	401.28	GRA	custom graphene enhanced plastics and multiple nano material projects.
8	asx	Talga Group	1.79	327.36	323.40	TLG	vertically integrated ,high grade Vittangi, Sweden and Germany divs, coated electrode powders
9	asx	Syrax Resources	1.02	315.61	323.40	SYR	Balama, Mozambiqueproduction halted back in March. A\$56mm convertible launched this week.
10	tsxv	Nouveau Monde	0.59	143.88	150.48	NOU	Mac's Lead. Quebec focused mines. jv pilot planf with Olin. Pallinghurst shareholder.
11	asx	Mineral Commodities	0.37	124.08	124.74	MRC	Skaland 90% owned. Mineral sands deposits in Western Cape. Munglinup Graphite project in WA.
12	Nasdaq	Westwater Resources	5.22	113.52	108.24	WWR	Coosa Alabama located graphite project. (previously Uranium Resources)
13	asx	Sovereign Metals	0.37	104.28	101.64	SVM	Malawi : Malingunde deposit. Duwi Flake project. Also focused on the rutile deposit, Kasiya

It is true that there are many more downstream manufacturing names, some in semiconductors and various healthcare biotech names that could be included as participants in the graphene story. The list is not exhaustive and readers are welcome to be in touch if they know of other emerging sector candidates for the next summary

Tier 2 and Tier 3 names

The next two groups straddle either side of the \$50mm mark. There will be big winners in the microcap group simply because the electric vehicle revolution looks unstoppable, even if it is temporarily overcooked. Like the lithium story that was on hold until September this year, we'll see junior upstream players with current and near term production potential back in focus. The energy storage agenda is gathering pace and in addition to graphite, operators with economically feasible vanadium assets deserve attention too. Many of these are quite difficult to buy and sometimes impossible to sell. That said, there should be m&a potential as asset owners struggle to maintain the licenses and for new entrants, many of these names represent 'rto' or 'shell' company optionality.



	Exchange	Company	local price	US \$mm	EV\$	symbol	# key words
14	tsxv	Zen Graphene Solutions	1.46	99.00	95.04	ZEN	Guelph, Ontario: Albany graphite project: graphene oxide dehumidification membranes.
15	asx	Magnis Energy Technologies	0.19	90.02	93.72	MNS	Nachu graphite deposit, Rutamba North , Tanzania
16	asx	First Graphene	0.26	85.80	80.52	FGR	Formerly First Graphite, partnered in UK with Kainos Innovation
17	LSE AIM	Versarien	37.17	85.80	87.12	VRS	UK based developer, various graphene related projects, inks, platelets. Lanstead shareholding.
18	asx	Archer Materials	0.56	83.16	80.52	AXE	Quantum computing ambitions : some graphite exposure, Qiskit software & chip development.
19	LSE	Directa Plus	76.38	64.68	59.40	DCTA	Basic G+ products range. £6mm revenue run rate in 2020. 38 patents and 24 pending. Textile skills.
20	aus	EcoGraf	0.17	50.16	47.52	EGR	Tanzania, formerly Kibaran Resources. Epanko project : 60/tpa bankeable feasibility study 2017 (IPEX)
21	asx	Black Rock Mining	0.09	41.58	41.58	BKT	Mahenge Tanzania. POSCO South Korea JV negotiations continue.
22	tsxv	Mason Graphite	0.32	39.47	19.80	LLG	Lac Gueret Quebec, board reshuffle completed, CEO search continues. Spherical purified graphite.
23	asx	Triton Minerals	0.05	38.28	35.64	TON	Mozambique , 8 licenses inc Balama South
24	asx	Walkabout Resources	0.15	36.96	34.58	WKT	Lindi jumbo graphite project in Tanzania
25	tsxv	SRG Mining	0.64	35.64	35.64	SRG	Benoit La Salle, La Fola in Guinea Conachry
26	tsxv	Next Source Materials	0.08	34.32	33.00	NEXT	Molo, Madagascar : 141mm graphite resource at 6.13% : may shift focus more downstream.
27	Nasdaq	CVD Equipment	4.40	29.30	35.77	CVV	chemical vapor deposition systems for use in aerospace, carbon nanotubes, solar cells
28	LSE AIM	Applied Graphene	40.19	23.76	18.48	AGM	graphene powders, 3D inks
29	asx	Battery Minerals	0.02	23.36	20.46	BAT	Montepuez, Mozambique, 39mm tonnes at 10.2% TGC. Limited activity.
30	LSE AIM	Haydale Graphene	3.63	22.44	25.48	HAYD	plasma processed graphene. Dowty propellers marine and BAC Mono supercar graphene wheel arches.
31	asx	Volt Resources	0.01	14.52	15.84	VRC	Bunyu Graphite, 461mm tonnes at 4.9 TGCTanzania, Namangale, and a Mozambique license. Guinea too.
32	tsxv	Gratomic Inc	0.23	14.52	15.84	GRAT	Namibia : Aukam project in Bethanie district.
33	tsxv	Ceylon Graphite	0.27	14.26	15.71	CYL	Sri Lanka focused, 131 grids of over 121sq km - K1 mine permitted, producing.
34	tsxv	Focus Graphite	0.06	13.33	11.88	FMS	Lac Knife deposit, Fermont, Quebec Lac Tetepisca Quebec. Lac Guinecourt graphite. Dormant.
35	tsxv	Graphite One	0.40	13.07	17.29	GPH	Graphite Creek deposit, Nome, Alaska.\$1.03bn in the 2017 PEA. 10.3 mm tonnes indicated, 7.2% Cg.
36	asx	Hexagon Energy Materials	0.06	12.80	13.20	HXG	McIntosh project Western Australia, Ceylon Graphite project Alabama.
37	tsxv	Northern Graphite	0.26	11.88	10.56	NGC	Bisset Creek, Ontario
38	asx	Renascor Resources	0.01	10.56	9.24	RNU	Arno graphite, Siviour Battery Anode Material Project. Fundraising prospectus , A\$3.45mm committed.
39	tsxv	Elcora Advanced Materials	0.07	4.88	5.94	ERA	Sri Lanka : previously produced 500t a year but now on care and maint.
40	tsxv	Lomiko Metals	0.05	4.88	5.02	LMR	Quatre Milles East and West proipertie, Quebec
41	csCanada	Graphite Energy	0.37	3.70	3.83	GRE	Lac Aux Bouleaux Graphite Proport, Southern Quebyec
42	asx	Blackearth Minerals	0.05	3.56	3.30	BEM	Formerly Graphite Australia. BFS underway.
43	asx	Bass Metals	0.01	2.86	2.86	BSM	Graphmada deposit, Madagascar. Non compliant 2012 resource 14.3mm tonnes JORC at 4.0% TGC
44	tsxv	St Jean Carbon	0.03	2.38	2.38	SJL	BC and Quebec property claims. Last raise c\$122,000 in November.
45	tsxv	Goldcore Resources	0.09	1.58	1.58	GEM	Berkwood Graphite Project, Lac Gueret south project
46	tsxv	Eagle Graphite	0.05	1.58	1.58	EGA	Black Crystal graphite quarry BC
47	tsxv	New Energy Metals	0.07	1.32	1.32	NXE	was Darien Resources

~	tsxv	Novo Carbon		~		GLK	suspended : trading as Great Lakes Graphite
~	asx	Quantum Graphite		~		QGL	suspended : Uley Graphite resource :5.0Mt @ 11.5% Total Graphitic Carbon (M&I June 30, 2019)
~	tsxv	DNI Metals		~		DNI	suspended : 4mm tonne inferred resource in Madagascar - inactive currently.
~	asx	Lanka Graphite		~		LGR	suspended : Sri Lankan focussed but gave up licenses.

PRIVATELY HELD OPERATORS

Finally, the privately held names - only a few of them are currently structured to accommodate private equity or pre-ipo financings. We're happy to discuss some of the UK based opportunities and strategic sector investors are welcome to be in touch to discuss where such doors are open.

1	prvt UK	Advanced Material Development	~	~	Elects, nano-composites & sensors developer: Qinetiq, Honeywell amongst key commercial partners
2	prvt china	Ao Yu Graphite	~	~	1300 staff, founded 1988. Heilongjiang based, vertically integrated, substantial player.
3	prvt UK	BGT Materials	~	~	Manchester based, CVD Graphene, silicon graphene anode materials: lighting and RFID tags spin offs.
4	prvt US	Cardea Bio Inc	~	~	San Diego based : graphene transistors, chipsets and gFET's, Bio infrastructure.
5	prvt china	BTR New Energy Materials	~	~	Beiterui New Energy Technology Institute : lithium titanate anode materials
6	prvt Spain	Graphenea	~	~	San Sebastian. GFET's, Foundry services, monolayer graphene substrates. 20 employees. Boston MA
7	prvt Sweden	GraphmaTech	~	~	Uppsala University spin off, Aros Graphene, Altris jv, sodium-ion battery research. Funded by Vinnova.
8	private UK	Integrated Graphene	~	~	graphene foam, Gii Cap supercapacitors, biosensing
9	prvt china	LuiMao Graphite	~	~	Synthetic and spherical producer with extensive state backing.
10	prvt Braz	Nacional de Grafite	~	~	founded 1939 - 3 processing sites producing various grades - @ 70,000 tonnes of material annually.
11	prvt German	Schunk	~	~	major player in multiple automotive sectors using graphite materials.
12	prvt china	Qingdao Black Dragon	~	~	Shandong integrated business, downstream processing, lithium titanate anodes.
13	prvt Sweden	Northvolt	~	~	Vasteras Sweden HQ. BMW/VW backed, cell designs and manufacturing ambitions of 32gwh by 2023.
14	prvt china	Ningbo Shanshan	~	~	Another fully integrated state entity with full product range and in house processing.
15	prvt china	Great Wall S-Volt	~	~	cobalt free batteries plant in Germany announced in Saarland
16	prvt Canada	Targray Technology	~	~	Kirkland Quebec : \$600mm revs provider of advanced materials across several renewables areas.
17	prvt UK	Tirupati Graphite	~	~	Vatomina Madagascar - and India - upstream. UK Listing expected in 2021.

CONCLUSION

Graphite and its downstream potential is a fascinating niche and both the US and EU have labelled it a critical raw material. From an investor perspective on the pure upstream names, we are looking at the risks of stranded assets and are therefore preferring names with the means to add some demonstrated IP to the raw material. We suspect that many of the lower grade deposits will never be developed even in boom conditions – a lot of naturally occurring graphite is not suitable for the advanced applications we consider likely to catch investor attention. Performance will inevitably be influenced by overzealous PR so investors do need to exercise caution. Supposed graphene efficacy in Covid 19 facemasks and the like represent the more promotional end of the spectrum. Understanding the risks of a delayed commercial product timeline will require the discipline to buy smaller names on set-backs. ‘Breakthrough’ applications need the credibility and support of major industrial/commercial partners – cross reference all versions of key product development releases.

We will revisit the subject again in 6 months’ time and see just how the group fared. The Dyson swarm won’t be any closer to reality but the ESG revolution and calls for new energy solutions are real. There is a proper chance of graphite/graphene participating in a vast reallocation of capital.

Festive greetings all. USIL London 14th December 2020

Union Securities Intl maintains a capital markets oriented structured database of nearly all mining sector companies. Our valuation approach is based on measured, indicated and inferred asset values in relation to enterprise value. That’s often an aggregated display of per tonne ‘rock values’ and NPV 10. We think this comparable approach works well for groups of companies chasing the same upstream material upstream. By looking at the 43-101/JORC resources for all names in a given material, we aim to assess implied confidence levels and take a view on whether individual operators are in a position to move a project through feasibility and towards construction . Next up, in January: Platinum Group Metals.

We have not been sponsored or paid by any of the companies referred to this note and nor do we currently own shares in any of the names discussed.
The accompanying disclaimer that follows is integral to the overall note.

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