Monday, September 21, 2020

HALLGARTEN & COMPANY

Sector Review

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Manganese & the Battery Revolution

A Base Metal No More….

The EMD Universe

	Strategy	Ticker	Price	12mth range	Market Cap	Target
Manganese X	Long	MN.v	0.84	$0.055-$1.11	CAD$79.6mn	$1.10
Euro Manganese	Neutral	EMN.v	0.10	$0.05-$0.20	CAD$25.8mn	$0.12
Giyani Metals	Long	EMM.v	0.235	$0.04-$0.31	CAD$23.7mn	$0.42

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Manganese & the Revolution

A Base Metal No More….

- + The fears about Cobalt's viability in Lithium Ion Batteries were long only price-oriented but now the most crucial fear is on strategic access grounds
- + Increased Manganese weighting in new LiB formulations is driving a refocusing on the potential of this metal
- + Manganese's two main virtues, are that it is "cheap" and "not difficult", both of which make it the least problematic battery metal
- + The wild gyrations in Vanadium's price has made Manganese look like a tempting option to replace, in part, Vanadium in Redox Flow Batteries for mass storage
- + Lack of Manganese production or resources in North America, makes the few deposits that exist, interesting as crucial assets in the hunt for non-Chinese supply chains for LiBs
- ✗ Cobalt is down, but not out for the count, as a Lithium Ion Battery component
- ✗ There is a perception that Manganese (somewhat like Nickel) is prolific and thus "nothing to worry about"

Manganese – The Road Less Travelled in Battery Metals

The pace of change in the battery space has shifted up a few gears since a small group of developers moved into the Manganese space in 2016/7. Lithium plays first proliferated (and then came tumbling back to earth) and then Cobalt became the word on everyone's lips as the Cobalt crisis moved into centre stage and focusing minds on supply issues in the battery space. Manganese was regarded as the worry-free component of the Lithium Ion Battery formulations, however this ignored the fact that there is almost no production of the metal in North America, outside of Mexico's Grupo Autlan.

Now, however, the metal is receiving increasing attention for its potential to reduce the Cobalt component in various battery types using that metal via the rebalancing of the relative weightings of elements in the battery cathode formulations, particularly Nickel/Cobalt/Manganese in NMC batteries.

In this review we shall look at various trends related to Manganese's usage in batteries, not just LiBs but also mass storage devices. We shall ponder some of the developers and look at a case study of one in particular, Manganese X Energy.

A Blizzard of Technologies

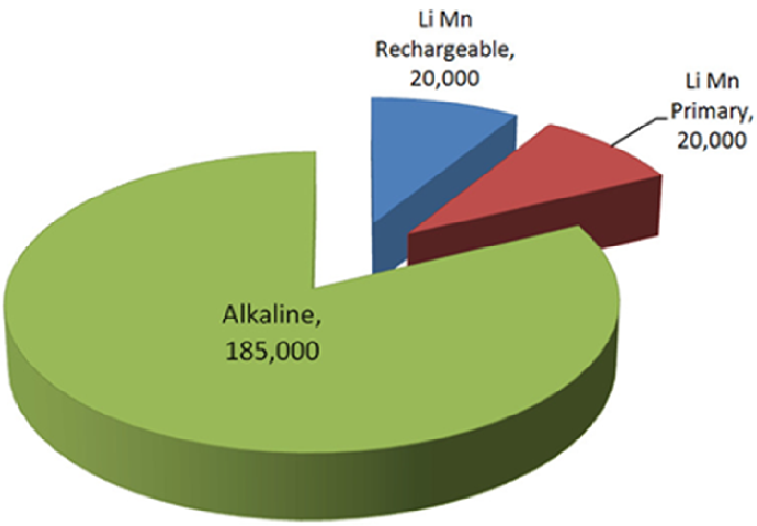
Battery technologies have been proliferating in recent years like mushrooms after the rain. Despite this there are batteries and batteries. Many of the newly invented storage devices have specific usages and one new application is not necessarily a replacement for an existing type of battery. Unfortunately most parents still have reason to curse the ubiquitous *Double A* batteries that have long powered Christmas gifts for children and never seemed to have an up-to-date, cost-effective or long-lasting alternative.

Most of the buzz in the mainstream media is about battery options that extend the life of cellphones or laptops and other PDAs or with regard to hybrid- or all-electric vehicles. However, the really great economic leap forward has to do with mass storage devices which mesh with energy grids to provide off-peak storage of electricity. Industrial or natural gas has been stored since its inception in the industrial revolution in massive tanks, caverns or gasometers, while a solution to massive electricity storage has been much more elusive. With conventional dry-cell battery using two electrodes separated by an electrolyte, it would require thousands of individual cells, the size of soft drink cans, to be strung together in a massive installation to create a mass storage battery of any usefulness to be attached the grid.

The relevance of this has been heightened with the burgeoning of alternative energy sources (wind and solar) that are irregular in their generating periods and do not always coincide with peak demand. While Elon Musk muses on giving his auto-batteries a life-after-death as Powerwalls, the real mass storage device catching attention is Redox Flow Batteries (RFBs), with Vanadium (hitherto) being the main beneficiary of investor enthusiasm. However, this has overlooked the different ways in which Manganese can be mobilized for battery and mass storage technologies.

Manganese Usage in Batteries

We should start by noting that manganese is currently employed in that most prosaic of battery formats, the alkaline battery (think AA or AAA). There is nothing new in that but it does provide a constant demand for manganese and has done for over half a century. It is also one in which little effort goes into the recycling of the Manganese metal in batteries.

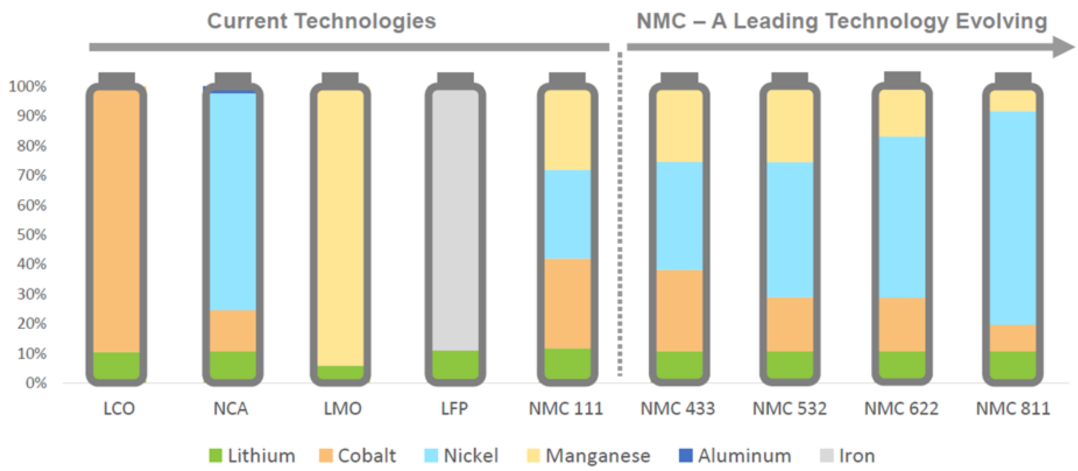


The cutting edge application is the Lithiated Manganese Dioxide (LMD or LMO) Battery. The Lithium-Mn oxide spinel is a relatively new material with some proposing that, the ongoing expansion of the EV market may rely on its greater use in rechargeable batteries. LMO batteries are associated with good structural stability, low-cost and good electronic and lithium-ion conductivity. With growing concern over the safety and viability of other cathode designs spinels based on $LiMn_2O_4$ are growing in popularity as cathode materials.

The standard mix of LMD used in batteries contains 4% Lithium, 61% manganese and 35% oxygen by atomic weight. The attractions of this format are that LMD has high power output, thermal stability and enhanced safety when compared to other lithium ion battery types. For these reasons LMD batteries are used in the Chevy Volt and Nissan Leaf. Research at the University of Illinois has achieved an advanced prototype battery, using Lithiated Manganese that can be recharged in as little as two minutes (equivalent to filling a gas tank).

The Chinese market is currently heavily weighted towards the Lithium iron phosphate (LFP) battery formulation with little to no Cobalt involved. However, Manganese is a key ingredient in the cathodes of two of the most prominent up and coming electric vehicle battery types: the nickel-manganese-cobalt (NMC) battery, and the LMD/LMO battery.

As the cathode markets develop toward NMC, it is felt by many observers that the LFP format favored by Chinese manufacturers, with lower suitability for electric vehicles will lose market share. Current NMC ternary lithium-ion batteries from South Korean and Japanese makers typically employ a ratio of 60% nickel to 20% manganese, and 20% cobalt (6:2:2), but as that ratio moves to 8:1:1 in 2018 and beyond, the cathode is a key element in achieving vast cost efficiencies. Currently though other formulations such as 5:2:3 and 1:1:1 have higher global markets shares than those favoured by the Japanese and Koreans.



Source: HIS Markit

The LiB Format – Flawed but Entrenched

The shortcomings of Lithium Ion batteries are becoming more and more evident by the day. As if the travails of the Samsung Galaxy Note 7 were not enough there is a rising tide of frustration with the chargeability (or lack thereof) with the most common example of LIBs, namely in mobile phones. With rising usage (in terms of minutes and hours spent online) and ravenous apps continuing to operate even when a phone is not being actively used, the batteries are lasting ever shorter amounts of time and necessitating that users carry back-up power packs or spend their lives in search of "somewhere to plug in". If this is the future it looks very fraught and grim.

The die has already been cast though with regards to the type of battery that will go into the next few generations of EV and HEVs. It would be too expensive and disruptive for Western car makers to execute a *volte face* away from LiBs. However as applications proliferate, so do technologies. Prominent amongst these are batteries utilizing Manganese as a key component.

Collateral Advantages from the Cobalt Crunch

The pace of change in the battery space has quickened since the red-hot days of 2017/18, with Lithium plays dividing into the "serious" and the "non-serious" and the Cobalt crisis moving into centre stage and focusing minds on supply issues in the battery space, particularly as regards the "blue" metal. The price of Cobalt soared above 2008 levels and even breached $60 per lb. Despite a plethora of Cobalt wannabes appearing on the scene, the talk in markets was of an imminent supply crunch in absolute terms that might precipitate rationing by price and possible switching to other elements.

While there is no direct "switch" out of Cobalt into other metals there are patents out there for other technologies, both currently employed and theoretical, that employ other metals and minerals such as Manganese (Lithiated Manganese Dioxide batteries), Titanium (Lithium Titanate batteries) and Antimony/Magnesium (Molten Salt batteries), Vanadium (Vanadium Redox Flow batteries) and in other metals. Arguably, the Lithium Ion battery that looks to be a favorite amongst EV makers is the NMC (Nickel Manganese Cobalt) battery which can be produced in a range of ratios of these three elements. Current emphasis is on producing cathode chemistries with lower cobalt content like the (1-1-1), (5-2-3), and (6-2-2).

Conventional wisdom has it that battery manufacturers, particularly in the HEV/EV sphere, are committed to Lithium Ion batteries and will pay through the nose rather than retool or adapt. However, if there is a Cobalt shortage in absolute terms or supply becomes highly irregular then they may not have any choice but to consider changes in battery formulations that attempt to minimize the Cobalt component.

Battery chemistries that rely on higher percentage of Manganese at the expense of Cobalt open up the interesting possibility that EMM/EMD, the production of which is currently dominated by China, might be tempting as a strategic choice within China in light of that country's lack of guaranteed Cobalt supplies.

Electrolytic manganese dioxide (EMD)

There are two primary forms of electrolytic manganese: Electrolytic Manganese Metal (EMM) and

Electrolytic Manganese Dioxide (EMD). EMD is the critical component of the cathode material in alkaline, Lithium Ion, and sodium batteries. It is also important in electrochemical supercapacitors and hydrogen production.

Electrolytic manganese is a refined manganese product created through the purification and electrolysis of a manganese-rich solution that is made by dissolving Manganese carbonate ore or calcined Manganese oxide ore.

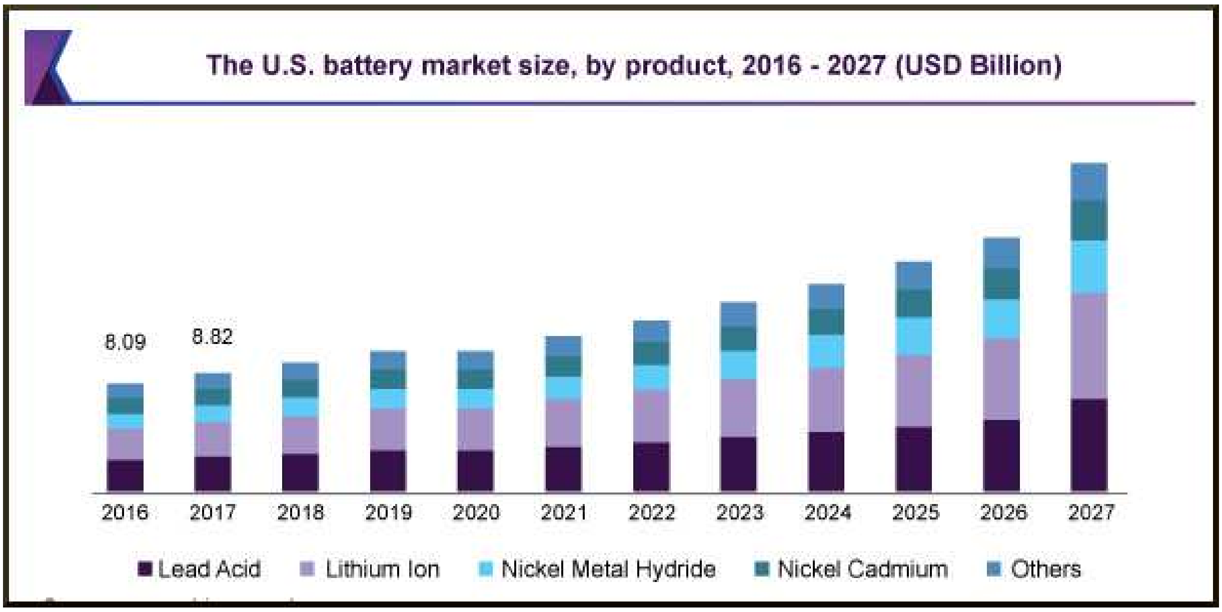
Energy storage devices made from alternative and inexpensive sources, such as low-grade Manganese ores, have a niche in the renewable energy and portable electronics market. Along with substantial primary Manganese sources, there is also potential in modified EMD materials from synthetic solutions and secondary sources.

The recent investigations of fundamental advances in the electrochemical mechanisms involved in aqueous rechargeable batteries and electrochemical supercapacitors, are leading to an improved energy storage performance, which is essential for their long-term use in storing renewable energy supply.

Likely Demand

Electrolytic Manganese Dioxide (EMD) is a vital ingredient in the production of alkaline batteries with total annual production capacity estimated by the International Manganese Institute at roughly 430,000 mt. Battery consumption of Electrolytic Manganese Dioxide (EMD) has been predicted to be fastest growing segment of Manganese production with a CAGR of 5.1% from 2015 to 2022.

Below one can see the rising of projected usages of different battery types in the United States alone:



Source: Grand View Research

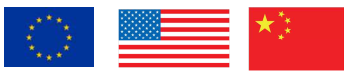
The U.S. battery market size was valued at USD$10.49bn in 2019.

North American Supplies

The USGS in its latest survey of Manganese as it pertains to the US reported that Manganese ore was consumed mainly by eight firms, with plants principally in the East and Midwest. Most ore consumption was related to steel production, either directly in pig iron manufacture or indirectly through upgrading the ore to ferroalloys. Additional quantities of ore were used for such non-metallurgical purposes as production of dry-cell batteries, in fertilizers and animal feed, and as a brick colorant.

A particularly dire statistic is that Manganese ore (containing 20% or more manganese) has not been produced domestically since 1970. The value, in 2019, of domestic consumption, estimated from foreign trade data on a manganese-content basis, was ~ $1.2bn. However these numbers are before the expected ramp-up in US-based production of LiBs for EVs, for which there are a plethora of new plants on the drawing boards (mainly in the South and the Mid-west).

Battery Metals - Chemical Processing/Refining



Nickel	13%	1%	65%
Cobalt	17%	0%	82%
Graphite	0%	0%	100%
Lithium	0%	4%	59%
Manganese	7%	0%	93%

Source: Benchmark Minerals

Manganese was recycled incidentally as a constituent of ferrous and nonferrous scrap; however, scrap recovery specifically for manganese was negligible. Manganese is recovered along with iron from steel slag. As for imports, some 70% came from Gabon and then 17% from South Africa. Rather embarrassingly, the USGS has estimated in-ground reserves of Manganese at zero!

Poignantly, Electrolytic Manganese metal was newly added to the National Defense Stockpile in 2019 as a critical material for defense purposes. The last time Electrolytic Manganese metal was held in the government stockpile was in 2004.

Pricing

The devastation wreaked by the Virus Crisis has not spared the Manganese markets. According to the Paris-based International Manganese Institute, global manganese metal production dropped by 11% in

July to 115,000 mt, and it was 22% lower than in the same period of last year. Global output decreased by 15% in the first 7 months of this year.

EMM Supply in July 2020

(in '000 mt)	Supply	MoM % Change in Supply	YoY % Change in Supply	Supply since January	Supply Same Period Last Year	% Change YoY
China	110	-11%	-22%	759	882	-14%
Rest of the World	5	0%	-23%	36	48	-25%
World	**115**	**-10.7%**	**-22.4%**	**795**	**930**	**-14.6%**

Source: International Manganese Institute (IMnI)

In China, EMM supply decreased by 11% in July to 110,000 mt, and it was 22% lower than in July 2019. More plants suspended production as domestic EMM price was near or below production cost. The YTD production was 14% lower than the first 7 months of last year.

In the rest of the world, production remained stable in July from the previous month, at around 5,000mt, but it was 23% lower than in the same period of last year. In the first 7 months of this year, the supply from the rest of the world was 25% lower than in Jan-Jul of 2019.

Below we can see the price for EMM min 99.7%, fob US warehouse, US$ per lb.

Source: Argus Metals

Mass Storage Devices

The important consideration is that mass storage devices do not even need to be connected to the grid and thus can be in the middle of nowhere bridging the infrastructure gap (and cost) that weighs on emerging economies (and isolated minesites).

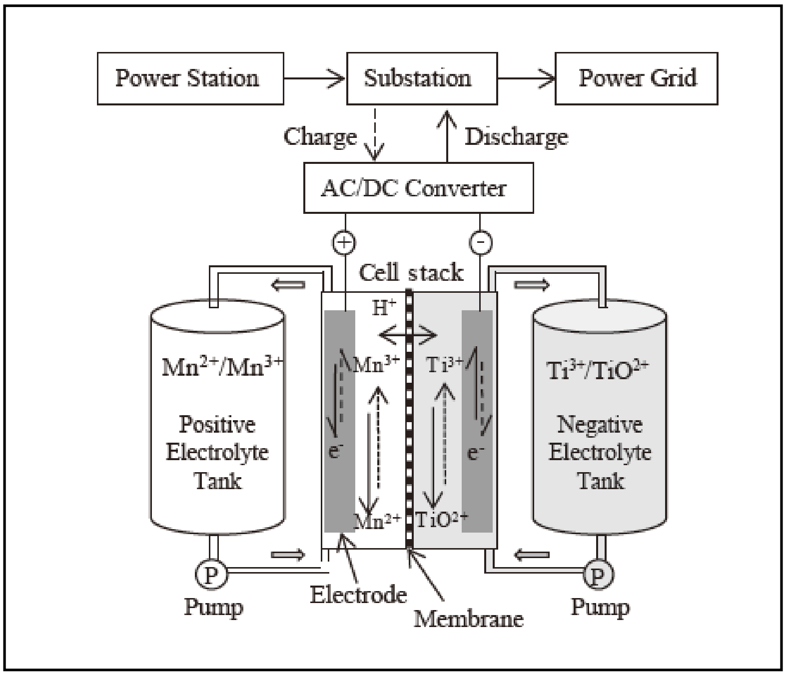
In recent years the principal mass storage device we have concerned ourselves with has been the Vanadium Redox Battery (VRB) with its shipping container-sized housing. This is a very real and efficient alternative for those isolated locations we mentioned.

Redox Batteries – Muscling in on Vanadium's Patch

Vanadium has hogged the limelight when it comes to discussion of Redox Flow Batteries (RFBs). These Large-scale batteries play an important role in the effective use of renewable energy like wind and solar power. Compared to other mass storage battery technologies, RFBs provide high-speed response, independent design of power and energy, high safety.

All-Vanadium RFBs are the most mature technology and have been used in practical applications. However, Vanadium has earned some black marks against its utilization due to the propensity for its price to go soaring (and then plunging) which complicates the lives and business plans of those wishing to put it to greater use in mass storage devices.

As the prices of renewable energy power generation continue to decline, cost reduction of the battery system has become the major issue. When Vanadium soared in 2018 to around $30 per lb, we were conversing with RFB makers who said that the metal was only viable for employment in their products at prices of $10 per lb or less. It was a slight exaggeration we thought as we suspect slightly higher prices could be sustainable but $30 definitely was not feasible. In any case, the Chinese pulled the plug on the V_2O_5 price and it went tumbling as low as $6 and has been doodling around beneath the magic $10 pain barrier ever since. The problem with that level is that no developer wants to bring on a new mine with such skinny (or negative) margins for their metal output.



In order to reduce the cost, many efforts have been made to develop a low-cost electrolyte. We have noted some researchers have been focusing on employing a low-cost manganese material, and developed a Ti (IV) and Mn (II) mixed aqueous electrolyte, and applied it to a Ti-Mn RFB.

Scientists have turned their attention to the development of electrolyte research and the characteristics of the Ti-Mn electrolyte have made that formulation a prime candidate. A titanium-manganese electrolyte is claimed by some to be a promising low-cost candidate. Both Titanium and Manganese are inexpensive materials and relatively more abundant than Vanadium.

Manganese has hitherto been little explored for RFBs due to the instability of Mn(III) leading to precipitation of MnO_2 via a disproportionation reaction. The challenge arises when the manganese dioxides settle in the tank, the battery capacity can be reduced and clogging of the cell stack can take place. When applying this material to RFBs, measures must be taken to stabilize the Mn3+ ion and suppress MnO_2 precipitation.

In their work on the potential of Titanium-Manganese electrolytes, Dong et al. discovered that the principle issue of the precipitation of solid $MnO_{2,}$ due to a disproportionation reaction, could be alleviated by mixing Ti with the Mn electrolyte to stabilize Mn3+ ions and suppressing the particles growth of MnO_2. In the evaluation of a small flow cell using this Ti-Mn electrolyte, energy density as high as 23.5 kWh/m^3 could be achieved, which should significantly reduce the cost of the electrolyte.

Another group of researchers, Javier Rubio-Garcia et al., have shown that by combining the facile hydrogen negative electrode reaction with electrolytes that suppress Mn(III), it is possible to construct a Hydrogen/Manganese hybrid RFB with high round trip energy efficiency (82%), and high power and energy density, at an estimated 70% cost reduction compared to Vanadium redox flow batteries. This is the type of saving that Vanadium's bulls would not want to see too widely publicized.

Over and beyond the specific mixes that include Manganese, one should note that standalone mass storage devices march to a different beat than EV batteries. Auto manufacturers like to have a standard (such as Lead-acid long provided) to which they can standardise their designs. As mass storage devices can all, potentially, be standalone and/or bespoke there is no point at which it is "too late" to implement new standards with higher Manganese and less (or no) Vanadium in RFBs.

Supercapacitors

One subject seldom talked of in metals markets but widely discussed in scientific circles is the potential of supercapacitors. These can also be called ultracapacitors. This device is a high-capacity capacitor with a capacitance value much higher than other capacitors, but with lower voltage limits, that bridges the gap between electrolytic capacitors and rechargeable batteries. It typically stores 10 to 100 times more energy per unit volume or mass than electrolytic capacitors, can accept and deliver charge much faster than batteries, and tolerates many more charge and discharge cycles than rechargeable batteries

Among transition metal oxide materials, MnO_2 is well recognized as a good candidate for the positive electrode in supercapacitors due to its wide potential range in the positive side and high theoretical specific capacitance, high stability, low cost, abundance, and absence of environmental hazard.

Although manganese oxide- and graphene-based supercapacitors have been widely studied, their charge storage mechanisms are not yet fully investigated.

The charge storage mechanisms of MnO2-based supercapacitors are not yet fully clear. Understanding how the Mn oxidation states change during the charging/discharging processes is crucial to the development of this material.

The Listed EMD Players

For a long time the main claimant to the EMD story was a company called American Manganese with a project called Artillery Peak in Arizona. The rise of the battery metal phenomenon in the middle of the decade added Manganese X, Giyani Metals (both of which we have covered in depth) and Euro Manganese on which we have also written (and was briefly & profitably in the Model Mining Portfolio).

The EMD Developers

	Project	Country	Notes
Manganese X	Battery Hill	New Brunswick	Metallurgy in place, more exploration and PEA & Resource next
Euro Manganese	Chvaletice	Czech Republic	Tailings reprocessing, high capex
Giyani Metals	K-Hill	Botswana	DSO - stockpile operation, FS for mine in 1Q21

American Manganese faded away (well, drifted away towards Lithium recycling). The other three are our main focus in the EMD space still.

A Case Study: Manganese X Energy

Like many other companies, Manganese X (TSX-V:MN, OTC: MNXXF) was launched upon the tide of the second Battery Wave in the middle years of the last decade. Many of the other names, particularly in Cobalt and Lithium ended up grounded, on the rocks or sunk.

Though financing was almost non-existent across the swathe of battery metal juniors, the management at Manganese X battered down the hatches and stayed the course. Now that a certain confidence has returned to the broader mining markets it has had a firming effect on even the battery metals. However, the emphasis has shifted. Lithium still remains central to the LiB story, but Cobalt has fallen into deep disdain.

So Manganese X finds itself as one of the small “Band of Brothers” having survived the travails and emerging

The Battery Hill Project

The property, formerly titled Houlton Woodstock, covers a significant portion of the known historic manganese-bearing horizon(s) in an area approximately 6.3km northwest of the town of Woodstock, southwestern New Brunswick.

The Battery Hill project encompasses all or parts of five manganese-iron zones including Iron Ore Hill, Moody Hill, Sharpe Farm, Maple Hill and Wakefield. The southern-most portion of the claims is located approximately 5 km west-northwest of town of Woodstock. The USA-Canada border is approximately 12 kilometres west of licence 5816. Route 95, a twinned highway running from Woodstock to connect to the US interstate I-95 highway, is located approximately 3 km south of the claims.

The background to this is that, in 2010, Globex Mining Enterprises acquired 100% interest in the Houlton Woodstock property by staking. Manganese X acquired control of the property in April 2016 and added to the claims so now the property consists of 55 claims covering 1,228 hectares.

The Deal

According to the agreement, Manganese X could earn a 100% interest in the properties by making aggregate cash payments of $200,000 to Globex, issuing an aggregate of four million common shares to Globex, incurring aggregate exploration expenditures of one million dollars on the property and delivering a PEA on, or before, the fourth anniversary of the of April 26, 2016. The agreement also included a 3% Gross Metal Royalty to be paid to Globex on all metals produced from the property. This transaction was completed in December 2018 with the PEA clause being dropped. An advance Royalty payment of $20,000 per year, payable to Globex by Manganese X Energy starting on the 6th anniversary of the agreement, remains in place.

The deal in its current form looks very attractive for Manganese X, particularly as the PEA requirement went by the wayside.

History

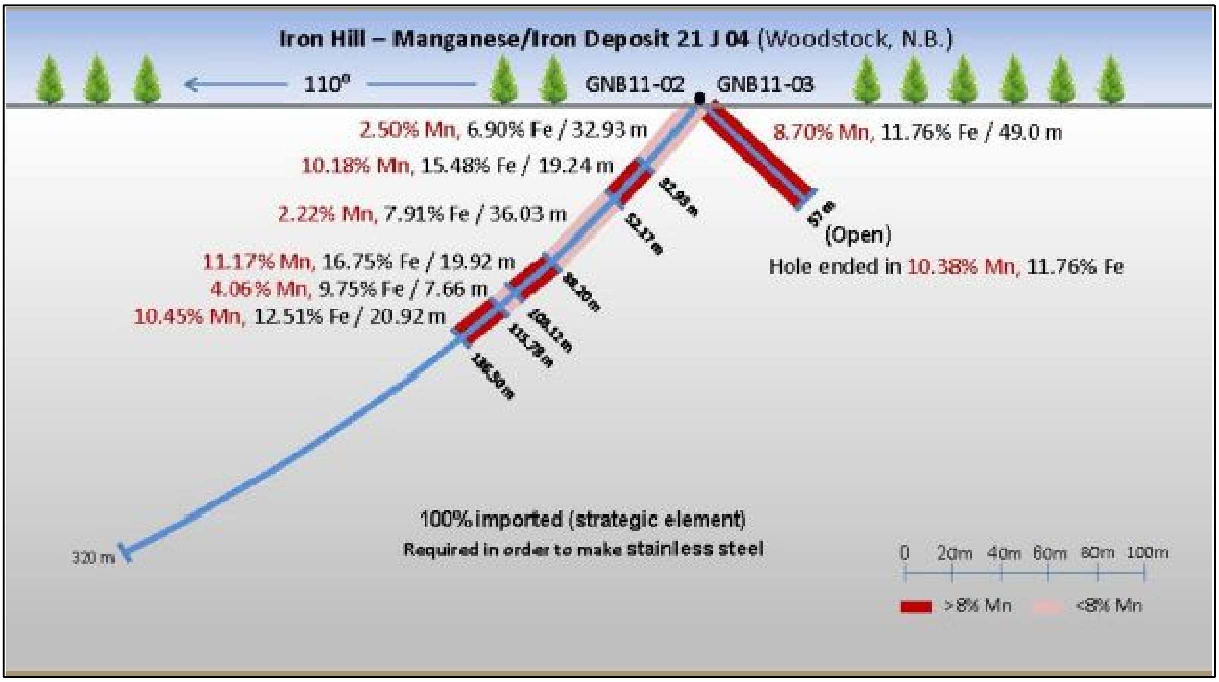
The iron-manganese occurrences in the Woodstock area were first brought to light by Dr. C.T. Jackson in 1836. Two small blast furnaces operated between then and the early 1860’s when most activity ceased until the Stratmat began exploration in the early 1950’s. To this point, the mining activity was primarily in the Iron Ore Hill area, whereas afterward, the main focus has been around the Plymouth deposit. Exploration was mainly driven by larger gravity anomalies obtained at Plymouth as compared to the rest of the surveyed area. Gravity anomalies were found to extend northwards toward and beyond the Iron Ore Hill occurrence.

Resource Potential

In his Master’s Thesis on the Woodstock area manganese occurrences, Brian Way (2012) reported that the area “hosts a series of banded iron formations that collectively constitute one of the largest manganese resources in North America, approximately 194 million tonnes”.

From 2011 Globex drilling, sampling from wide intervals of this mineralization returns assays greater than 11% MnO and 16% Fe2O3.

The drill program, planned and implemented by the author, consisted of 16 holes totaling 3589 meters and was designed as an initial evaluation of the three historic manganese occurrences on the property (Iron Ore Hill, Sharpe Farm and Moody Hill occurrences). Five holes totaling 1051 meters were completed in the Iron Ore Hill sector of the property and eleven holes for 2538 meters in the Sharpe Farm – Moody Hill sector. Drilling was completed over a 1.8 kilometer strike length of the prospective manganese occurrence trend. Most holes intercepted significant grades and widths of manganese mineralization such as 10.75% Mn over 52.6 meters (core length) in SF-16-05 and 12.96% Mn over 32.85 meters (core length) in SF-16-08.



Metallurgy

In recent times the company has been focusing on the metallurgy of its deposit. In early September it announced favourable metallurgical results from Kemetco Research that demonstrated greater efficiency and improved economics leading to commercialization.

The company completed Phase 1 yielding Manganese Sulphate ($MnSO_4$), with a purity exceeding 99.95% with low levels of base and alkali metals using material from the Battery Hill property.

Various Phase 2 bench scale metallurgical bulk tests have been conducted, and results to optimize leaching, neutralization and solid-liquid separation were reported as "very positive". The team is advancing the development of a workable extraction process and flowsheet to further reduce purification steps, which, if successful, could lead to lower costs of processing.

Revival

Due to the major "derailment" of the battery metal space caused by the retreat from the overheated 2017 market, Manganese X has lost three years when it could potentially have been moving forward. All has not been in vain though as the market has transitioned through a mind-shift during the downtime that has downplayed Cobalt's future and upgraded the prospects of Manganese.

As can be noted below, after a long quiescence, the stock's price has come to life, largely as a result of the market's hunt for collateral beneficiaries of Tesla's hunt for alternative (read non-Cobalt) battery metal formulations.

The market cap is up, and financing more available, enhanced potential to finally kick up the resource calculation, potential mine development and moreover implementation of a demonstration plant prompt us to maintain a **LONG** stance on Manganese X Energy with a 12-month target price of $1.10.

Conclusion

If the Virus Crisis has been the cause of one positive development, it is the wake-up call on China-dependency in the West (and the non-Chinese) East. The Japanese and Koreans were already mightily concerned and quietly weaning themselves off *Mother China*, but the West naively believed that "Peking will provide". Without a single gunboat having sailed the realization has now set in that the West is vulnerable. Action is afoot to start the process of asserting resource independence from the all-embracing grip of the Panda.

The issue at the root of all this though is the availability of metal supplies. Lithium seemingly has a supply situation with little in the way of constraints for a long way out. Cobalt though is relatively scarce, moreover with the Chinese having cornered the supply, as least as it pertains to the largest producer, the DRC. Manganese remains the unspoken metal in the LiB mix (with Fluorspar, we might note) and is often dismissed as "easy to get" and "cheap". Relatively speaking yes, but with no current supplies of Manganese in the US or Canada, and battery-grade Manganese processing capacity held in a headlock by the Panda, the US ambitions in the EV space are essentially at the mercy of taking whatever scraps the Chinese feel inclined to sweep off their table. The US is reduced to the status of a Manganese scavenger unless it has access to not only non-Chinese sources of ore (which it has in Gabon and South Africa…. for now) but also, and more importantly, regional Manganese Sulphate ($MnSO_4$) sources.

With the strategic stockpile starting to have EMM added again, for the first time since 2004, there is clearly rising concern in Washington. It needs more though than just ferreting away a few months' worth of consumption. It needs a complete North American supply chain.

RFBs have become a well-rehearsed discussion for energy storage and Elon Musk would have us believe that superannuated Tesla batteries have a "life after death" but we remain unconvinced on the latter. Work on decoupling RFBs from Vanadium dependence is not well-known, but the potential winner from these studies could be Manganese as both a cheaper and more accessible alternative.

In terms of environmental and cost considerations, EMM/EMD is likely to maintain its advantages as an energy material for the future generation, as it has been in recent decades.

Combined the rise of EVs and the possibility of Manganese muscling in on Vanadium's turf in the RFB space and the developers in the battery-grade Manganese (mining) space are few and far between. Increasingly the hunt for enhanced economics in EV production (to tease consumers into the auto showrooms to take up the EV "promise") will mean that cheaper, more secure and more efficient battery formulations will be required and Manganese might well be the secret sauce to make EV economics more palatable to the mass market.

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Important disclosures

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