H2GM – Green Hydrogen, Energy and Metals FACTSHEET

Overview (Confidential)

January 2, 2025

H2 Green Metals (H2GM) is a novel, cutting-edge extractive metals special purpose entity designed to be at the heart of Critical (Green) Metals production, Sustainability and combatting Climate Change. Our modern world depends upon metals for its very existence, but incumbent methods for their recovery leave much to be desired, both in terms of carbon footprint and sustainability. Historical mining and extractive methods were not very efficient, and there are numerous old tailings dumps and waste rock piles around the world which contain the metals now in short supply. The principal mineral in these tailings is pyrrhotite, which has always been a significant problematic issue in conventional processing, whether it be smelting or leaching, due to its high reactivity. This reactivity leads to severe environmental problems in terms of acid drainage and the leaking of toxic metals, notably arsenic, into the surrounding environment. H2GM is designed to take advantage of this reactivity to generate Clean Power or Green Hydrogen and recover the contained critical metals, whilst at the same time remediating the environment. Whilst iron is not in short supply, GREEN IRON & STEEL is almost non-existent, and the hydrogen generated from pyrrhotite technically can be combined with the hematite also generated from the pyrrhotite to produce green iron and steel..

Snapshot			
Metals Jurisdiction:	Worldwide	**Entity:**	H2GreenMetals SPV
Start Launch Date:	H1 2025	**Portfolio:**	Critical and Battery Metals, Clean Power, Green Hydrogen, Green Iron & Steel, Green Titanium, HP Silica
Input:	3000 tonnes pyrrhotite/day	**Output:**	49 tonnes/day H_2 (equivalent to 100MW electrolysis plant)
Carbon footprint saving:	**15 million tonnes CO_2 avoided (circa 2025-2040)**		

Pathway to Green H_2 Production

Pyrrhotites typically contain around 50% iron and 35% sulphur. Incumbent technologies are generally unable to effectively and efficiently process this mineral, and certainly do not recover either the iron or the contained intrinsic energy, yet pyrrhotite is present in most massive sulphide mineral deposits. Historic and even present sulphide processing operations have endeavoured to eliminate as much pyrrhotite as possible, and store it in tailings impoundment facilities. Such tailings also contain valuable metals such as nickel, copper, cobalt and PGMs, or lead, zinc, silver, cadmium, gallium, germanium and indium, all of which can also be recovered by H2 Green Metals Technology. The energy can be recovered either as green hydrogen or electric power or both, and is thus a way of leading towards decarbonisation of metal production, and ultimately Green Steel production.

Table 1. Road Map to Commercialisation

Task	Size	Capital US$ million	Operating US$/tonne pyrrhotite
Pilot Plant	1 tonne/day	10	Included in capital
PEA (Preliminary Economic Assessment)			
Demonstration Plant	100 tonnes/day	80	1200[c]
DFS (Definitive Feasibility Study)			
Commercial – clean power Commercial - hydrogen	3000 tonnes/day[a]	500[b] 1600	30[d] 50[d]

[a] – equivalent to a 100MW electrolysis plant producing ~40 tonnes/day of hydrogen. Plants up 10-15,000 tonnes/day are feasible

[b] - does not include hydrogen recovery circuit, just the basic Clean Power

[c] - no allowance for any by-product credits

[d] - inclusive of by-product credits for critical metals, precious metals and Clean Power or Hydrogen

Figure 1 shows the basic block flow diagram of the H2 Green Metals Process Technology through to green steel. Optionally, instead of hydrogen production, clean power can instead be generated directly, up to 50MW for a 3000 tonne/day plant. This flowsheet also does not include the further option of processing the base metal and PGM concentrate to pure, refined metals or battery-grade metal salts. These by-products are important in terms of the overall process economics, giving the process flexibility which electrolytic hydrogen, for example, does not have.

Hydrolysis (Acid Recovery) Pilot Unit

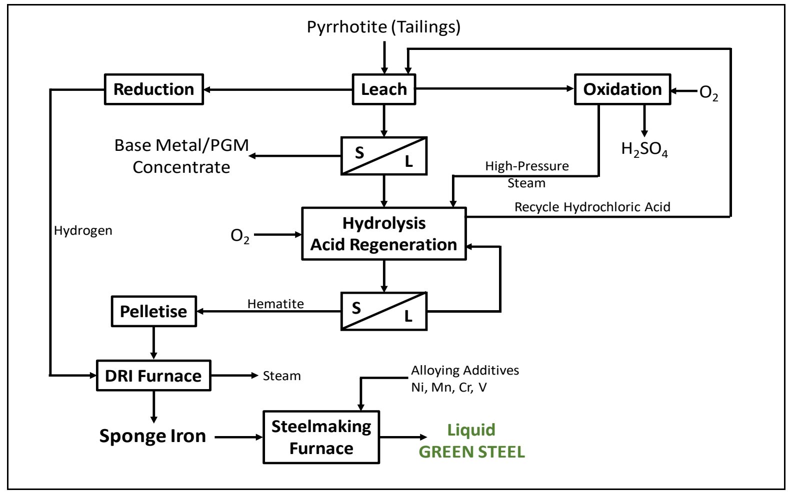

Figure 1. Block Flow Diagram of Basic H2 Green Metals Process

A. Roadmap

The process is highly flexible. There are two options for recovering energy, either as hydrogen, which can be further used to produce green iron/steel from the iron contained in the pyrrhotite feed if so desired, or directly as clean electric power. It will be noticed that green iron and steel can be recovered without recourse to mining iron ore since the iron naturally comes with the mineral pyrrhotite. Swedish company Stegra, for example, simply cannot do this. Further, H2GM can also recover whatever base and precious metals are contained in the pyrrhotite. High-purity sulphuric acid, which is in increasing demand for redox flow batteries and other electronic applications, can also be generated. Finally, there is an alumino-silicate leach residue which can be used for high-purity silica production, CO_2 sequestration or as a clean cement additive.

B. By-Product Credits

Pyrrhotites nearly always come associated with base and precious metals, e.g. the nickeliferous pyrrhotite in the Sudbury Tailings in Ontario Canada, which have an estimated value >US$2 billion of in-demand battery metals contained therein. Similarly, elsewhere in Canada, there are equivalent tailings in Manitoba and virgin deposits in Nunavut, and also significant stockpile in New Brunswick, the latter being predominantly lead-zinc-tin-silver-based. Table 2 shows the potential, again taken from the nickeliferous pyrrhotite tailings and for the clean power option only.

Table 2. Iron and By-Product Credits (3000 tonne/day pyrrhotite tailings feed)

Item	Annual Production	Price*, US$/unit	Revenue US$ M/year
Nickel as Ni, in mixed sulphide	8,000 t	15,584/t	124
Copper as Cu, in mixed sulphide	8,000 t	9,150/t	73
Cobalt as Co, in mixed sulphide	800 t	24,300/t	19
PGMs as metal (mainly Pd)	64,000 oz	950/oz	61
Hematite (100% Fe_2O_3)	753,000 t	150/t	113
Sulphuric acid	1,100,000 t	200/t	220
Surplus power	50 MW	0.05/kWh	Free carry
* - prevailing commodity metal prices as of January, 2025			

By-product credits are included here because they add empirically to the overall process economics. For this exercise, iron was calculated as hematite, but could produce up to 365,000 tonnes of green sponge iron, which in turn is the precursor to green steelmaking. In such a case, producing hydrogen and converting 67% of the hematite to iron, H_2 would essentially replace surplus power.

C. Decarbonisation Potential

Due to its intrinsic energy, pyrrhotite has the potential to replace energy currently supplied by fossil fuels such as coal and natural gas. The H2GM Process is able to recover this energy in the form of electrical power or as green hydrogen. The following table summarises the potential savings in terms of fossil fuel usage and CO_2 emissions that can be expected if replacing the energy potential of fossil fuels with pyrrhotite. It is assumed that coal is 100% C and that natural gas is 100% methane (CH_4). The potential is even greater with higher hydrocarbons, such as ethane (C_2H_6) and propane (C_3H_8).

Table 3. Decarbonisation Potential

Annual feed of pyrrhotite mineral	1 million tonnes
Coal equivalent, tonnes	182,750 (low) to 246,500 (high)
Natural gas equivalent, tonnes	120,000 (176,000m^3) (low) to 161,500 (237,500m^3) (high)
CO_2 not emitted by coal, tonnes	670,650 (low) to 900,000 (high)
CO_2 not emitted by gas, tonnes	330,000 (low) to 650,000 (high)

Additionally, and frequently overlooked, is the pyrrhotite tailings leach residue which is a mixture of calcium, aluminium and, to a lesser extent, magnesium silicates, as well as the base and precious metals. The alkalinity of such minerals is becoming increasingly recognised, important and applied in terms of atmospheric carbon dioxide sequestration. Normally, such residues have either been put in a tailings storage facility (TSF), or, where benign, used as road aggregate. The H2GM Process, after recovery of the base and precious metals, generates an environmentally-benign magnesium-silicate-based residue. Rather than storing such a residue in a TSF, however, because it is benign and has a degree of alkalinity, it can, for example, be spread out over crop fields, where it can react with atmospheric carbon dioxide, to form calcium, magnesium and aluminium carbonate minerals. Spreading out over crops fields gives maximum surface area to react with the atmosphere, which cannot be achieved in TSFs.

D. Relevance to the Iron/Steel Industry – Green Steel Production

The following indicates the key metrics as applied to the iron/steel industry. If the plant is sited adjacent to an existing steel mill, any waste heat generated by the mill can be used by the pyrrhotite plant, resulting in additional green power being available for sale. For this exercise, 3000 tonnes/day of pyrrhotite feed has been chosen as a reasonable size for a first commercial plant. Ultimately, there is no reason why this could not be doubled or tripled, but will be dependent upon mining rate and feedstock availability.

Cautionary Note: Current world production of crude steel is 1.89 billion tonnes, and generates approximately 7% of total global GHG emissions and 11% of CO_2 emissions. Generating green steel is significantly more expensive than producing crude steel, irrespective of the hydrogen source, and despite some lip service to its production, the iron and steel industry has not to date embraced the idea to any extent. Economically, it is more attractive to produce hydrogen and sell it rather than use it for green steel under present economic regulations, although this is projected to change if hydrogen prices come down and/or there are significant carbon credits available. H2GM, therefore, is positioned ready when such scenarios materialize.

Table 4. Key Metric for the Iron/Steel Industry (single plant - 3000 tonnes/pyrrhotite tailings/day)

365,000*	**0**	**<1%**	**15 million**	**>365,000****
tonnes of Green Sponge/Iron annually per plant	tonnes of iron ore needing to be mined	CO_2 Emissions	tonnes of CO_2 avoided per plant by 2040	tonnes of Green Steel annually per plant
* - for one single plant only, using iron and hydrogen from pyrrhotite. Potential for multiple brown or even greenfield plants ** - the amount of Green Steel will be dependent upon the type of steel being produced				
H2 Green Metals converts environmentally damaging metallurgical waste into clean, net-zero carbon-free energy, Green Steel *and* valuable critical commodities.				

Hydrochloric Acid Regeneration Technology (AR5)

E. Summary of its Economic Worth and Potential

- This section summarises the Hydrochloric Acid Regeneration (AR) Process application. The process solves many of the problems currently encountered in the traditional sulphate-based processing of mineral resources, notably "the iron problem" and the recovery and recycle of high-strength (30-35%) hydrochloric acid. In the cases of the projects listed below, it is the only economically-viable real option for the recovery of all of the metals involved.
- Based on anticipated revenues and current prices, the projected value of the technology ranges from US$237 million to US$2.4 billion.

F. Pyrrhotite Tailings – Green Hydrogen Production

- This is essentially two projects, although different in nature, but based on the same fundamentals of treating pyrrhotite tailings, or even primary pyrrhotite, with recycled hydrochloric acid from the AR process.
- There are two options as to how this proceeds. In the first option, electric power is generated, and surplus power is fed back into the grid. In the second option, proprietary green hydrogen is liberated, which in turn may be sold or it converts the iron in the feed into green sponge iron, and thence into green steel.

A. Summary

Eight currently active projects, i.e. those which are currently in discussion, have been considered, namely two projects for the treatment of VTM (Vanadiferous Titaniferous Magnetite) ores and concentrates (including mineral sands); production of high purity manganese sulphate; the processing of a nickel laterite and/or associated ferronickel slag; Zncore, the recovery of zinc (and associated metals) from EAFD (Electric Arc Furnace Dust), a steel plant waste; recovery of critical and battery metals from spent batteries; de-toxification and metal recovery from Chingola Tailings in Zambia; production of clean power and green hydrogen from pyrrhotite tailings; production of green metals in combination with hydrogen production. These are areas where incumbent technologies are either totally inadequate, or where the technology does not even exist. Total revenues accruing from the projects under consideration, all of which require acid regeneration as the cornerstone of a commercial plant, have been assessed using current metal prices. The valuation of the AR Process has then been taken as 0.5% of these revenues as the low end, and using a more common 5% royalty rate for the high end. Under this assessment, the AR Process is estimated to have a current value of US$237 million at the lower end, and US$2.4 billion at the upper end.

The intent is to create a H2GM Hub centred on Port Belledune in New Brunswick on Canada's eastern seaboard. This is currently a depressed mining area, with the last major operation, the Glencore-owned Brunswick Lead Smelter, having shut down in 2019. There are over 50 years worth of pyrrhotite-based tailings close by, as well as an experienced local work force, four year-round deep sea ports and ready access to N. and S. American, European and southern African markets. The New Brunswick government, through the BPA (Belledune Port Authority), has issued a master plan to create a Green Hub, which is in perfect synchronization with the aspirations of H2GM.

B. Background

Global Warming and Climate Change are issues that effect every single person on this planet, and there is, at last, a realisation that something has to be done about it. The move towards "Net (carbon) Zero" is proceeding apace, and electrification coupled with environmental responsibility is key in this respect. We have to look after our planet – unlike our forebears, we cannot just pack up and sail off to a Brave New World. The nearest exo-planet is some 4.5 light years away, and even if we were able to travel at the Warp speed of Star Trek, it would still take a long time to get there.

Metals extraction, and more importantly, process-efficient, environmentally-friendly, energy-efficient metals extraction has a huge role to play in electrification and the move to Net Zero, and hence in combatting Climate Change and Global Warming. Hydrogen, along with the energy metals, such as nickel, cobalt, copper, lithium, zinc, manganese and vanadium are key to the low-carbon future. In this respect, current extraction technologies, which are either largely sulphate-based or involve smelting in one form or another, are the antithesis of what the modern world needs. This is especially true for vanadium extraction (salt roast) and nickel extraction from laterites (HPAL – High Pressure Acid Leach). These technologies are unable to recover the maximum metal amount from the ore, generate huge amounts of iron-based toxic wastes and are unable to recover any of the intrinsic energy contained in the ore, especially from sulphide feeds. There are also numerous base and precious metals tailings impoundments scattered around the globe that contain billions of dollars of discarded metals, not to mention the fact that they are huge environmental liabilities.

Chloride-based processing offers many advantages, ones that can sensibly and efficiently address the shortcomings of the incumbent sulphate-based pyrometallurgical and hydrometallurgical processes. Seventy years ago, the renowned metallurgist Herbert H. Kellogg wrote:

> *"CHLORINE metallurgy has attracted metallurgists for more than a century because the unusual properties of the metallic chlorides - low melting point, high volatility, and ease of formation from the oxides - make possible many useful extractive*

processes. Interest in chlorine processes is undergoing a renaissance due to present availability of chlorine at relatively low prices, and to recent advances in technology."

Despite this, sustainable chloride-based metallurgy has not been widely adopted by the metals extraction industry. However, the Climate Crisis mandates that this has to change. The main drawback to the wide adoption of such processes has been the inability to efficiently and selectively recycle hydrochloric acid within the flowsheet. The most common methodology of doing this has been pyrohydrolysis, either via spray roasting or fluid bed roasting, which is costly, energy-intensive, cannot selectively recover any valuable metals contained in the feed solution, and generates sub-azeotropic (<20%) hydrochloric acid. With its proprietary acid regeneration (AR) process, H2GM overcomes all of these issues, by being able to generate 30-35% HCl, and simultaneously allow for the recovery of a high-purity iron product which has a market value rather than having to be disposed of, and is able to recover any valuable base metals contained therein. Even the so-called waste of the process can find application in carbon sequestration.

C. Projects Considered for Acid Regeneration Evaluation

At the present time (January, 2025), H2GM has eight active projects wherein hydrochloric acid regeneration has a crucial role to play. These comprise two VTM/Mineral Sands (Vanadiferous Titaniferous Magnetite) ores and concentrates, a high-purity manganese sulphate project based on either or both of manganese fines and geothermal lithium brines purification cakes, a nickel laterite/ferronickel slag, EAFD (Electric Arc Furnace Dust), generation of clean power and/or hydrogen from pyrrhotite tailings in conjunction with environmental remediation and the recovery of critical metals, the production of green metals, in conjunction with the hydrogen project, remediation of copper/cobalt tailings in Zambia, and the recovery of critical/battery metals from spent batteries. Beyond these, the technology also has huge potential in the reprocessing of other base metal and gold tailings (and also ores), and for metalliferous massive sulphide deposits.

1. Green Titanium, Vanadium, Iron from VTM Ores, Concentrates and Mineral Sands

Current technologies for these types of ores are pyrometallurgical or a combination pyro/hydrometallurgical for the recovery of titanium, or pyrometallurgical (salt roast) for the recovery of vanadium. Strangely, and wastefully, these processes only focus on one of the main metals, with no effort made to recover the other. Titanium is usually recovered from a slag formed by smelting to generate pig iron. The slag is then further processed in another pyrometallurgical process, the so-called high temperature "Chloride Process" to recover a TiO_2 product suitable as a feed for pigment manufacture. Generally, no attempt is made to recover the vanadium. Alternatively, titanium is recovered from the so-called "syn-rutile" (synthetic rutile) which is produced hydrometallurgically from ilmenite, and which is then fed into the "Sulphate Process," with the generation of huge volumes of toxic iron wastes. With the increasing demand for vanadium, a number of so-called "salt roast" projects are being (re-)considered, wherein no attempt is made to recover the titanium. Such projects are marginally economic at best.

H2GM technology recovers both high-purity TiO_2 and V_2O_5 directly in the same flowsheet, the former suitable for pigment manufacture and the latter for generating electrolyte for VRFBs (Vanadium Redox Flow Batteries). Acid regeneration is the key unit operation in this process. Currently, H2GM is actively working with two companies with a view to processing both VTM ore and a mineral sands concentrate (tailings from zircon production). The annual production is taken as the average of the proposed production from the two operations.

Table 5. Economics of Processing VTM Ores

Metal	Production tonnes/annum	Price* US$/tonne	Revenue Million US$/annum
Titanium, as TiO_2	200,000	3000	600
Vanadium, as V_2O_5	5,000	12,000	60
Iron, as hematite	700,000	150	105
Total for one plant			765
Total for two plants			**1,530**
* - prevailing commodity metal prices as of January, 2025			

2. High Purity Manganese Sulphate (HPMSM) from Hydrothermal Brines and/or Manganese ROM/Fines and/or Ferromanganese Steel dust

Traditionally, lithium extraction involves either open-pit mining or evaporation ponds, which work by pumping lithium-containing brine to the surface and waiting for the water to evaporate. Both of these methods have huge land footprints, are often very water intensive and can create a lot of contamination and waste. At the Salton Sea in Southern California, three companies are developing chemical processes to extract lithium (so-called DLE, Direct Lithium Extraction, a resin-based ion exchange process) in a much cleaner way, taking advantage of the Salton Sea's rich geothermal resources, and without impacting the water table. Near the lake, there are already 11 operating geothermal power plants, 9 of which are owned by Berkshire Hathaway's renewable energy division, BHE Renewables. Two other companies, Energy Source Minerals (ESM) in conjunction with Arcadian Lithium (now to be owned by Rio Tinto as of the end of 2024), and Controlled Thermal Resources, or CTR, are also developing joint geothermal-lithium facilities at the Salton Sea. General Motors has already committed to source lithium from CTR if it becomes operational.

In order for the DLE (Direct Lithium Extraction) Process to function, pre-treatment of the brine is necessary to remove manganese and zinc, which is an impurity for lithium, but a potential source of additional revenue otherwise. H2GreenMetals is involved as being the only process available to be able to separate Zn and Mn from an intermediate containing these deleterious impurities, and is projected to be the only technology capable of generating both high purity Mn and Zn as co-products by way of the first standalone Manganese Sulphate Monohydrate plant in United States. The company is targeting making energy metals as a precursor for battery metals.

Table 6. Economics of Processing Cake from Hydrothermal Brine

Metal	Production tonnes/annum	Price US$/tonne	Revenue Million US$/annum
Zinc as Zn metal in ZnO	16,210	2880	47
Mn as MSMH (sulphate monohydrate)	98,400	1500	148
Total for one plant			**195**
* - prevailing product prices as of January, 2025			

3. Electric Arc Furnace Dust (EAFD)

There are approximately 6 million tonnes of EAFD generated annually with an intrinsic metal value of over US$8 billion. Where any treatment is applied at all, it is by the Waelz Kiln, a costly pyrometallurgical process which is energy-intensive, has a very high carbon footprint, and only generates an intermediate, impure zinc oxide (Waelz Oxide) which requires further processing to be of any value. H2GM (ZnCore process) recovers high-purity zinc oxide directly, as well as generating a valuable by-product used in the fertiliser industry, sodium bisulphate. Currently, ZnCore is in discussions to build one commercial plant of 400 tonnes/day in Quebec. Table 7 summarises the high-level economics for a 400 tonne/day plant. There are also other metals such as copper, cadmium and manganese present which can be recovered, but are not included in the economic analysis below.

Table 7. Economics of Processing EAFD

Metal	Production tonnes/annum	Price* US$/tonne	Revenue Million US$/annum
Zinc, as ZnO	41,500	2909	121
Iron, as hematite	80,000	1500	12
By-product, $NaHSO_4$	78,800	500	39
Total for one plant			**172**
* - prevailing commodity metal prices as of January, 2025			

The process also allows for small modular plants that can be put on site for throughputs as low as 10 tonnes/day, and in Europe, in particular, several operations have indicated interest in doing so.

4. Green Hydrogen and
5. Green Steel

These two projects, although different in nature, are based on the same fundamentals of treating pyrrhotite tailings, or even primary pyrrhotite, with regenerated hydrochloric acid from the H2GM AR process being the critical unit operation. There are two options as to how this proceeds. In the first option, clean electric power is generated and this surplus power is used within the process or fed back into the grid. In this case, the products, in addition to the base and precious metals, are sulphuric acid and hematite.

In the second option, instead of sulphuric acid and power, green hydrogen and green iron sponge are generated. The production of sponge iron as a precursor to final-product green steel is accomplished via reducing the hematite with hydrogen in a standard steel plant DRI furnace. In this way, green iron is produced, along with other contained metals, Ni, Co, Cu, PGMs, etc. Table 8 (reprise of Table 2) shows the high-level economics of treating pyrrhotite tailings. In this analysis, it is assumed that electric power will be produced – this is simply because extensive work has been carried out on this option. The overall result of producing green sponge iron and surplus green hydrogen will not be markedly different.

Table 8. Economics of Processing Pyrrhotite Tailings

Item	Production tonnes/annum	Price* US$/tonne	Revenue Million US$/annum
Nickel as Ni, in mixed sulphide	8,000 t	15,584/t	124
Copper as Cu, in mixed sulphide	8,000 t	9,150/t	73
Cobalt as Co, in mixed sulphide	800 t	24,300/t	19
PGMs as metal**	64,000 oz	950/oz	61
Hematite	753,000 t	150/t	113
Sulphuric acid	1,100,000 t	200/t	220
Surplus power	50 MW	0.05/kWh	Free carry
Total for one plant			**610**
* - prevailing commodity metal prices as of January, 2025 ** - predominantly platinum			

These economics are based on treating 3000 tonnes/day of reclaimed tailings, which are 84% pyrrhotite, and with an average Ni grade of 0.8%. This is typical of what might be encountered in nickeliferous tailings in Canada. Lead-zinc pyrrhotite tailings, such as those found in New Brunswick in Canada, contain similar amounts of pyrrhotite, and equivalent amounts of base and precious metals. In fact, these tailings are well-known for their reactivity, and have been responsible for several fires – they are, therefore, a considerable environmental liability, and should be remediated.

It should be noted that the capital investment for the plant in Table 8 is US$500 million, whereas that for generating hydrogen is US$1600 million. The corresponding 10-year IRR and NPV are 50% and US$1300 million for the clean power option, and 21% and US$762 million for the hydrogen option at an assumed long-term hydrogen selling price of US$6/kg. This also assumes that there are no tax incentives or carbon credits available.

6. Battery Metals Recycling - Cobalthium

Recycling of Spent Batteries is assuming increasing importance in that for the electric revolution to be sustainable, recycling of the nickel, cobalt, lithium and copper (along with manganese) is essential if the supply chains are to be maintained. Most current recycling technology involves smelting, which is both energy-intensive and environmentally unsound, and really recovers only the nickel, cobalt and copper. There are numerous start-up companies claiming "novel hydrometallurgical processes" capable of high recoveries of all metals at battery-grade purity. To date (September, 2024), none of these companies has actually been able to deliver on this. These processes are generally based on multiple different solvent extraction (SX) circuits, which when run in combination are simply incapable of delivering what is claimed. Some companies, having realised this, are now promoting "cathode precursors" wherein a mixed oxide product is being produced, supposedly in the ratios demanded by the battery OEMs. H2GM has developed a non-SX process which solves the problems of the above circuits, and is capable of generating pure, battery-grade products of all of the metals.

Table 9. Economics of Processing Recycled Spent Lithium-ion Batteries

Metal	Production tonnes/annum	Price US$/tonne	Revenue Million US$/annum
Nickel, as metal	1487	15,584	23
Cobalt, as metal	1277	24,300	31
Copper, as metal	200	9,150	2
Manganese, as HPMSM	3800	1500	6
Lithium, as Li_2CO_3	2870	18,220	52
Total for one plant			**114**
* - prevailing commodity metal and product prices as of January, 2025			

The high-level economics are based on treating 10 tonnes/day of each of NMC (EV batteries) and LCO (consumer batteries) in a combined plant. It is worth noting that battery recycling can be carried out in either sulphate or chloride media. The latter offers a more flexible flowsheet, with the options of generating chloride salts or metal oxides. The former generates metal sulphate salts, which up to date are the preferred form required by the Battery OEMs. However, this is changing, simply due to the vast volumes of sodium sulphate thus generated in formulating the battery cathodes, which is becoming an environmental issue in terms of its disposal, since there is no market for such volumes.

7. Copper/Cobalt Mine Tailings, Zambia

The Copperbelt of Zambia has been mining ores for nearly a century. In the early days, cobalt was (surprisingly in view of its role today) regarded as a nuisance and not worth recovering, so the tailings contain appreciable levels of cobalt that is worth recovering. In the 1970s, Zambia was one of the first countries to recognise the need for re-processing of tailings for metal recovery, but again, copper was the only the focus, and the iconic Tailings Leach Plant was built at Chingola. However, this plant focused only on the copper **oxide** tailings. There remain significant **sulphide** tailings, containing both copper and cobalt. In this evaluation, cobalt has not been considered, because its concentration is not known at this time. Zambian ores typically contain Cu:Co ratios anywhere from 100:1 to 10:1, and it would be anticipated that the cobalt content of the tailings would be higher than this relative to the copper, but this is not known at this time.

The H2GM chloride process is perfectly suited to treat these sulphide tailings, and discussions are underway to this effect. Based on the work done with pyrrhotite tailings, and again assuming a treatment rate of 3000 tonnes/day at 0.2% Cu, Table 10 presents the high-level economics. This project will not, however, be one carried out at the Port Belledune Hub, but rather on-site in Zambia.

Table 10. Potential Economics for Zambian Tailings

Metal	Production tonnes/annum	Price US$/tonne	Revenue Million US$/annum
Copper	2000	9,150	22.8
Total for one plant			**22.8**
* - prevailing commodity metal prices as of January, 2025			

8. Nickel Laterite Ore/Ferronickel Slag

Over 70% of the world's nickel reserves are contained in laterites. These ores also contain appreciable cobalt values, and therefore offer a "non-conflict" source not reliant on the DRC. They are, however, traditionally difficult to process, particularly so in that they are not amenable to simple physical upgrading. The rapidly increasing demand for nickel (and cobalt) means that laterites will have to be processed in one way or another to recover the nickel (and associated cobalt). Smelting is not an option, since it generates ferronickel (which is not suitable for batteries), is very energy intensive, does not recover the cobalt, and has a very high carbon footprint. In this context however, there are slags from ferronickel smelting which contain appreciable nickel, and upgraded cobalt which can be processed on their own, or, preferably along with fresh laterite ore. Additionally, such slags are an ideal feed for generating high-purity silica, although this option has not been considered in the following economic analysis.

The current "supposedly proven" process, High Pressure Acid Leaching (HPAL) has never been successful. Eleven HPAL plants have been commissioned, and none of them has been a success. Even the Sumitomo plants in the Philippines have experienced significant problems. The problems with HPAL are considerable. The capital outlay for a 50,000 tonne/annum nickel plant is considerable, being several billions of dollars. The process generates approximately 1.5 tonnes of toxic, slimy iron residue for every tonne of laterite mined, and has a massive physical footprint because it is impossible to filter the leach residue, thus requiring a series thickeners. It is also incapable of recovering any metal values other than nickel and cobalt.

Despite these issues, and in accord with the increasing Chinese determination to control the nickel/cobalt supply chain, the approval, construction and commissioning in Indonesia of 10 Chinese-owned and operated HPAL plants, with three currently (September 2024) in operation and seven under development, have "taken place in record time," according to the energy consultancy, Wood Mackenzie. These plants are generating vast amounts of toxic tailings, which are posing considerable problems in Indonesia due to the topography of the country, and there is increasing pressure to address these issues.

The H2GM Process addresses all of these challenges, and Acid Regeneration is the key unit operation which permits this. In this case, the leach residue is reduced to about 20% of the ore mined, and can be used as road aggregate or flux for a steel mill. Other metals such as iron, manganese, magnesium and aluminium can all also be recovered in a useful form. Furthermore, the process can treat all horizons of the orebody, limonite, transition zone and saprolite, whereas HPAL is limited to just the limonite (ferronickel smelting is limited to predominantly just the saprolite horizon). This effectively doubles the resource. H2GM is currently in advanced discussions with a significant landmark project in Western Australia.

To illustrate this point, consider a typical nickel laterite, with a composition of 1.2% Ni, 0.1% Co, 5% Al, 15% Mg, 30% Fe is processed with 90% recovery of Ni, Co, and Fe, and 75% recovery of Al and Mg. Taking prices of US$7.21/lb for Ni, US$11/lb for Co, $0.2/lb for Al_2O_3, $200/tonne for Fe_2O_3 and $350/tonne for MgO, the following revenues are generated for a plant nominally producing 50,000 tonnes of LME grade Ni.

Table 11 Economics of Processing Nickel Laterite Ores

Metal	Production tonnes/annum	Price US$/tonne	Revenue Million US$/annum
Nickel, as metal	50,000	15,584	779
Cobalt, as metal	4150	24,300	101
Iron, as hematite	1,780,000	150	267
Magnesium, as MgO	1,510,000	350	530
Aluminium, as Al_2O_3	328,000	440	140
Total for one plant			**1817**
* - prevailing commodity metal prices as of January, 2025			

By this analysis, the revenues of the project can be increased significantly against those generated simply by considering nickel (and cobalt). Furthermore, there are additional benefits in that there are close to 3.3 million tonnes of toxic residues that will not have to be disposed of and monitored.

Carbon Capture

A common theme of the these eight identified projects is that all generate a leach residue. As noted earlier, such residues from the H2GM process are benign, and generally composed of calcium-aluminium silicates. Due to their inherent alkalinity, these residues can be used to sequester carbon dioxide from the atmosphere if spread out in thin layers over, for example, crop fields, as well as adding alkalinity to the soil. Alternatively, some of the residue may be used for the generation of high-purity silica.

D Projects Breakdown

The following Table 12 summarises the revenues to be anticipated from each of these projects wherein the Acid Regeneration Technology is a key operating component.

Table 12. Summary of AR-correlated Projects

Metal/Project	Production tonnes/annum	Price US$/tonne	Annual Revenue Million US$
P1 - Green Titanium - VTM Ores (Vanadiferous Titaniferous Magnetite)			
Titanium, as TiO_2	200,000	3000	600
Vanadium, as V_2O_5	5,000	12,000	60
Iron, as hematite	700,000	150	105
Total from one plant			765
Total from two plants			**1,530**
P2 - Manganese and Zinc - HPMSM			
Zinc as Zn in ZnO	16,210	2909	47
Mn as MSMH (sulphate monohydrate)	98,435	1500	148
Total from one plant			**195**
P3 - EAFD (Electric Arc Furnace Dust)			
Zinc, as ZnO	41,500	2909	121
Iron, as hematite	80,000	150	12
By-product, $NaHSO_4$	78,800	500	39
Total for one plant			**172**
P4/P5 - Green Steel – Green Hydrogen - H2 Green Metals			
Nickel as Ni, in mixed sulphide	8,000 t	15,584/t	124
Copper as Cu, in mixed sulphide	8,000 t	9,150/t	73
Cobalt as Co, in mixed sulphide	800 t	24,300/t	19
PGMs as metal (mostly Pt)	64,000 oz	950/oz	61
Hematite	753,000 t	150/t	113
Sulphuric acid	1,100,000 t	200/t	220
Surplus power	50 MW	0.05/kWh	16

Total for one plant			**626**
P6 - Battery Metals/Recycling - Cobalthium			
Nickel, as metal	1487	15,584	23
Cobalt, as metal	1277	24,300	31
Copper, as metal	200	9,150	2
Manganese, as HP $MnSO_4 \cdot H_2O$	3800	1500	6
Lithium, as Li_2CO_3	2870	18,220	52
Total for one plant			**114**
P7 – Green Copper/Cobalt Tailings			
Copper	2,000	9,150	18.3
Total for one plant			**18.3**
P8 – Green Nickel/Cobalt from Laterite Ore/Ferronickel Slag			
Nickel, as metal	50,000	15,584	779
Cobalt, as metal	4,150	24,300	101
Iron, as hematite	1,780,000	150	267
Magnesium, as MgO	1,510,000	350	530
Aluminium, as Al_2O_3	328,000	440	140
Total for one plant			**1817**
Overall Total Annual Revenue			**4472**
Low valuation – 0.5% of 10-year revenue			**224**
High valuation – 5% royalty on 10-year revenue			**2236**

E AR valuation

The following table summarises the revenues from the above projects:

Table 12. Summary of Potential Revenues from Ongoing AR Plants

Plant	Annual Revenues Million US$	10-Year Revenues Billion US$
VTM Ores	1,530	15.30
Nickel Laterites	1,817	18.17
EAFD	172	1.72
H2 Green Metals	626	6.26
Battery Metals	114	1.14
Zambian Tailings	18	0.18
High-Purity Manganese and Zinc	195	1.95
Total	**4,472**	**44.72**
Low- 0.5% of 10-year revenue		**223 million**
High – 5% royalty on 10-year revenue		**2.2 billion**

- The above is an indication what the adoption of the H2GM AR Technology is worth in terms of hard cash. There are, however, significant intangibles that have not been taken into consideration. These are based on the fact that all of the above projects are simply not viable without the AR process. They would not, therefore, be able to take advantage of the prevailing Carbon-Neutral climate, the prevailing march towards electrification and the fight against the disasters of Climate Change.
- In summary, this analysis indicates that the AR technology has a minimum value of US$223 million. If a typical royalty scenario of 5% of gross revenues is taken (H2GM already has multiple such licence agreements in discussions), then the current value would be US$ 2.2 billion.

Forward-looking Statement

This document may contain forward-looking information [including forward-looking information within the meaning of applicable Canadian, UK, and United States securities legislation], with respect to H2GreenMetals' operations and future financial results. Such forward-looking statements involve known and unknown risks, uncertainties and other factors that may cause the actual results, performance, or achievements of H2GreenMetals and or the commercial sectors in which it operates to be materially different from future results, performance or achievements expressed or implied by these forward-looking statements.

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