345 **DA14.1**

Projet d'usine de transformation de concentré de fer en fonte brute et en ferrovanadium à Saguenay

6211-19-027

“BlackRock Metals positions itself globally as the greenest company in the VTM extraction field”

Life cycle thinking: key to every aspect of sustainabiltity

BRM technology is the cleanest in the industry

Game changing factors:

- ✓ 1/3 the CO_2 emissions of VTM industry standard, with the potential to further reduce this to 1/5.
- ✓ BRM has assembled a GreenTech suite to produce some of the cleanest and greenest Fe, V and Ti products in the world.
- ✓ Polymetallics/polyproducts: ambition to approach zero waste at its metallurgical complex.
- ✓ Treatment in Quebec, where electricity is nearly all Hydro (opportunity for global impact reduction).

Transportation impact analysis

- The climate change spread between scenarios is narrow accounting for 3 to 4.5% of the overall impacts of its global activities.

- The choice of a 100% recycled aluminum scenario has more influence on the results (3%) than the choice of the transportation scenario (1.5%).

- The use of clean technology actually allows BlackRock to produce three products instead of one, dividing the environmental impact between these products.

BRM Vanadium further improves downstream efficiencies for its customers:

- Vanadium-strengthened steel products, on a mass-to-mass basis, offer a superior yield-strength/mass relationship, requiring up to 50% less vanadium alloyed steel for the same component.

- Vehicle parts made with low-carbon alloyed steel replacing traditional steels (such as strength class 300) with steel (strength class 500) reduces the total mass by approximately 30–50%, leading to the manufacture of lighter, and thus more fuel-efficient vehicles.
- The service life of alloyed steels is also increased. Structural steel can expect life-in-use of 40-100 years (or more with proper maintenance) as a result.
- End-of-life recycle for steel products has an 85-95% efficiency and essentially closes the environmental loop approaching a near-circular economy.
- BlackRock proactively uses a component of recycled metals in its current process. This recycle comes from internally and externally generated material.

The life cycle of steel

- Vanadium in reduction-oxidation “redox” flow batteries -- essential because renewable energy sources are intermittent and often at their peak when they are less needed.
  - more than 200,000 charge/discharge cycles.
  - do not generate any toxic vapours or hazardous gases, they present a low risk of explosion, and they have a relatively minor environmental impact.
  - Pure, single element vanadium batteries demonstrate one of the greatest efficiencies (~83-87%).

I. Cradle-to-Gate Life Cycle Assessment

I. Life Cycle Assessment

- BlackRock performed a cradle-to-gate Life Cycle Assessment of its activities
- This LCA was performed by a third party, Ellio. It respects the ISO 14040 standards, but has not undergone external review.
- The functional unit was defined as:

  One year of operation, leading to the extraction of

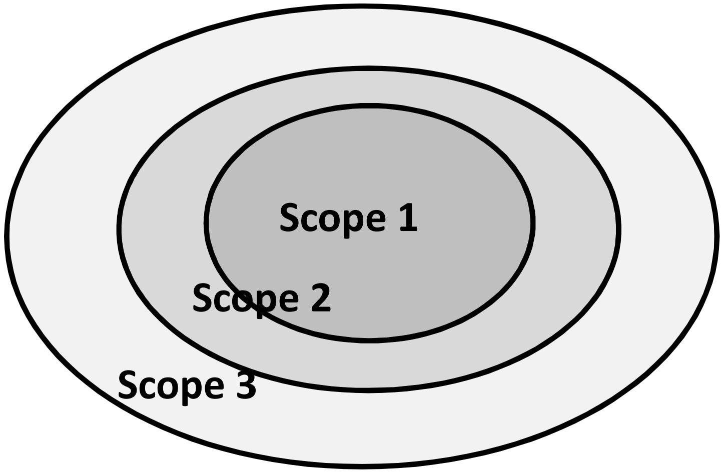
  - 843 000 tons of magnetite;
  - the production 519 300 tons of HPPI;
  - 5 803 tons of FerroVanadium, and
  - 116 633 tons of Ti-slag

I. Life Cycle Assessment

I.1. Commitment: If it's not being measured, it can't be managed

- Life Cycle Assessment can be used to reduce environmental impact and waste, reduce costs, focus product development, support marketing claims, improve product/corporate image and/or identify appropriate performance indicators. Further, doing an LCA creates common metrics that can be shared across companies, or with suppliers and partners who wish to improve their own footprint through using documented 'green sourced" materials.
- By performing an LCA BlackRock joins the vanguard in a global trend toward mastery and holistic understanding of impacts (Scope 1-3).
- BlackRock is positioned to align with supply companies and clients who wish to reduce their Scope 3 emissions and help drive global climate change initiatives through leveraging the its green products.

I. Life Cycle Assessment



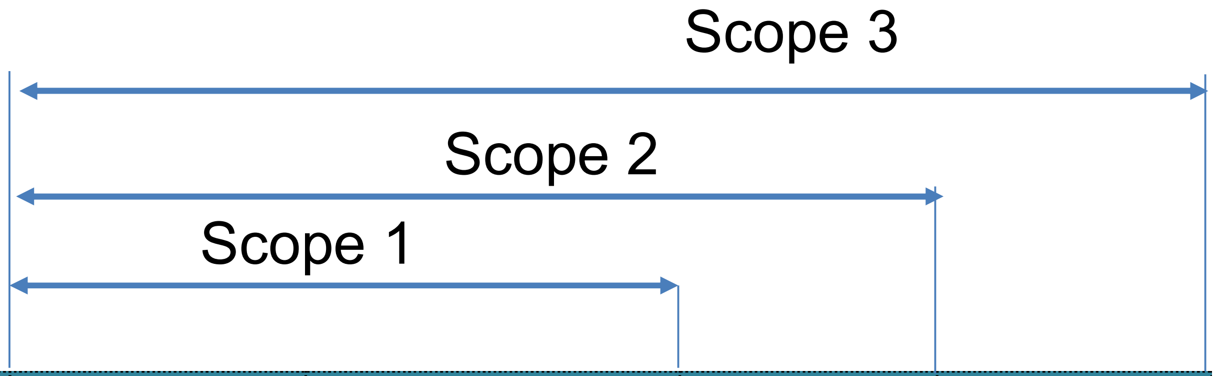
Scope 1 are also referred to as Direct GHG, and are defined as 'emissions from sources that are owned or controlled by the organization'

Scope 2 are also referred to as Energy Indirect GHG, and are defined as 'emissions from the consumption of purchased electricity, steam, or other sources of energy

Scope 3 are also referred to as Other Indirect GHG, and are defined as 'emissions that are a consequence of the operations of an organization, but are not directly owned or controlled by the organization'. Scope 3 includes a number of different sources of GHG including employee commuting, business travel, third-party distribution and logistics, production of purchased goods, emissions from the use of sold products, and several more. Based on data from many companies that have conducted comprehensive assessments of their Scope 3 emissions, it is evident that Scope 3 GHG are by far the largest component of most organizations' carbon footprint.

I. Life Cycle Assessment

I.2. Main results


Scope 3

Scope 2

Scope 1

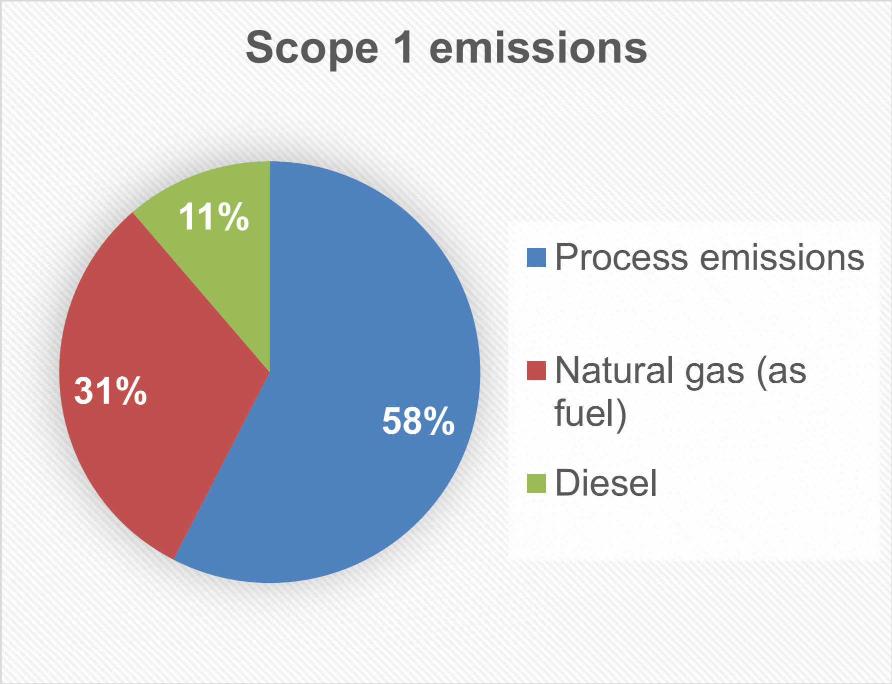
	Total (kt CO_2)	Process emissions	On-site energy use (diesel/natural gas)	Electricity	Up-stream processes
Mining	33	0	27	4	2
Transport	22		22		
Pelletizing	47	0	32	1	14
DR	418	209	105	0	104
OSBF	80	49	9	7	14
Converter	72	55	12	0	5
V Treatment	68	7	28	0	33
TOTAL	740	319	235	12	173

I. Life Cycle Assessment

I.2. Main results

- 73.5% of BlackRock's impact on climate change comes from Scope 1. Around 60 % of Scope 1 emissions come from process emitted CO_2.

- Due to HQ's leading position in renewable energy supply, Scope 2 electricity accounts for only 1.5% and helps firmly position BlackRock at the forefront semi-finished steel and steel additives industry.



- The remaining 25% of BlackRock's from Scope 3 emissions which are related to the production of raw materials used in BlackRock's process.

I. Life Cycle Assessment

I.2. Main results

↗ Regarding Scope 3, the main upstream processes include:

- Pelletizing: Calcined dolomite, material transportation to site, cement
- Direct reduction: Natural gas as ingredient
- OSBF: Calcined dolomite, ferrosilicon, electrodes
- Converter: Anthracite
- Vanadium treatment: Aluminum, sodium carbonate

I. Life Cycle Assessment

I.2. Main results

- Transportation between the mine and the metallurgical processing plant contributes to around 3% of the impacts on climate change and ozone depletion regardless of which combination of trucks and rail that are used.
- The metallurgical processing plant contributes to around 93% of the impacts of BlackRock on climate change and ozone depletion
- Direct reduction is the main “hot spot” of the metallurgical processing plant : 66% of the impact of the metallurgical processing plant on climate change comes from direct reduction (and 83% of the impact of the plant on ozone depletion comes from direct reduction).

I. Life Cycle Assessment

I.2. Main results

- BlackRock has already taken serious action on this hot spot, by being the first and only in the VTM industry to implement a technology that uses natural gas (rather than the industry standard coal, that has been long known for its harmful environmental impacts).
- CO_2 emitted by the direct reduction process contributes to 50% of the impact of the DR step on climate change.
- This CO_2 is food-grade, thanks to the use of the natural gas technology (which is not the case with the coal technology), meaning that it can be valorized in the food industry (ex. beverages, green houses for accelerated growth etc.)
- Capturing CO_2 at the direct reduction step would allow BlackRock to reduce its overall impact on climate change by 30%.
- BlackRock is exploring other impact reduction strategies (ex: using recycled aluminum instead of virgin aluminum in its vanadium treatment process)

I. Life Cycle Assessment

I.3. Transportation scenarios

- Three scenarios were studied:

1. Transport from the mine to Scierie Gagnon transhipment center by 100t truck (25 km) – Transport from Scierie Gagnon to Grand-Anse by train (400 km)
2. Transport from the mine to Chibougamau transhipment center by 100t truck (81 km) – Transport from Chibougamau to Grand-Anse by train (425 km)
3. Transport from the mine to port Grand-Anse by 42t truck (400 km)

- The difference in impact on climate change between the most impactful and the least impactful scenario is around 1.5% on the overall impact of BR activities.
- This means that the choice of a 100% recycled aluminum scenario has more influence on the results (3%) than the choice of the transportation scenario (1.5%).
- Transportation through Scierie Gagnon is the scenario with the lowest environmental impacts.
- The 100% truck scenario is the scenario with the highest impacts on climate change (13% higher than the Chibougamau scenario, and 30% higher than the Scierie Gagnon scerario).

II. Contextualization of the results

II. Contextualization

- For BlackRock's high purity iron product, the impact on climate change is calculated to be:
  - **996 kg CO_2e/t of HPPI**
- A literature review identified the following study as an interesting reference to contextualize BlackRock's results. This study was conducted in a Chinese context on a similar VTM feedstock, and making a similar suite of products:

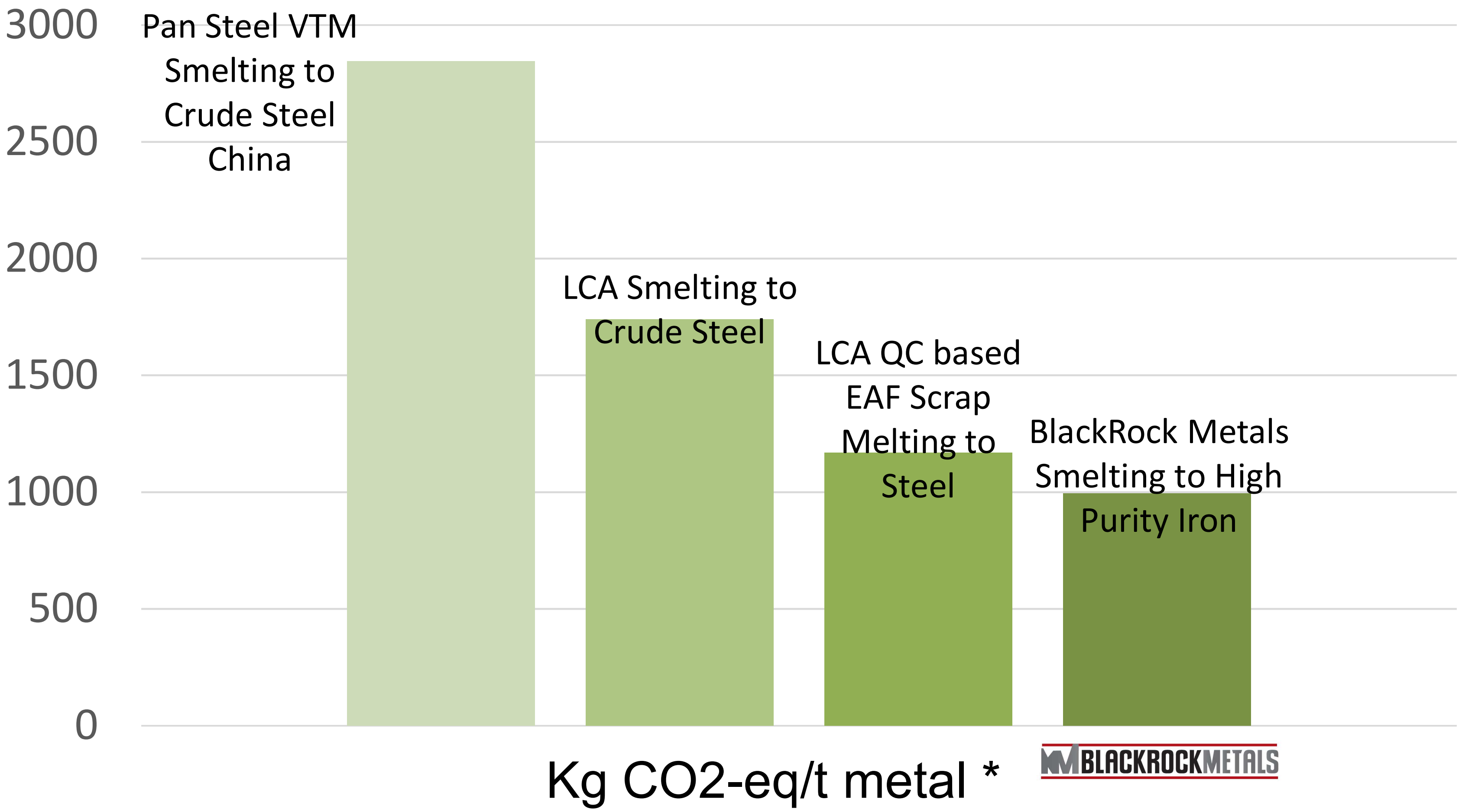
  Chen, S. et al (2015), Life cycle assessment of the comprehensive utilisation of vanadium titano-magnetite
- The stated impact on climate change is: **2846 kg CO_2e/t of crude steel**.

II. Contextualization

Other data that can be used to contextualize the results against similar metal products on a qualitative basis, so provide good context:

- From the ecoinvent LCA database on pig iron. Impact on climate change using a global context is **1740 kg CO_2e/t of pig iron**.
- From ArcelorMittal production data averaged from 2014, 2015 and 2016 for company-wide production (from mine to finished steel) there is a self reported **2123 kg CO_2e/t of finished steel**.
- From the ecoinvent LCA database on remelting recycled steel scrap in QC there is a stated impact of **1170 kg CO_2e/t of finished steel**. This category represents the lowest footprint of any of the steel industry players due to its use of a recycled feedstock with no CO_2e burden of its own. 45% of the CO_2e is attributable to fluxing lime, and 17% to NG. The remaining is in aggregate for equipment and transportation burdens etc.

II. Contextualization



* This graph is meant only to put BlackRock's results in perspective with other results found in the literature. It is not about performing a comparative LCA, as methodological differences may exist between studies.

A limitation of the comparison between BR results and Pan Steel comes the fact that Pan's magnetite has only 54% Fe content whereas BRM's 62%

II. Contextualization

- Because Pan is also a VTM processor, its production data is very close to BlackRock’s in terms of scope and objectives, and the relatively high quality of the VTM ore in BlackRock’s case lies at the core of its superior performance.
- Production of pig iron in a BF (like Pan and the pig iron LCA case) exerts the most extensive impacts on climate change, which is consistent with BlackRock’s study where the Direct Reduction step is the main “hot spot” on climate change among all BlackRock’s global activities.

II. Contextualization

- The ratio of 1:3 between impact scores of BR and Pan steel can be mainly attributed to two phenomena:
    1. The use of natural gas instead of a coal-based BR reduction technology. This is the step that represents the main leverage point on climate change within the whole cradle to gate life cycle.
    2. Electricity in a Quebec context is 97% hydroelectricity, whereas in Sichuan, China, where the study is conducted, it is 25% coal, 75% hydroelectricity.
- The use of Tenova's HYL natural gas reduction directly addresses the hot spot of the pig iron production, and firmly places BlackRock's VTM process as a game changer in the industry.
- BlackRock is the first company that has made the switch. Added to that the uses hydro electricity, BlackRock is currently poised as the greenest company in the VTM extraction field, and on par with the EAF scrap melters with the lightest CO_2e footprints in the steel industry.

II. Contextualization

- Regarding FerroVanadium, BlackRock's study resulted in an estimation of **12 600 kg CO_2e/kg** Vanadium.
- A literature review identified the following study as an interesting reference to contextualize BlackRock's results:

  Nuss P, Eckelman MJ (2014) Life Cycle Assessment of Metals: A Scientific Synthesis. PLoS ONE 9(7): e101298. doi:10.1371/journal.pone.0101298

- In this study, the impact on climate change is**:** 33.1 t CO_2e/kg of Vanadium (or **33 100 kg CO_2e/t of Vanadium**).
- Again, a ratio of roughly 1:3 is found between this generic study and the environmental impacts of BlackRock is seeing.

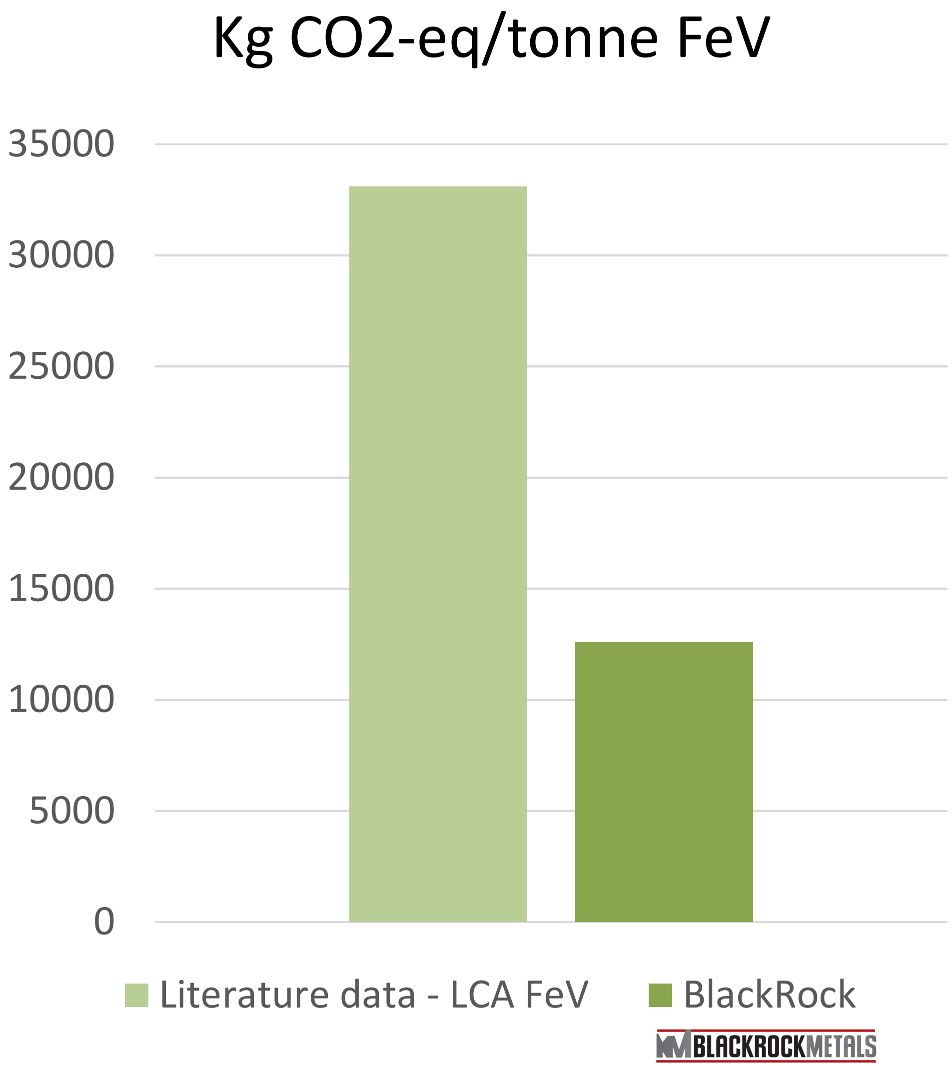
II. Contextualization

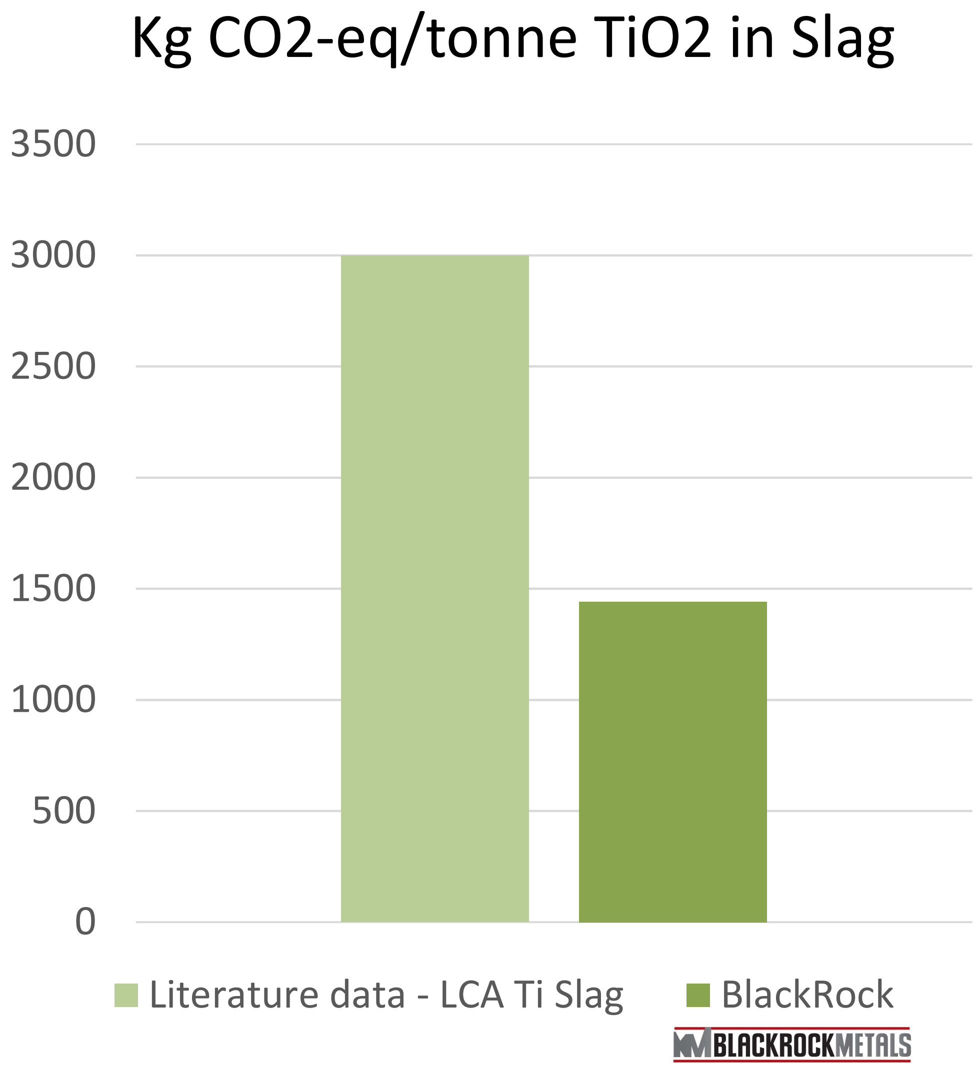
- Regarding TiO_2 slag, BlackRock's impact on climate change is around **1 442 kg CO_2 per tonne of TiO_2 in Slag**.
- A literature review identified the following study as an interesting reference to contextualize BlackRock's results:

  Middlemas, S. et al (2015) Life cycle assessment comparison of emerging and traditional Titanium dioxide manufacturing processes,Journal of Cleaner Production, Volume 89, 15 February 2015, Pages 137-147

- The impact of Ti Slag – which would be the equivalent to BlackRock's product – is **3 000 kg CO_2 per tonne of TiO_2 in Slag**.
- This results in a roughly 1:2 ratio.

II. Contextualization





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II. Contextualization

- Through each step of BlackRock’s process the products get purified; the use of a clean natural gas technology eliminates the introduction of any outside contaminants. Therefore, the use a clean technology actually allows BlackRock to produce three products instead of one, dividing at the same time the environmental impact between these products.
- Another source of difference between BlackRock’s impact scores and the literature data comes from using natural gas instead of coal, and the use of nearly 100% hydroelectricity.

III. Vanadium’s use phase (literature review)

III. Vanadium’s use phase

- In 2013, the total world consumption of vanadium was approximately 79,000 tonnes per annum, representing almost a doubling over the previous decade.
- Currently, about 90% of vanadium is used as an alloying element in steels
- 50% of vanadium was consumed in China in 2013.
- The vanadium-strengthened steels have proven to be up to twice as strong as ‘mild’ steel, the workhorse structural steel. On a mass-to-mass basis, its superior yield-strength/mass relationship roughly means that up to 50% less vanadium alloyed steel is required for the same component.
- Recent forecasts predict a vanadium deficit with an increase in vanadium consumption in some countries, particularly in China in light of its new national regulations calling for greater resistance in construction materials. Indeed, the largest use of vanadium microalloyed steels is currently in Chinese concrete reinforcing bar (re-bar).

III. Vanadium’s use phase

- Microalloyed steels enable the production of equipment with a longer working life, a greater reliability and durability of machine parts, and increased seismic stability in construction materials resistant to alternating loads and to damping
- Mechanical properties of low-carbon microalloyed permit the use of the same high-strength steel for different vehicle parts, both reducing their mass and increasing their dependability. These parts include frames and side-frame, fenders, door reinforcements, among others. In turn, replacing traditional steels (such as strength class 300) with steel (strength class 500) reduces the total mass by approximately 30–50%, leading to the manufacture of lighter, and thus more fuel-efficient vehicles.

III. Vanadium’s use phase

- Another major application of vanadium is found in reduction-oxidation “redox” flow batteries (VRFBs, one of the batteries that transform and store other forms of energy into chemical energy). These batteries are promising alternatives for hospitals, air traffic control, or broadcasting industries that demand uninterrupted, stable supplies of electricity that come from uber-local and reliable energy storage solutions.
- Such solutions are essential, particularly because renewable energy sources are intermittent and often at their peak when they are less needed (like in the case of roof solar panels collecting energy at empty residential spaces during work hours, or of wind-turbines working late at night). Moreover, although renewable energy sources excluding hydroelectric provide around 4% of electricity production worldwide, their growth is expected to reach 25% by 2030. This trend is accompanied by the likelihood that grids will become unstable if renewable sources provide more than 20% of the energy but lack an adequate energy storage system that serves as a buffer. (Hence the need for large-scale rechargeable batteries, such as VRFBs.)

III. Vanadium’s use phase

- VRFB employs the same ion-element (vanadium) in both electrolytes. This means that the ions themselves are not consumed and there is no cross-contamination across electrolytes, thus preventing capacity decrease. According to some records spanning three years or more, these batteries have successfully completed more than 200,000 charge/discharge cycles. The vanadium redox reactions also do not generate any toxic vapours or hazardous gases, they present a low risk of explosion, and they have a relatively minor environmental impact. In turn, according to some studies, the all-vanadium batteries demonstrate one of the greatest efficiencies (~83-87%).

III. Vanadium's use phase

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- Notably, Ibid, esp. p. 1082.

Appendix

Appendix I.1 : distribution of CO_2 eq emissions associated with the production of 1 tonne of HPPI

Mining	50 kg CO_2 - eq
Pelletizing	71 kg CO_2 - eq
DRI	625 kg CO_2 - eq
OSBF	120 kg CO_2 - eq
Converter	130 kg CO_2 - eq
1 tonne HPPI	**996 kg CO_2- eq/ tonne HPPI**

Appendix I.2 : distribution of CO_2 eq emissions associated with the production of 1 tonne of FerroVanadium

Mining	13 kg CO_2 - eq
Pelletizing	18 kg CO_2 - eq
DRI	162 kg CO_2 - eq
OSBF	31 kg CO_2 - eq
Converter	631 kg CO_2 - eq
Vanadium Treatment	11 797 kg CO_2 - eq
1 tonne FerroVanadium	**12 652 kg CO_2- eq / tonne FerroVanadium**

Appendix I.2 : distribution of CO_2 eq emissions associated with the production of 1 tonne of TiO2 in slag

Mining	82 kg CO_2 - eq
Pelletizing	117 kg CO_2 - eq
DRI	1 043 kg CO_2 - eq
OSBF	200 kg CO_2 - eq
1 tonne Ti-slag *	**1 442 kg CO_2- eq / tonne TiO_2**

* BRM's Ti-Slag contains 61% TiO_2. Here results have been normalized to 1 tonne TiO_2