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Les Minéraux Harsco Inc.

Verification report on a Greenhouse Gas Emissions (‘’GHG’’) reduction project – Quantification of CO2eq Emission Reductions from Slag-based Recycling Operations

April 13, 2017

360 Lawrence (coin Taschereau), suite 2000
Greenfield Park (Québec) J4V 2Z4
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April 13, 2017

M. Philippe Bouchard, ing.
Assistant manager Environment and Metallurgy
Les Minéraux Harsco Inc.
1200 Route des Aciéries
Contrecoeur, Québec, J0L 1C0

Dear Mr. Bouchard:

Subject: Verification report on a greenhouse gas emissions ("GHG") reduction project

Please find enclosed our verification report on a GHG emissions reduction project performed at 1200 Route des Aciéries, Contrecoeur, Québec, J0L 1C0

The quantification report that is subject to our verification is included in Appendix 3.

Please do not hesitate to contact us for any additional information you may require.

Yours truly,

Roger Fournier CPA, CA

GHG Lead Verifier

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M. Philippe Bouchard, ing.
Site Manager
Les Minéraux Harsco Inc.
1200 Route des Aciéries
Contrecoeur, Québec, J0L 1C0

Mr. Bouchard:

We have been engaged by Les Minéraux Harsco to perform the verification of a GHG Emissions Reduction project performed at 1200 Route des Aciéries, Contrecoeur, Québec, J0L 1C0 as an independent third party verifier.

We have verified the accompanying greenhouse gas ("GHG") emissions reduction quantification report entitled "Quantification of CO2eq Emission Reductions from Slag-based Recycling Operations by Les Minéraux Harsco *Greenhouse Gas Project Report Period January 1st 2016 to December 31st 2016* (the "quantification report"). This quantification report dated April 12, 2017 is included in Appendix 3 of our report which is intended to be posted on CSA's GHG CleanProject TM registry.

Management is responsible for the relevance, consistency, transparency, conservativeness, completeness, accuracy and method of presentation of the quantification report. This responsibility includes the design, implementation and maintenance of internal controls relevant to the preparation of a GHG emissions reduction quantification report that is free from material misstatements. Our responsibility is to express an opinion based on our verification.

Les Minéraux Harsco Inc.

Les Minéraux Harsco is the branch of the multinational Harsco Corporation in the province of Québec. Harsco Corporation has a goal of developing environmental solutions for waste management of the metal industry. *Les Minéraux Harsco* has its head office in Contrecoeur in the province of Quebec and its plant in Sorel-Tracy is the "mineral" branch of Harsco Corporation.

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The company recycles slag and mining waste and transforms it into ferrous and non-ferrous metals as well as aggregates (sand and different size stone). *Les Minéraux Harsco* recovers slag that meets its criteria. The plant has the equipment and technology to carry out operations such as crushing, sifting, drying, and cleaning of the slag

The emissions reduction project

The project is located at 1200 Route des Aciéries, Contrecoeur, Latitude 45° 48' 24.74" N and Longitude 73° 16' 23.10" W and at 1690 Marie-Victorin, Sorel-Tracy, Latitude 46° 02' 23.31" N and Longitude 73° 08' 38.08" W and 1499 Montée Lapierre, Contrecoeur, Latitude 45° 48' 24.74" N and Longitude 73° 16' 23.10" W.

The project achieves GHG emissions reduction since it makes possible to reduce greenhouse gas emissions by recycling slags and residues from mining and metal industries. Harsco recycle slags and residues from mining and metal industries and get two products from the recycling operations which are metal and aggregates.

The recycled metal is then reused in the metal industries. Those industries will mix virgin metal with the recycled metal in their processes.

The recycled aggregates is also reused in the manufacturing of asphalt. The industries will use a mix of virgin and recycled aggregates in their own production. Harsco with his recycling operations will then avoid landfilling of aggregates.

The first part of the project (Metal) is additional to a baseline scenario which is the production of virgin product meaning that Harsco's clients would have used only virgin metal in the processing of their products.

The second part of the project (Aggregates) is additional to a baseline scenario which is the landfill avoidance meaning that without Harsco's project, a huge quantity of aggregates would have been sent to the landfill and Harsco's clients would have used virgin aggregates in their processes.

The baseline scenario and the project scenario (Metal) deliver the same type and level of product service (i.e. they are functionally equivalent) in a sense that they both meet the client needs.

The project start date is October 23rd, 2003 and this is the second crediting period. This second crediting period started on January 1st, 2014 and is expected to end on December 31, 2023. A first verification report has been issued in 2009 for the period 2003 to 2007. A second verification report has been issued for the year 2014 and a third verification report has been issued for year 2015. This is the fourth verification report for this project.

For the Metal Project, the main GHG sources come from raw Materials acquisition process, manufacturing process energy and transportation.

For the aggregates project the main GHG sources come from the avoided virgin inputs process, avoided virgin inputs transportation, recycled inputs manufacturing, landfill transportation and operating equipment. The various gases involved at Les Minéraux Harsco Inc. are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

The project was under the responsibility of Mr. Philippe Bouchard, Site Manager and Mr. Richard Provençal, Quality, Environment and Technical Support. Mr. Claude Arsenault, Regional Controller was responsible for the data collection and monitoring.

The quantification report

The quantification report was prepared by Eco-credit, in accordance with ISO 14064-2 "*Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancement (2006)*".

For the first part of the project (Metal) the quantification is done in accordance with the methodology entitled: *Solid Waste Management and Greenhouse Gases : A Life-Cycle Assessment of Emissions and Sinks* from the EPA and the quantifier also uses as a guideline a study from ICF Consultants entitled *"Determination of the impact of waste management activities on Greenhouse Gas Emissions.*

As per the ICF study, all GHG emissions related to the project are those related to the recycling production of steel and for the baseline all GHG emissions are related to the production of virgin steel. The quantifier has applied all energy factors proposed by the study and then used the appropriate emissions factors for all energy sources proposed by the study.

For the second part of the project (Aggregates) the quantification is done in accordance with the methodology entitled: *Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks* from the EPA and the quantifier also uses as a guideline a study (suggested by the EPA) from ICF Consultants entitled: "*Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)"*
The GHG emissions for the project are those related to the recycling operations of the aggregates and the avoidance of virgin input process of aggregate.
For the baseline, the GHG emissions are those related to landfill operations and transportation.

The approach that was used for the quantification of the GHG emissions reductions was one of comparing the GHG emissions generated by various sources of emissions included in the baseline scenarios with those resulting from the project scenarios. The quantifier determined the GHG emissions for every source of emissions by using appropriate emission factors multiplied by the consumption of every GHG source

The emission factors have been chosen from the National Inventory Report 1990-2014, *Greenhouse Gas Sources and Sinks in Canada*.

The verification team

Before undertaking this assignment we ensured there were no conflicts of interest that could impair our ability to express an opinion and the conflict of interest form was completed and is included in Appendix 2 to this report. We also ensured we had the skills, competencies and appropriate training to perform this specific assignment.

The Verifier assigned to this audit work was:

Roger Fournier CPA, CA, Lead verifier.

Roger Fournier has received the CSA ISO 14064-3 training. Mr. Fournier was the lead verifier in the previous verification reports and has also been involved in others similar projects. Over the last ten years, Mr. Fournier has been involved in the audit of more than 100 projects and most of them as a Lead Verifier.

The verification work

Standards:

Our verification was conducted under ISO 14064-3 International Standard, entitled: *Specification with guidance for the validation and verification of greenhouse gas assertions (2006)*. This standard requires that we plan and perform the verification to obtain either a reasonable assurance or a limited assurance about whether the emission reductions declaration that is contained in the attached quantification report is fairly stated, is free of material misstatements, is an appropriate representation of the data and GHG information of Client and the materiality threshold has not been reached or exceeded

Scope:

A reasonable assurance engagement with respect to a GHG statement involves performing procedures to obtain evidence about the quantification of emissions, and about the other information disclosed as part of the statement. Our verification procedures were selected based on professional judgment, including the assessment of the risks of material misstatement in the GHG statement. In making those risk assessments, we considered internal control relevant to the entity's preparation of the GHG statement.

Our engagement also included:

- Assessing processes and control over data.
- Evaluating the appropriateness of quantification methods and reporting policies used and the reasonableness of necessary estimates made by Les Minéraux Harsco Inc.
- Identifying GHG sources sinks and reservoirs, types of GHG involved and time periods when emissions occurred.
- Establishing quantitative materiality thresholds and assessing compliance of results to these thresholds.
- Ensuring ownership of the project by observing that all reductions are obtained directly by the client.

Level of assurance:

It was agreed with Les Minéraux Harsco's representatives that a reasonable assurance level of opinion would be issued and we planned and executed our work accordingly. Consequently, our verification included those procedures we considered necessary in the circumstances to obtain a reasonable basis for our opinion.

Planning:

At the planning phase of this verification assignment, we assessed the quantification report in order to understand the major processes of Les Minéraux Harsco's operations, the different production or operation stages with the purpose of assessing the complexity of the operation. We then made a first assessment of the inherent risk.

We also got information on Les Minéraux Harsco's internal control with the purpose of assessing our first evaluation of control risk and detection risk for this assignment. We also assessed the emission sources and GHG involved.

A verification plan and sampling plan have been prepared and designed to mitigate the detection risk

Our verification plan establishes, among others, the terms of the engagement, level of assurance, objectives, criteria, scope and materiality threshold. Various other steps are also described in our verification plan as the first documents necessary for the conduct of the audit. These documents allow us to corroborate various elements of different monitoring systems. The audit plan also includes discussions with various stakeholders at Les Minéraux Harsco Inc. to ensure that different controls are in place.

Assessing Materiality:

Materiality is an amount that, if omitted or misstated, will influence the reader of the report in his decision making. Materiality is defined by the lead verifier in accordance with the agreed level of assurance. This materiality is also based on professional judgment and risk assessment.

The materiality for this project is 5% of declared emission reductions

The inherent risk, control risk and detection risk were assessed at an acceptable level for verification purposes.

Sampling Plan:

Our sampling plan included the verification of all recycled metal and recycled aggregates for the year 2016. This verification was done by reviewing the supported documents related to slag and mining wastes received and shipments of recycled metal and aggregates. During our verification, our sampling plan was not modified.

Execution:

A draft of the quantification report was submitted to us on February 27, 2017. Our initial review of the documentation was undertaken on March 7, 2017 and a verification plan was prepared. We also toured Les Minéraux Harsco's premises on April 11, 2017. In doing so we interviewed Mr. Philippe Bouchard, (Site Manager) and M. Richard Provençal (Quality, Environment and Technical Support).

This visit allowed us, among others, to reassess our audit risks, to get a good comprehension of the different productions stages. The final quantification report is dated April 12, 2017.

We have identified each monitoring system that may have an effect on the data used for emissions reduction calculations. During the course of our audit, we have received all requested available information from the staff responsible for data input and reporting out of these systems (Mr. Philippe Bouchard, Mr. Richard Provençal and Mr. Claude Arsenault) and the control procedures were described and assessed. All reports used in the calculation were reconciled to the calculations.

We have assessed, among others the appropriateness of using the methodology entitled "*Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks"* from the EPA and the studies from ICF Consultants entitled *"Determination of the impact of waste management activities on Greenhouse Gas Emission and* "*Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)"*
We also assessed the appropriateness of using the National Inventory Report 1990-2014 for emissions factors and we agree with it.

The materiality level, which has been established at 5% of the declared emissions reductions has not been exceeded.

Restricted usage and confidentiality

This verification report is produced to be used by the management of Les Minéraux Harsco Inc and parties interested in the above described GHG emissions reduction project. Reliance on the conclusions of this verification report for any other usage may not be suitable.

The quantification report entitled "*Quantification of CO2eq Emission Reductions from Slag-based Recycling Operations by Les Minéraux Harsco Greenhouse Gas Project Report Period January 1st 2016 to December 31st 2016* and dated April 12, 2017 is an integral part of this verification report and should in no circumstances be separated from it.

This verification report and the supporting work files are kept confidential and are available to the client on request and will not be disclosed to anyone else unless compelled by law. They will be safeguarded for 10 years after which period they will be safely destroyed.

Fournier Toupin CPA Inc.
Cabinet Comptable

Appendix 1

Report to:

M. Philippe Bouchard, ing.
Site Manager
Les Minéraux Harsco Inc.
1200 Route des Aciéries
Contrecoeur, Québec, J0L 1C0

Object and objectives of the verification

We have verified the attached quantification report entitled: "*Quantification of CO2eq Emission Reductions from Slag-based Recycling Operations by Les Minéraux Harsco Greenhouse Gas Project Report Period January 1st 2016 to December 31st 2016***.** The objective of the verification is to assess data, controls and process that are supporting the emissions reductions calculations presented in the attached quantification report (Appendix 3).

Criteria :

1. The attached quantification report is in conformance with the requirements and principles of ISO 14064-2
2. The approach and methodologies used for the quantification are appropriate.
3. The baseline scenarios are appropriate
4. The supporting data available are subject to sufficient controls to be considered fair and accurate and should not cause any material discrepancy
5. The calculation supporting the GHG assertion are sufficiently accurate to be considered fair and accurate and should not cause any material discrepancy
6. The quantification report has a low degree of uncertainty and the materiality threshold has not been reached or exceeded

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7. There are no competing claims to the ownership of the GHG project and the resulting emission reductions or removals.

8. The project start date is accurate and the lifetime of the project is well stated

Reasonable assurance opinion

Our verification was conducted under ISO 14064-3 International Standard, entitled: *Specification with guidance for the validation and verification of greenhouse gas assertions (2006)*.

In our opinion:

1. The quantification report is prepared in accordance with ISO 14064-2 standard: *Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements* (2006), and the principles of relevance, completeness, consistency, accuracy, transparency and conservativeness have been respected.

2. The approach and methodologies used for the quantification are appropriate.

3. The baseline scenarios are appropriate.

4. The client's data controls management system is appropriate.

5. The quantification report and the GHG assertion are free of material misstatements and are an appropriate representation of the data and GHG information of Client.

6. The quantification report has a low degree of uncertainty and the materiality threshold has not been reached or exceeded.

7. To our knowledge, there are no competing claims to the ownership of the GHG project and the resulting emission reductions or removals

8. The project start date is accurate and the lifetime estimation of the project is fairly stated

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9. The GHG emission reductions presented in the quantification report entitled "*Quantification of CO2eq Emission Reductions from Slag-based Recycling Operations by Les Minéraux Harsco Greenhouse Gas Project Report Period January 1st 2016 to December 31st 2016* and dated April 12, 2017 are, in all material respect, fairly stated at 137879 tCO_2e for the period from January 1st, 2016 to December 31st, 2016 and are additional to what would have occurred in the baseline scenarios.

10. The following breakdown of those emission reductions for the year 2016 is fairly stated (in units of CO_2e):

CO_2	CH_4	N_2O	Total
136925	119	835	137879

Note: Other GHG such as PFC, HFC and SF_6 are not accounted for because they are not specific to Natural gas, electricity and fuel consumptions

Roger Fournier, CPA, CA

Lead Verifier

Greenfield Park, April 13, 2017

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Appendix 2

Conflict of Interest Review

Client Name: Les Minéraux Harsco Inc.

Report Identification: Verification Report on a GHG Reduction project entitled: "*Quantification of CO2eq Emission Reductions from Slag-based Recycling Operations by Les Minéraux Harsco Greenhouse Gas Project Report Period January 1st 2016 to December 31st 2016*.

Date of report: April 13, 2017

Professional: Roger Fournier CPA, CA, Lead Verifier

I confirm the following:

Independence

I remained independent of the activity being verified, and free from bias and conflict of interest and I maintained objectivity throughout the verification to ensure that the findings and conclusions will be based on objective evidence generated during the verification

Ethical conduct

I have demonstrated ethical conduct through trust, integrity, confidentiality and discretion throughout the verification process

Fair presentation

I have reflected truthfully and accurately verification activities, findings, conclusions and reports.
I have reported significant obstacles encountered during the verification process, as well as unresolved, diverging opinion with the responsible party and the client

Fournier Toupin CPA Inc.
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Due professional care

I have exercised due professional care and judgment in accordance with the importance of the task performed and the confidence placed by clients and intended users.
I have the necessary skills and competences to undertake the verification

April 13, 2017

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APPENDIX 3

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Quantification of CO_2eq Emission Reductions from Slag-based Recycling Operations by Les Minéraux Harsco

Greenhouse Gas Project Report
Period January 1st 2016 to December 31st 2016

Project proponent: *Les minéraux Harsco*
1200, Route des Aciéries
Contrecoeur (Québec)
J0L 1C0

Prepared by: *Eco-credit*
71, Baril Bvd.
Princeville (Québec)
G6L 3V4

April 12, 2017

SOMMAIRE EXÉCUTIF

(*Please note that the rest of the document is in English*)

Melri et Recmix, deux compagnies spécialisée dans le traitement et le conditionnement de différents produits comprenant des métaux ferreux tels que l'acier et des métaux non ferreux tels que l'alumine, ont fusionné et ont créé une nouvelle entreprise appelée *Les Entreprises Matériaux Excell* en 2005. En 2010, *Matériaux Excell* est devenu *Les Minéraux Harsco*, la succursale québécoise de la multinationale Harsco Corporation. *Les Minéraux Harsco* a son siège social à Contrecoeur au Québec et possède des installations à Sorel-Tracy.

L'entreprise recycle les scories et des résidus miniers pour les transformer en métaux ferreux, non-ferreux et divers types d'agrégats. *Les Minéraux Harsco* récupère les scories qui rencontrent leurs critères. L'usine a les équipements et la technologie nécessaires afin de traiter les matières reçues, donc ses équipements permettent les opérations suivantes : écraser, tamiser, sécher et nettoyer les scories.

Le scénario de projet est le recyclage des scories et des résidus miniers et de l'industrie de la métallurgie en récupérant le métal, en utilisant la partie récupérable de la portion non métallique comme agrégats pour la construction. Tout est récupéré, aucun résidu n'est envoyé à l'enfouissement. Ce scénario est comparé à la situation qui aurait été implantée c'est-à-dire pour la partie métallique, l'utilisation de matériaux vierges pour produite le métal et pour la partie non métallique, l'enfouissement et l'utilisation de ces matières pour le recouvrement des sites d'enfouissement.

Le projet et les réductions d'émissions de GES seront enregistrés au Registre des GES ÉcoProjets®. Ces réductions sont quantifiées conformément aux principes et lignes directrices de la norme ISO 14064 tel que stipulé par le Registre des GES ÉcoProjets®. La méthodologie utilisée est basée sur la méthodologie définie dans le document de l'U.S. EPA (Environmental Protection Agency of the United States) nommé : "*Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sink*"[1]. Elle a été sélectionnée afin de choisir les sources, puits et réservoirs de GES à inclure dans la quantification ainsi que comme guide pour les calculs de réductions et les facteurs d'émissions.

Les réductions d'émission pour l'année 2016 sont au nombre de :

Année	Réductions d'émission (tCO2e)
2016	137 879

[1] SOLID WASTE MANAGEMENT AND GREENHOUSE GASES: A Life-Cycle Assessment of Emissions and Sinks, (September 2006), 3rd edition.

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ABBREVIATIONS

BS	Baseline Scenario (GHG Emission Source)
CDM	Clean Development Mechanism
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent (usually expressed in metric tons)
CSA	Canadian Standards Association
EF	Emission Factor
EPA	Environmental Protection Agency (USEPA)
HDD	Heating degree day
GHG	Greenhouse gases
ISO	International Organization for Standardization
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilowatt hour
N_2O	Nitrous oxide
PS	Project Scenario (GHG emission source)
SSR	Source, Sink and Reservoir
t	Ton (metric)
VERR	Verified Emission Reductions-Removals

1. INTRODUCTION

Melri and Recmix, two companies specialized in the treatment and conditioning of different products containing ferrous metals such as iron and non-ferrous metals such as alumina, merged together and created a new company called *Les Entreprises MATÉRIAUX EXCELL* in 2005. In 2010, *Matériaux Excell* became *Les Minéraux Harsco*, the Quebec's branch of the multinational Harsco Corporation. Harsco Corporation has a goal of developing environmental solutions for waste management of the metal industry. *Les Minéraux Harsco* has its head office in Contrecoeur in the province of Quebec and other sites in Sorel-Tracy.

The company recycles slag and mining waste and transforms it into ferrous and non-ferrous metals as well as aggregates (sand and different size stone). *Les Minéraux Harsco* recovers slag that meets its criteria. The plant has the equipments and technology to carry out operations such as crushing, sifting, drying, and cleaning of the slag. No contaminated material is treated at *Les Minéraux Harsco*'s plants. If some material is contaminated, contaminants are removed before being purchased by *Les Minéraux Harsco*.

The project scenario of the recycling of the entire amount of slags and mining and metal industry wastes is compare to the scenario that would have been implemented which is the use of virgin inputs for metals and the aggregates and remaining slag would have been sent to landfill or those wastes would have been used in landfill as a covering material[2].

Two different methodologies are selected as a reference documents for the project. Two cases are evaluated: the metal part of the waste and the remaining of slag and waste used as aggregates.

In the first case, a methodology based on a study realized for Environment Canada and Natural Resources Canada called: "*Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions: 2005 Update*[3] is selected to identify the sources, sinks and reservoirs (SSRs) to be included in the quantification and chosen to offer a guideline for the calculation of emission reductions. This methodology is deemed to be the most appropriate. In fact, in the report, the SSRs that are included and the methodology that is applied slightly differ from what is stated in the methodology. Those differences are explained in section 2.8, 4 and 5.

In the second case, a methodology based on the U.S. EPA (Environmental Protection Agency of the United States) document called: "*Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sink*"[4] and its evolution: "*Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)*" [5], is selected to identify the sources, sinks and reservoirs (SSRs) to be included in the quantification and chosen to offer a guideline for the calculation of emission reductions.

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[2] Recyc-Québec. *Bilan 2012 de la gestion des matières résiduelles au Québec*, (2014). pp. 28-29. Internet link: http://www.recyc-quebec.gouv.qc.ca/Upload/Publications/Bilan_2012_accessible.pdf

[3] *Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions: 2005 Update*, (October, 2005).

[4] *SOLID WASTE MANAGEMENT AND GREENHOUSE GASES: A Life-Cycle Assessment of Emissions and Sinks*, (September 2006), 3rd edition.

[5] *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)*, (March 2015), Version 13.

This methodology is deemed to be the most appropriate. As in the previous case, in the report, the SSRs that are included and the methodology that is applied slightly differ from what is stated in the methodology. Those differences are explained in section 2.8, 4, and 5.

In section 3, the selection of the baseline scenario and the assessment of additionality were performed according to best practices and the expertise of the quantification team. A barrier analysis is performed and used to confirm the most plausible scenario and to provide a solid argumentation on which to base the additionality assessment.

This GHG report meets the requirements of the CSA's GHG CleanProjects® Registry and the ISO 14064-2 guidelines and principles:

- Relevance

All relevant GHG sources are meticulously selected and presented in section 4. A precise methodology is used along with project specific parameter values.

- Completeness

A complete assessment of GHG sources is made and all GHG types are considered in the applied quantification methodology. Complete information regarding project implementation, activities and GHG quantification is given through this GHG report.

- Consistency

Chosen quantification methodologies are appropriate for *Les Minéreaux Harsco*'s project. The established baseline scenario, as described in section 3, is consistent with the project level of activity related to waste management of slag and other metal and mining industry waste.

- Accuracy

Calculation uncertainties are kept as small as possible.

- Transparency

Project related information is transparently communicated throughout this document so that the intended user can identify important data, how they are collected, and how the project actually leads to GHG emission reductions. Data monitoring and GHG emission reductions calculation are clearly detailed in order to provide the reader sufficient information to allow the user to confidently make decisions.

- Conservativeness

GHG emission reductions are not overestimated. When accuracy is jeopardized because of assumptions, conservative choices are made to make sure that GHG reductions are not overestimated.

This report will be made available for public consultation. It is intended to serve as a transparent reference document to support the prospection of potential verified emission reductions (VER) buyers.

2. PROJECT DESCRIPTION

The project consists of quantifying the greenhouse gas emissions reduction resulting from *Les Minéraux Harsco*'s activities taking place at their plants in Contrecoeur and Sorel-Tracy, in the Province of Quebec, Canada. *Les Minériaux Harsco* is the Quebec's branch of Harsco Corporation and was formerly known as *Matériaux Excell*. Post-consumer slag-based products are recycled by transforming materials recovered from different industries into sand, alumina, steel and iron oxide. Those products are sold to different industries integrating the recycled products into new products.

2.1. Project Title

Quantification of CO2eq Emission Reductions from Slag-based Recycling Operations by *Les Minéraux Harsco*

2.2. Objectives

The objective of this project is to lower the total amount of GHG emitted by recycling slags and residues from metal industry and use them as valuable products instead of using raw material and instead of emitting GHG emissions for the manufacturing process of those products.

2.3. Project Lifetime

Expected reductions are presented for only ten years in this report since the general market situation and the regulation can change and cause a change in the baseline scenario. The start date was October 27th, 2003. The second crediting period starts January 1st, 2014 and will end December 31st, 2023 as long as the project is still additional.

2.4. Type of GHG Project

The project is one of waste management by recycling slag-based metals. Emission reductions result from a decrease of acquisition and manufacturing of raw materials leading to less GHG emissions produced since the recycling manufacturing and transportation processes emit a smaller amount of GHG emissions.

2.5. Location

Les Minéraux Harsco's head office is in Contrecoeur and its main plant is also in Contrecoeur. Their coordinates are indicated below.

Head office

Les Matériaux Harsco
1200, Route des Aciéries
Contrecoeur, (Québec)
J0L 1C0
Latitude: 45°48'24.74"N
Longitude: 73°16'23.10"W

Main plant

1499, Montée Lapierre
Contrecoeur, (Québec)
J0L 1C0
Latitude: 45°48'36.24"N
Longitude: 73°16'46.89"W

2.6. Conditions prior to Project Initiation

Prior to the project activities, 2 different companies existed and they merged and opened a new plant to put the focus on their recycling activities.

2.7. Description of how the Project will achieve GHG Emission Reductions or Removal Enhancements

The project is the recycling of the slags and residues from mining and metal industry. The manufactured recycled products are compared to the situation that would have happened if they were not made from waste but from the actual mix of raw material and recycled inputs and takes account of the manufacturing processes that would have been used. The comparison is made based on a life cycle methodology for the calculations of GHG emissions. The change in GHG emissions is calculated to show how source reduction and recycling affect emissions of raw material acquisition and manufacturing processes. For the latter case, it requires energy intensive upstream processes which translate in significant GHG emissions. In the case of recycling, the energy required is far less so the GHG emissions are significantly reduced compared to the usual processes from raw material.

2.8. Project Technologies, Products, Services and Expected Level of Activity

The goal is to divert as much waste from the landfill to be recycled to provide aggregates or metals from those recuperated waste (project scenario) instead of the use of virgin inputs using the usual manufacturing processes (baseline scenario). To be able to realize the project scenario, the waste and slags need to be recuperated, crushed, sifted, dried, and cleaned.

A literature review of different methodologies, protocols and various studies which include detailed information on the methodology used has been done. None of the Clean Development Mechanism, Verified Carbon Standard methodologies and Climate Action Reserve protocols is suitable. Two studies conducted for National Entities have been selected and are presented in the following discussion, one for the metal portion of the waste and one for the remaining waste. The two studies are necessary since none of them cover both portions of the waste.

In the case of metal recycling, the *Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions: 2005 Update study*[6] is used. The methodology used in this study leads to diverse data such as energy consumed or avoided for different waste management options for many materials and other data such as emissions related to those options and those materials. The emissions are calculated from the energy consumed or avoided and lead to an aggregated emission factor. The data of energy consumed or avoided will be used since it reflects the energy related to the processes and transportation through a life cycle study and since the processes GHG emissions are mainly due to the energy use. Data for the appropriate energy emissions factors included in the *National*

[6] *Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions: 2005 Update*, (October, 2005).

Inventory Report (NIR) 1990-2014[7] of Canada will be used to transfer the energy data from the study into the corresponding level of emissions for Canada and when the data is available directly for the province of Quebec. Doing so, the calculated values can have the rigor of the data from the study but can represent the site specific reality of the project. The end products sold all come from ferrous metals and they are all products containing iron with a content of carbon (steel, stainless steel or cast iron) or from the steel production process (calamine: oxide layer on steel), they are all assimilated to steel for the calculation. This is considered relatively fair since the end products production derived from iron involves very similar energy-intensive processes.

For the case of the aggregates, the EPA *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)* [8] study is used. The methodology employed in this study leads to diverse data such as energy consumed or avoided for different waste management options for many materials and other data such as emissions related to those options and those materials. The emissions are calculated from the energy consumed or avoided and lead to an aggregated emission factor. The aggregated factor is reverse engineered to picture which quantity of each GHG is emitted. This can be done because the overall GHG emissions amount stays the same and it is only possible in this case because of the simplicity of the processes related to recycling, manufacturing and transportation of aggregates that can all be assimilated to mobile or fixe equipments using diesel combustion engines. All aggregates are assimilated to asphalt concrete category because the composition is essentially the same, as per the document definition: "*Asphalt concrete is composed primarily of aggregate, which consists of hard, graduated fragments of sand, gravel, crushed stone, slag, rock dust or powder*" [9], the only difference will be the biding agent used in asphalt.

Further details on the data used are shown in section 4 and 5.

2.9. Aggregate GHG Emission Reductions and Removal Enhancements likely to occur from the GHG Project

A first report was done at the end of 2009 to report emissions for years 2003 to 2007. A second report was produced for the year 2014 and a third for year 2015. This is the fourth report for the project and it reports emissions for the year 2016.

We can assume that this is the second crediting period for the project. Since *Les Minéraux Harsco* is the only company to recycle those wastes and to market them in valuable and good quality products, a second crediting period of 10 years (ending in year 2023) is conceivable and seems adequate. The viability of the project will be revalidated at each report submitted.

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[7] *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks*, (2016).

[8] *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)*, (March 2015), Version 13.

[9] *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)*, (March 2015), Version 13. p. 1-10

Table 2.1: Expected and Achieved Emission Reductions (t CO2e)

Year	Expected Emission Reductions (t CO2e)	Achieved Emission Reductions (t CO2e)
2003	24000	108468
2004	142000	149467
2005	142000	124751
2006	142000	141145
2007	142000	154774
2014	142000	148565
2015	142000	180369
2016	142000	137879
2017	142000	
2018	142000	
2019	142000	
2020	142000	
2021	142000	
2022	142000	
2023	142000	
TOTAL	2012000	1145418

2.10. Identification of Risks

Major changes in the Quebec market for the slags and mining and metal industry residues could be problematic if the project scenario becomes a common way to deal with those wastes, the project would no longer be additional. A change in the regulation could also lead to the same problem if it becomes mandatory. Regulation and the Quebec market for those residues and co-products will be monitored for each report to make sure that the project is still additional.

Even if the study *Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions: 2005 Update study* is now a more than 10-year old document, the newest version of the *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)* still refer to that study. Moreover, the energy quantities required for the processes should remain equivalent for the same processes and the emission factors for the various energy sources used are those from the latest NIR to be able to be the most accurate.

Furthermore, the EPA document used for the methodology is completed by a tool and documentation which offer updated emission factors based on the latest studies and statistics. If this tool and its related documents are not being supported anymore and are no longer updated, the data for emission factors can be outdated and no longer usable. Another appropriate methodology would need to be found or to be developed for the calculation related to aggregates to pursue the GHG project. This is more a long-term risk since the data have been updated in March 2015 for both the tool (model)[10] and its documentation[11].

This emission reductions report was written according to ISO 14064-2 Specifications Requirements for quantification, monitoring and reporting of greenhouse gas emission reductions and removal enhancements assertions. In order to minimize risks, the methodology and GHG emission factors were selected based on their completeness and their international recognition.

2.11. Roles and Responsibilities

2.11.1 Project Proponent and Representative

<u>Les minéraux Harsco</u>

Philippe Bouchard
Directeur de site
1200 route des Aciéries
Contrecoeur, Québec
J0L 1C0
pbouchard@harsco.com

2.11.2 Monitoring and Data Collection

Les minéraux Harsco is responsible for the project implementation and data monitoring. Data are provided by Richard Provençal, in charge of the quality, the environment and technical support in the company.

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[10] *Waste Reduction Model (WARM)*, (March 2015). Internet link: http://www3.epa.gov/warm/index.html
[11] *Warm*, (March 2015), Version 13. Internet link: http://www3.epa.gov/warm/pdfs/WARM_Documentation.pdf

Les minéraux Harsco
Richard Provençal
Quality - Environment - Technical Support
1200 route des Aciéries
Contrecoeur, Québec
J0L 1C0
rprovencal@harsco.com

2.11.3 Quantification and reporting Responsible Entity

Eco-credit is a firm specialized in non-traditional corporate financing. An expertise has been developed in the quantification of GHG emissions. Services are offered for GHG inventory, GHG emissions reduction project implementation, GHG markets advising, regulatory requirements and much more.

Joséanne Bélanger-Gravel works as consultant of environment and climate change. She has a mechanical engineering degree from Université de Sherbrooke and EPF-École d'ingénieurs de Sceaux in France. She also completed an engineering master degree in renewable energies and a second master in environment with a specialization in sustainable development. She also developed a keen expertise on the carbon market and GHG reduction projects. She is responsible for GHG project planning and development and acts as team leader in this project.

Joséanne Bélanger-Gravel, B.Eng, M.A.Sc, M.Env.
Consultant - Energy, Environment & Climate change
joseanne.bg@gmail.com
438-275-7499

2.11.4 Authorized Project Contact

Yves Legault has the signing authority for Eco-credit. He is authorized by the project proponent to perform requests and administrative tasks regarding the project registration.

Yves Legault, BAA, C.Admn
VP and General Manager
Eco-credit
ylegault@eco-credit.ca
514-994-0009

2.12. Project eligibility under the GHG Program

The project is eligible under the GHG CleanProjects® Registry. It is implemented following the ISO 14064-2 guidelines and principles, is not attempted to be registered under another GHG program and does not create any other environmental credit.

2.13. Environmental Impact Assessment

There are limitations to the use of the wastes treated by *Les Minéraux Harsco* especially for aggregates. A valorization agreement exists between *Les Minéraux Harsco* and the government of Quebec to identify the specific uses for the aggregates. *Les Minéraux Harsco* complies with the local regulation.

The very nature of the project and of the company is to limit or diminish the impacts of the residues on the environment. Other than reducing GHG emissions, recycling those wastes provides a safer way to manage them since the treatment and conditioning help to extract the maximum of the metals in the wastes which means less metals oxides leakage in the environment. Ferrous oxides are already present in important quantities in nature so their impact is limited but non-ferrous oxides can be damaging for the environment. Other waste management methods such as combustion can be more damaging for the environment so recycling those residues is beneficial on many aspects for the environment not only for GHG emission reductions: less contaminants in general and less raw materials extraction as examples.

Moreover, the company is certified ISO14001:2004 which demonstrates its commitment to manage its environmental impacts.

2.14. Socio-Economic Impact Assessment

Les Minéraux Harsco helps the economic development of the region of Sorel and represents well its values related to sustainable development by merging economic development and environmental protection. *Les minéraux Harsco* offers jobs to around 90 qualified employees and promote innovation and expertise to continue offering high quality products.

2.15. Stakeholder Consultations and Mechanism for on-going

Les *Minéraux Harsco* is responsible for the communications with the quantifier, the verifier and with all relevant stakeholders within and outside the company. The company has an open dialog with the city and presents the city and the government with all the required reports and documentation.

2.16. Detailed Chronological Plan

In the first crediting period, one report was done for years 2003 to 2007. The project start date was October 27th 2003. The project second crediting period started in 2014 and will end in 2023. A second report was produced for year 2014 and a third one for year 2015. GHG emission reductions are reported in this report for the year 2016. This is the fourth report.

Table 2.2: Chronological Plan

	Date	Steps in Process
Before Project Implementation	-	-
During Project	October 27th, 2003	Project start date
	2009	1st GHG report covering 2003-2007
	2015	2nd GHG report covering 2014
	2016	3rd GHG report covering 2015
	2017	4th GHG report covering 2015
After Project	-	-

2.17. Ownership

Matériaux Excell is the name under which Nova Scotia Company (3230907) operated in Quebec. Nova Scotia Company (3230907) has been constituted in 2005 from a fusion of Nova Scotia Company (3191285) and Harsco Metal Canada Inc. Since 2010, the company operates under the name *Les Minéraux Harsco* in Quebec. Legal documents can be produced if additional proof is necessary. *Les Minéraux Harsco* owns the subsequent credits.

3. SELECTION OF THE BASELINE SCENARIO AND ASSESSMENT OF ADDITIONALITY

The baseline scenario is selected among alternative scenarios representing what would have happened in the absence of this project. The alternative scenario that is most likely to occur is selected as the baseline scenario.

Scenarios identified are options normally used for waste management and that are included in the two main studies used as reference for this report[12,13]. Those waste management options normally include landfill, combustion, compost, and recycling and source reducing. In the case of reducing and recycling, the acquisition and manufacturing of the products are also taking into account and the production of the recycled product is compared to the one that would have happened otherwise which is the production of the end use product with virgin inputs or the current mix inputs (partially from virgin inputs and partially from recycled inputs) depending of the product and studies. The options for the baseline scenario can be summarized as the use of virgin inputs and one of the following waste management options:

Option 1: landfill

Option 2: combustion

Option 3: compost

Option 4: recycling or source reducing the co-products

The waste received by *Les minéraux Harsco* can be qualified in two categories of end use products once processed: metals and aggregates. With each of those products, a baseline scenario is associated in the case of recycling or source reducing.

Landfill can be a plausible scenario because the residues can be safely managed and no non-ferrous oxides can leak and damaged the environment. Aggregates can go to compost but if there is a possibility that the aggregates still contain a great amount of non ferrous oxides, it can be damaging for the environment. One composting site was accepting slags in Quebec but it is now closed as per the enterprise register of Quebec.[14] Combustion is not recommended because when metals are in a combustion chamber it takes all the heat and that diminishes the effect of the combustion process on other waste, resulting in waste not being fully combusted. Furthermore, the ashes will contain a high level of metals which can be toxic for the environment and cannot be used for any purposes, therefore combustion for those kinds of waste is not recommended. Recycling is the other option left besides landfilling, more metal is extracted from the slags and the residues are used mostly as aggregates for mainly construction purposes.

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[12] *Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions: 2005 Update*, (October, 2005).

[13] *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)*, (March 2015), Version 13.

[14] Recyc-Québec. *Guide sur la collecte et le compostage des matières organiques du secteur municipal: Document technique*. (2006). Internet link: http://www.recyc-quebec.gouv.qc.ca/upload/publications/MICI/GuideCollCompostMatOrgMun.pdf

Table 3.1: Barrier Assessment

Potential Barrier	Baseline Landfilling	Project Scenario Recycling	Other Scenario Compost	Other Scenario Combustion
Law and regulation	Not a barrier	**Barrier** Specific agreement needs to be made with the government of Quebec.	**Barrier** Compost needs to meet specific standards.	Not a barrier
Financial	Not a barrier	**Barrier** Manufacturing of recycled products needs equipments which lead to substantial investments.	Not a barrier	Not a barrier
Technology/ feasibility	Not a barrier	**Barrier** Manufacturing of recycled products needs research and development to stay competitive with products manufactured by virgin inputs.	Not a barrier	**Barrier** Not recommended since it affect the combustion of other waste in the combustion chamber.
Common practice	Not a barrier	**Barrier** A very few companies are specialized in the waste management of those waste. Most companies recuperated and recycled metals from scraped metals not from slags and other mining and metals industry waste.	**Barrier** Not often chosen because it can affect the quality of the compost.	**Barrier** Not a recommended option.

For the assessment of additionality of the project scenario, a barrier analysis has been performed.

The compost and combustion options have barriers since the waste recuperated by *Les minéraux Harsco* can alter the process or the product of those waste management options and those situations are not wanted. Those options are ruled out.

Sending the recuperated waste to landfill is the usual option and presents no barrier to his implementation, therefore this option is the baseline scenario.

The recycling option is chosen as the project scenario and it has a few barriers. Concerning the law and regulation barrier, the use of the aggregates made from the recuperated waste is regulated and a specific agreement with the government of Quebec is needed to define uses allowed for those waste. The financial barrier is important. The equipments required to process the recuperated waste necessitate substantial investments and are more complex than those used in landfill or for compost. Those equipments also need regular maintenance and repair, and specific training for the employees. The quantities treated and involved are important and need a site with an important size to accommodate the materials and equipments. Discussing the technology / feasibility barrier, specific knowledge, equipments and research and development is needed to keep the recycled products valuable products on the market to compete the products made from virgin inputs.

A company such as *Les minéraux Harsco* cannot be improvised since the project of recycling need important planning regarding law and regulation, specific know-how (employees, R&D, maintenance and repair, etc.) and substantial financial resources (site, equipments, repair, etc.) to process those waste. Furthermore, this is the only company in Canada processing this kind of waste and one of the few internationally.

4. IDENTIFICATION AND SELECTION OF GHG SOURCES, SINKS AND RESERVOIRS

The SSRs for the baseline and the project scenarios are identified in the table below which also indicates whether they are included or excluded from the quantification and whether they are controlled, related, or affected. Since the calculations used 2 different studies based on the end use products: metals and aggregates, the SSRs for the baseline and project scenarios will be presented separately for both products. Even if the two reference studies have a very similar approach, they both advice to use the data presented in the study for both the project and baseline scenarios, so not to use them separately. The goal is to obtain more accurate and consistent results. The first case to be studied is the metal portion of the waste. In the second case, the remaining of the waste is studied: aggregates and ultimate waste.

In the first case, the "*Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks*"[15] has been chosen because the methodology is well described and the selection of GHG sources, sinks, and reservoirs accounted for in the data presented for the quantification is well described as well. Furthermore, the material, steel, is considered and analysed in that study. All the metals recuperated is associated to the category of the study named steel. This hypothesis has been made since steel is the most important metals to be treated in quantity by the company and all the metals are related pricewise to the one of steel. The exhibit 2-1 of the study (see next image) presents the SSRs included and the philosophy behind the methodology for the calculations for all the management options and all the materials included in that study. First, the SSRs for the process for raw materials acquisition and manufacturing/fabrication are considered, then the carbon change in the forest or soil carbon sink is taken into account and finally the GHG emissions directly related to the waste management option are accounted for.

[15] *SOLID WASTE MANAGEMENT AND GREENHOUSE GASES: A Life-Cycle Assessment of Emissions and Sinks*, (September 2006), 3rd edition.

Exhibit 2-1. Components of Net Emissions for Various Waste Management Options

Solid Waste Management Strategy	GHG Sources and Sinks		
	Process GHGs from Raw Materials Acquisition and Manufacturing/Fabrication	*Change in Forest or Soil Carbon Sink*	*Waste Management GHG Emissions and Sinks*
Recycling	Decrease in GHG emissions due to lower energy requirements (compared to manufacture/fabrication from virgin inputs) and avoided process non-energy GHGs	Increase in forest carbon sink associated with forest products	Process emissions are counted in the manufacturing stage
Aerobic Composting	No emissions/sinks*	Possible increase in soil carbon after application of compost	Compost machinery emissions
Anaerobic Digestion	Baseline process emissions due to manufacture/fabrication from the current mix of virgin and recycled inputs	Possible increase in soil carbon after application of compost	Avoided utility emissions, no CH_4 emissions (because capture efficiency is assumed to be 100%)
Combustion	Baseline process emissions due to manufacture/fabrication from the current mix of virgin and recycled inputs	No change	Nonbiogenic CO_2, N_2O emissions, avoided utility emissions
Landfilling	Baseline process emissions due to manufacture/fabrication from the current mix of virgin and recycled inputs	No change	CH_4 emissions, long-term carbon sink, avoided utility emissions (in cases where CH_4 is recovered for energy)

* No manufacturing GHG emissions are considered for composting of food scraps and yard trimmings because these materials are not considered to be manufactured.

The specific SSRs analysed for the particular case of steel are presented in the next two tables for the baseline scenario and for the project scenario. GHG accounted for are CO2, CH4 and N2O since emissions are mostly related to fuel combustion. Those are also the GHG taken into account in the reference study for the combustion of fuel. PFC, HFC and SF6 are not included in the quantification.

Table 4.1: SSR's Baseline Scenario Inventory for Steel - Virgin Production of Steel

SSR - Baseline	Included / Excluded	Controlled/ Related / Affected	GHG	Explanation
Raw Materials Acquisition Process	Included	Affected	CO_2 CH_4 N_2O	---
Manufacturing Process - Energy	Included	Affected	CO_2 CH_4 N_2O	---
Manufacturing Process - Non-Energy	Excluded	---	---	The GHG emissions come from essentially the large amount of fuel combusted to provide the energy needed in the process. Not including the manufacturing process for non-energy related processes is conservative. The GHG emissions would be much higher in the case of the baseline scenario than for the case of the project scenario, therefore the GHG emissions are not overestimated.
Transportation	Included	Affected	CO_2 CH_4 N_2O	Transportation accounts for GHG emissions related to transport for each steps: raw materials acquisition, manufacturing, and transportation to end use with an average of 426km for the last one.

Table 4.2: SSR's Project Inventory for Steel - Recycled Production of Steel

SSR - Project	Included / Excluded	Controlled/ Related / Affected	GHG	Explanation
Raw Materials Acquisition Process	Included	Related	CO_2 CH_4 N_2O	The raw materials acquisition for recycled production is considered as the processes required to separate metals or steel from other products.
Manufacturing Process - Energy	Included	Controlled	CO_2 CH_4 N_2O	Those are the GHG emissions related to the manufacturing of the recycled inputs into the final product.
Manufacturing Process - Non-Energy	Excluded	---	---	The GHG emissions come from essentially the large amount of fuel combusted to provide the energy needed in the process especially for the recycled inputs.
Transportation	Included	Related	CO_2 CH_4 N_2O	Transportation accounts for GHG emissions related to transport for each steps: raw materials acquisition, manufacturing, and transportation to end use with an average of 426km for the last one.

In the second case, the "*Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)*"[16] has been chosen for the same reason as the previous one and because the type of materials is well analysed and presented in that study. The aggregates and ultimate waste is associated to the category of asphalt concrete in the study since their constitution is roughly the same (asphalt concrete is made of 94.8% of aggregates) [17] and the end use of aggregates is for the construction of roads, therefore most probably used as asphalt. Moreover the processes and equipments involved are highly similar.

The study presents at Exhibit 10-2 the sources and sinks considered in the model specifically for the category of asphalt concrete.

[16] *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)*, (March 2015), Version 13.
[17] Idem. p.10-3

Exhibit 10-2: Asphalt Concrete GHG Sources and Sinks from Relevant Materials Management Pathways

Materials Management Strategies for Asphalt Concrete	GHG Sources and Sinks Relevant to Asphalt Concrete		
	Raw Materials Acquisition and Manufacturing	Changes in Forest or Soil Carbon Storage	End of Life
Source Reduction	**Offsets** • Avoided process energy emissions, including aggregate production, asphalt binder production, combination of asphalt and binder • Avoided transportation for production of virgin crude oil • Avoided transportation of asphalt concrete materials to roadway project	NA	NA
Recycling	**Offsets** • Avoided virgin material extraction • Avoided process energy for aggregate and asphalt binder production • Avoided virgin material transport (especially crude oil)	NA	**Emissions** • Extraction/recovery • Transport to mixing plant • Crushing and remixing of asphalt concrete
Composting	Not applicable because asphalt concrete cannot be composted		
Combustion	Not modeled in WARM		
Landfilling	NA	NA	**Emissions** • Transport to construction and demolition landfill • Landfilling machinery

GHG accounted for are CO2, CH4 and N2O since emissions are related to fuel combustion. Those are also the GHG taken into account in the reference study for the combustion of fuel. PFC, HFC and SF6 are not included in the quantification.

In the specific case of the project scenario of this report, the entire amount of material received is recycled; therefore there is no ultimate waste sent to landfill. The remaining material is classified, stored and, kept to be used another year. Since there is transportation and the use of machinery on site to place the remaining material, the storage operation is considered highly similar to the operations of landfilling described in the above-mentioned study.

Table 4.3: SSR's Baseline Scenario Inventory for Aggregates - Virgin Inputs

SSR - Baseline	Included / Excluded	Controlled/ Related / Affected	GHG	Explanation
Virgin inputs process	Excluded from baseline	---	---	The study prescribes to account for GHG emissions avoided in the project scenario for recycling instead of putting those emissions in the baseline scenario. This is what has been done in this report to be consistent with the approach and methodology describes in the reference study.
Virgin inputs transportation	Excluded from baseline	---	---	
Landfill - transportation	Included	Related	CO_2 CH_4 N_2O	The GHG emissions for fuel combustion are included.
Landfill - operating equipment	Included	Related	CO_2 CH_4 N_2O	The GHG emissions related to operating equipment are included/studied but no GHG emission is emitted for the landfill of asphalt concrete according to the study.

Table 4.4: SSR's Project Inventory for Aggregates - Recycled Inputs

SSR - Project	Included / Excluded	Controlled/ Related / Affected	GHG	Explanation
Avoided virgin inputs process	Included	Affected	CO_2 CH_4 N_2O	The study prescribes to account for GHG emissions avoided in the project scenario for recycling instead of putting those emissions in the baseline scenario, therefore those emissions have a negative value.
Avoided virgin inputs transportation	Included	Affected	CO_2 CH_4 N_2O	
Recycled inputs manufacturing	Included	Controlled	CO_2 CH_4 N_2O	All GHG emissions related to operations related to recycled inputs acquisition and the manufacturing are calculated here.
Landfill - transportation (or storage operations)	Included	Related	CO_2 CH_4 N_2O	The GHG emissions for fuel combustion are included.
Landfill - operating equipment (or storage operations)	Included	Related	CO_2 CH_4 N_2O	The GHG emissions related to operating equipment are included/studied but no GHG emission is emitted for the landfill of asphalt concrete according to the study.

5. QUANTIFICATION OF GHG EMISSIONS AND REMOVALS

As it was done for the identification and selection of SSRs, two studies are used as reference and those studies are also the reference for the methodology for the calculations and they will be further described in this section. Like it was done in the previous section, the metal portion and the remaining of the waste (non metal portion) are studied separately.

5.1. Baseline and Project GHG Emissions for Steel

For the metal portion the methodology explained in this study is used: *"SOLID WASTE MANAGEMENT AND GREENHOUSE GASES: A Life-Cycle Assessment of Emissions and Sinks"*[18]. In the above mentioned document, emission factors and energy factors are elaborated from national studies and renowned expert studies. The study presents an aggregated emission factor which account for energy, transportation and non-energy processes. Since the standard requires a non-aggregated factor, the disaggregated energy factor is used. This is deemed to be conservative because it doesn't account for the non-energy process emissions. In that case, emissions come mostly from energy processes. Furthermore, the baseline scenario would have more process non-energy emissions than the project therefore the GHG emissions are not overestimated.

The energy factor account for energy used for raw materials acquisition, manufacturing and transportation and the energy embedded in materials that are consumed during the manufacturing processes. The disaggregated energy factor is presented per categories (raw materials acquisition, manufacturing, and transportation) and per type of materials or energy types (electricity, coal, natural gas, diesel, LPG, residual fuel, gasoline, oil/lubricant, and petroleum). In the case of the metal portion of the waste, the category related to is steel. In the study for the steel category, no LPG, residual fuel and oil/lubricant is accounted for. The petroleum is not included since it is normally used / consumed for electrodes in the manufacturing process, not combusted.

To be able to have non aggregated emission factors, the energy factors par energy types (GJ/metric tonne) are used[19] and converted in the unit appropriate for each type of energy per metric tonne using the RDOCECA[20] higher heating value (HHV). It is done for both scenarios: baseline (virgin inputs) and project (recycled inputs).

EnFelec = EnFGJelec * CF

EnFelec = Energy factor of electricity (kWh / tonne of steel)

EnFGJelec = Energy factor of electricity (GJ / tonne of steel)

CF = conversion factor for unit conversion

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[18] *SOLID WASTE MANAGEMENT AND GREENHOUSE GASES: A Life-Cycle Assessment of Emissions and Sinks*, (September 2006), 3rd edition.

[19] Idem pp. 127-128

[20] *Règlement sur la déclaration obligatoire de certaines émissions de contaminants dans l'atmosphère*, (Mars 2016). Tableau 1-1. Internet link: http://www.mddelcc.gouv.qc.ca/air/declar_contaminants/RDOCECA.pdf

EnFcoal = EnFGJcoal / HHVcoal * CF

EnFcoal = Energy factor (tonne of coal / tonne of steel)

EnFGJcoal = Energy factors (GJ / tonne of steel)

HHVcoal = Higher heating value (GJ / tonne)

CF = conversion factor for unit conversion

EnFng = EnFGJng / HHVng * CF

EnFng = Energy factor of natural gas (m3 / tonne of steel)

EnFGJng = Energy factor of natural gas (GJ / tonne of steel)

HHVng = Higher heating value of natural gas (m3 / GJ)

CF = conversion factor for unit conversion

EnFdiesel = EnFGJdiesel / HHVdiesel * CF

EnFdiesel = Energy factor of diesel (L / tonne of steel)

EnFGJdiesel = Energy factor of diesel (GJ / tonne of steel)

HHVdiesel = Higher heating value of diesel (GJ / kL)

CF = conversion factor for unit conversion

EnFoil = EnFGJoil / HHVoil * CF

EnFoil = Energy factor of light fuel oil (L / tonne of steel)

EnFGJoil = Energy factor of light fuel oil (GJ / tonne of steel)

HHVoil = Higher heating value of light fuel oil (GJ / kL)

CF = conversion factor for unit conversion

EnFgas = EnFGJgas/ HHVgas * CF

EnFgas = Energy factor of diesel (L / tonne of steel)

EnFGJgas = Energy factor of diesel (GJ / tonne of steel)

HHVgas = Higher heating value of diesel (GJ / kL)

CF = conversion factor for unit conversion

Then the quantities are calculated for the energy use for each type of energy using the quantity of steel recycled and the above calculated energy factor for both cases: baseline scenario and project scenario. In each scenario, the emissions are calculated for each category: raw materials acquisition, manufacturing, and transportation.

$$Eelec = Qsteel * EnFelec * (EFelec,co2+EFelec,ch4*GWPch4+EFelec,n2o*GWPn2o) * 0.000\ 001$$

Eelec = Emissions related to electricity consumption (tCO_2e)

Qsteel = Quantity of steel recycled (metric tonne)

EFelec,co2, EFelec,ch4, EFelec,n2o = Emission factors for CO_2, CH_4 and N_2O emissions related to electricity consumption (g/kWh)

$$Ecoal = Qsteel * EnFocal * (EFcoal,co2+ EFcoal,ch4* GWPch4 + EFcoal,n2o * GWPn2o) * 0.001$$

Ecoal = Emissions related to coal consumption (tCO_2e)

Qsteel = Quantity of steel recycled (metric tonne)

EFcoal,co2 = Emission factors for CO_2 emissions related to electricity consumption (kg/ tonne of coal)

EFcoal,ch4, EFcoal,n2o = Emission factors for CH_4 and N_2O emissions related to coal consumption (g/kg)

$$Eng = Qsteel * EnFng * (EFng,co2 + EFng,ch4 * GWPch4 + EFng,n2o * GWPn2o) * 0.000\ 001$$

Eng = Emissions related to natural gas consumption (tCO_2e)

Qsteel = Quantity of steel recycled (metric tonne)

EFng,co2, EFng,ch4, EFng,n2o = Emission factors for CO_2, CH_4 and N_2O emissions related to natural gas consumption (g/m3)

$$Ediesel = Qsteel * EnFdiesel * (EFdiesel,co2+EFdiesel,ch4*GWPch4+EFdiesel,n2o* GWPn2o) * 0.000\ 001$$

Ediesel = Emissions related to diesel consumption (tCO_2e)

Qsteel = Quantity of steel recycled (metric tonne)

EFdiesel,co2, EFdiesel,ch4, EFdiesel,n2o = Emission factors for CO_2, CH_4 and N_2O emissions related to diesel consumption (g/L)

$$Eoil = Qsteel * EnFoil* (EFoil,co2+EFoil,ch4*GWPch4+EFoil,n2o* GWPn2o) * 0.000\ 001$$

Ediesel = Emissions related to light fuel oil consumption (tCO_2e)

Qsteel = Quantity of steel recycled (metric tonne)

EFoil,co2, EFoil,ch4, EFoil,n2o = Emission factors for CO_2, CH_4 and N_2O emissions related to light fuel oil consumption (g/L)

$$Egas = Qsteel * EnFgas * (EFgas,co2+EFgas,ch4 *GWPch4 + EFgas,n2o * GWPn2o) * 0.000\ 001$$

Egas = Emissions related to gasoline consumption (tCO_2e)

Qsteel = Quantity of steel recycled (metric tonne)

EFgas,co2, EFgas,ch4, EFgas,n2o = Emission factors for CO_2, CH_4 and N_2O emissions related to gasoline consumption (g/m3)

5.2. Emission Reductions for Steel

ERsteel = BEsteel - PEsteel

ERsteel = Emissions reductions related to steel recycling for year y (tCO_2e)

BEsteel = Baseline scenario emissions for year y (tCO_2e)

PEsteel = Project scenario emissions for year y (tCO_2e)

BEsteel = BRAM + BM + BT

BRAM = Baseline emissions for raw materials acquisition for year y (tCO_2e)

BM = Baseline emissions for manufacturing for year y (tCO_2e)

BT = Baseline emissions for transportation for year y (tCO_2e)

PEsteel = PRAM + PM + PT

PRAM = Baseline emissions for raw materials acquisition for year y (tCO_2e)

PM = Baseline emissions for manufacturing for year y (tCO_2e)

PT = Baseline emissions for transportation for year y (tCO_2e)

BRAM = Eelec + Ecoal + Eng + Ediesel + Egas

BRAM = sum of the emissions related to energy consumption for the raw materials acquisition (tCO_2e)

The same operation is done for BM, BT, PRAM, PM, and PT.

5.3. Baseline and Project GHG Emissions for Aggregates

For the non-metal portion of the waste, the methodology explained in this study is used: "*Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)*"[21]. In the above mentioned document, emission factors and energy factors are elaborated from national studies and renowned expert studies. The study presents an aggregated emission factor which account for energy, transportation and non-energy processes. The project scenario is associated with the recycling case which is in the study: asphalt concrete recycled in a type of asphalt concrete or aggregate. This case is very similar to the project scenario. The way the methodology is done, the baseline is the case where all the non-metal waste goes to the landfill and for the project scenario, a part of the waste (ultimate waste) is still going to the landfill and a part is recycled into aggregates. The suggested methodology of calculation developed in the study is used, therefore the recycled part of the waste leads to input credit (negative value) because it is assumed that the recycled material avoids or offsets the GHG emissions associated with the producing of the aggregates from virgin inputs.

[21] *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)*, (March 2015), Version 13.

Since the standard requires a non-aggregated factor, the detailed information on how the aggregated factor is calculated is used to calculate emissions for each gas: CO2, CH4 and N2O. This is deemed to be appropriate because the processes involved are simple and can be related to mobile or fixed combustion of diesel:

- Landfill operations are done by mobile equipment therefore the data for diesel combustion is used.
- As per the explanation done in the study, the virgin inputs process and transportation are related to mobile equipment; therefore the data of diesel combustion is also used.
- Recycled production is related to mostly fixed equipment; therefore the data of oil combustion is used.
- Transportation of recycled production is related to mobile equipment; therefore the data of diesel combustion is used.

As explained in the previous section, CO2, CH4 and N2O are calculated in the quantification for both baseline and project emissions.

BASELINE EMISSIONS

BEagg = BElandfill

BEagg = Baseline scenario total emissions resulting from the baseline scenario in year y (tCO2e)

BElandfill = BCdiesel * (EFdiesel,co2 + EFdiesel,ch4 * GWPch4 + EFdiesel,n2o * GWPn2o) * 0.000 001

BElandfill = Baseline scenario total emissions resulting from the baseline scenario: landfill in year y (tCO2e)

BCdiesel = Baseline scenario diesel consumption related to landfill option (L)

EFdiesel,co2, EFdiesel,ch4, EFdiesel,n2o = Emission factors for CO2, CH4 and N2O emissions related to diesel consumption (g/L)

BCdiesel = CFLdiesel * Qaw

CFLdiesel = Consumption factor of diesel for landfill option (L/ metric tonne of material)

Qaw = Quantity of aggregates and ultimate waste (metric tonne)

Qaw = QT - Qsteel

QT = Total quantity of material recuperated (metric tonne)

Qsteel= Quantity of steel recycled (metric tonne)

CFLdiesel = AEFlandfill,m / (AEFdiesel/1000/1000)

AEFlandfill,m = Aggregated emission factor for landfill option (tCO2e / metric tonne of material)

AEFdiesel = Aggregated emission factor for diesel consumption (g/L)

AEFlandfill,m = AEFlandfill,s / 0.90718474

AEFlandfill,s= Aggregated emission factor for landfill option (tCO2e / short ton of material)

0.90718474 = Conversion factor (metric tonne / short ton)

AEFdiesel = EFdiesel,co2 + EFdiesel,ch4 * GWPch4 + EFdiesel,n2o * GWPn2o

EFdiesel,co2, EFdiesel,ch4, EFdiesel,n2o = Emission factors for CO2, CH4 and N2O emissions related to diesel consumption (g/L)

PROJECT EMISSIONS

PEagg = PEvip + PEvit + PErp+ PEstorage

PEagg = Project scenario total emissions resulting from the project scenario in year y (tCO2e)

PEvip = Project scenario credit resulting from avoided virgin inputs process in year y (tCO2e)

PEvit = Project scenario credit resulting from avoided virgin inputs transportation in year y (tCO2e)

PErp = Project scenario emissions resulting recycling production in year y (tCO2e)

PEstorage = Project scenario emissions resulting from ultimate waste sent to landfill (tCO2e)

PEvip = VIPCdiesel * (EFdiesel,co2 + EFdiesel,ch4 * GWPch4 + EFdiesel,n2o * GWPn2o) * 0.000 001

VIPCdiesel = Diesel consumption for virgin inputs process (L)

VIPCdiesel = VIPCFdiesel * Qagg

VIPCFdiesel = Consumption factor of diesel for virgin inputs process (L/ metric tonne of material)

Qagg = Quantity of aggregates (metric tonne)

VIPCFdiesel = AEFvip,m / (AEFdiesel/1000/1000)

AEFvip,m = Aggregated emission factor for virgin inputs process (tCO2e / metric tonne of material)

AEFvip,m = AEFvip,s / 0.90718474

AEFvip,s= Aggregated emission factor for virgin inputs process (tCO2e / short ton of material)

0.90718474 = Conversion factor (metric tonne / short ton)

PEvit = VITCdiesel * (EFdiesel,co2 + EFdiesel,ch4 * GWPch4 + EFdiesel,n2o * GWPn2o) * 0.000 001

VITCdiesel = Diesel consumption for virgin inputs transportation (L)

VITCdiesel = VITCFdiesel * Qagg

VIPCFdiesel = Consumption factor of diesel for virgin inputs transportation (L/ metric tonne of material)

VITCFdiesel = AEFvit,m / (AEFdiesel/1000/1000)

AEFvit,m = Aggregated emission factor for virgin inputs transportation (tCO2e / metric tonne of material)

AEFvit,m = AEFvit,s / 0.90718474

AEFvit,s = Aggregated emission factor for virgin inputs transportation (tCO2e / short ton of material)

0.90718474 = Conversion factor (metric tonne / short ton)

PErp = RPCoil * (EFoil,co2 + EFoil,ch4 * GWPch4 + EFoill,n2o * GWPn2o) * 0.000 001

RPCoil = Oil consumption related to recycling production (L)

EFoil,co2, EFoil,ch4, EFoil,n2o = Emission factors for CO2, CH4 and N2O emissions related to oil consumption (g/L)

RPCoil = RPCFoil * Qagg

RPCFoil = Consumption factor of oil for recycling process (L/ metric tonne of material)

RPCFoil = AEFrp,m / (AEFoil/1000/1000)

AEFrp,m = Aggregated emission factor for recycling process (tCO2e / metric tonne of material)

AEFrp,m = AEFrp,s / 0.90718474

AEFrp,s= Aggregated emission factor for recycling process (tCO2e / short ton of material)

0.90718474 = Conversion factor (metric tonne / short ton)

AEFoil = EFoil,co2 + EFoil,ch4 * GWPch4 + EFoil,n2o * GWPn2o

EFoil,co2, EFoil,ch4, EFoil,n2o = Emission factors for CO2, CH4 and N2O emissions related to oil consumption (g/L)

PEstorage = PCdiesel * (EFdiesel,co2 + EFdiesel,ch4 * GWPch4 + EFdiesel,n2o * GWPn2o) * 0.000 001

PCdiesel = Project scenario diesel consumption related ultimate waste going to landfill (L)

PCdiesel = CFLdiesel * Quw

CFLdiesel = Consumption factor of diesel for landfill option (L/ metric tonne of material)

Quw = Quantity of ultimate waste (metric tonne)

Quw = QT - Qsteel - Qagg

5.4. Emission Reductions for Aggregates

ERagg = BEagg - PEagg

ERagg = Emissions reductions related to aggregates recycling for year y (tCO2e)

5.5. Total Emission Reductions

TER = ERsteel + ERagg

TER = Total emissions reductions for year y (tCO2e)

5.6. Emission Factors and other Parameters

Table 5.1: Emission Factors Summary for Fuel Combustion

Factor	Gas	Value	Unit	Source
EFelec	CO2	2.1	g/kWh	National Inventory Report 1990-2014, Greenhouse Gas Sources and Sinks in Canada, Part 3, Table A13-6, p.93
	CH4	0.0002	g/kWh	
	N2O	0.0001	g/kWh	
EFcoal	CO2	2626	kg/tonne	National Inventory Report 1990-2014, Greenhouse Gas Sources and Sinks in Canada, Part 2, table A6-8 p.196
	CH4	0.03	g/kg	National Inventory Report 1990-2014, Greenhouse Gas Sources and Sinks in Canada, Part 2, table A6-9 p.196
	N2O	0.02	g/kg	
EFng	CO2	1887	g/m^3	National Inventory Report 1990-2014, Greenhouse Gas Sources and Sinks in Canada, Part 2, table A6-1, table A6-2 p.193
	CH4	0.037	g/m^3	
	N2O	0.033	g/m^3	
EFdiesel	CO2	2690	g/L	National Inventory Report 1990-2014, Greenhouse Gas Sources and Sinks in Canada, Part 2, table A6-12 p.198
	CH4	0.14	g/L	
	N2O	0.082	g/L	
EFgas	CO2	2316	g/L	National Inventory Report 1990-2014, Greenhouse Gas Sources and Sinks in Canada, Part 2, table A6-4 p.194
	CH4	0.068	g/L	National Inventory Report 1990-2014, Greenhouse Gas Sources and Sinks in Canada, Part 2, table A6-12 p.198
	N2O	0.02	g/L	National Inventory Report 1990-2014, Greenhouse Gas Sources and Sinks in Canada, Part 2, table A6-4 p.194
EFoil	CO2	2753	g/L	National Inventory Report 1990-2014, Greenhouse Gas Sources and Sinks in Canada, Part 2, table A6-4 p.194
	CH4	0.006	g/L	
	N2O	0.031	g/L	

Table 5.2: Primary Energy Factors for Steel for Virgin Inputs Summary (GJ/tonne)

	Electricity (EnFelec)	**Coal (EnFcoal)**	**Natural Gas (EnFng)**	**Diesel (EnFdiesel)**	**Gasoline (EnFgas)**
Raw Material Acquisition	0.7	0	0.7	0.8	0.003
Manufacturing	0.4	15.6	5.5	0	0
Transportation	0	0	0	0.6	0

Source: *SOLID WASTE MANAGEMENT AND GREENHOUSE GASES: A Life-Cycle Assessment of Emissions and Sinks*, (September 2006), 3rd edition, p. 127, Exhibit B-13. Internet link: http://www.rcbc.ca/files/u3/ICF-final-report.pdf

Table 5.3: Primary Energy Factors for Steel for Recycled Inputs Summary (GJ/tonne)

	Electricity (EnFelec)	**Coal (EnFcoal)**	**Natural Gas (EnFng)**	**Diesel (EnFdiesel)**	**Gasoline (EnFgas)**
Raw Material Acquisition	0.01	0	0	0	0
Manufacturing	3.7	0	5.5	0	0
Transportation	0	0	0	0.4	0

Source: *SOLID WASTE MANAGEMENT AND GREENHOUSE GASES: A Life-Cycle Assessment of Emissions and Sinks*, (September 2006), 3rd edition, p. 128, Exhibit B-14. Internet link: http://www.rcbc.ca/files/u3/ICF-final-report.pdf

Table 5.4: Parameters Summary

Parameter	Value	Unit	Source
GWP CH4	25	tCO2e / tCH4	https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html, table-2-14
GWP N2O	298	tCO2e / tN2O	http://www.ghgprotocol.org/files/ghgp/tools/Global-Warming-Potential-Values.pdf
Conversion factor metric / short ton	0.90718474	metric tonne / short ton	http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf
Conversion factor MJ / kWh	3.6	MJ / kWh	ISO System Unit : http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf
HHVdiesel	38.3	GJ / kL	*Règlement sur la déclaration obligatoire de certaines émissions de contaminants dans l'atmosphère*, (June 2016). Tableau 1-1. Internet link: http://www.mddelcc.gouv.qc.ca/air/declar_contaminants/RDOCECA.pdf
HHVgas	34.87	GJ / kL	
HHVoil	38.78	GJ / kL	
HHVcoal	29.82	GJ / tonne	
HHVng	38.32	GJ / m3	

6. DATA MONITORING AND CONTROL

6.1. Data Management and Backups

A data acquisition system is in place and directly linked to the plant scale. The scale is checked every quarter. Equipments in place have a long lifespan but regular maintenance and repair are done as well as equipment improvement. The company integrates a continuous improvement approach concerning its equipments so they are always in good working conditions.

The accounting system is managed by the software Oracle. A daily backup is done and data are linked with the main company in United States where the backups are managed.

6.2. Data Control and Procedures

Data from the scale are validated with the accounting system and there is a verification done on site with a loader to corroborate the data from the scale. Verifications are done to check if all the data (scale, loader, and accounting system) are consistent.

Table 6.1: Data Monitoring Summary

Data/ Parameters	Value	Units	Measurement method; Source of data to be used	QA/QC procedures
QT	538636.96	metric tonne	scale; data from the automated system linked with the scale	validated with on site loader and verification done with the accounting system
Qsteel	51148.1530384875	metric tonne	(scale); data used is the sum of the sales for metals	
Qagg	482896.694604	metric tonne	(scale); data used is the sum of aggregates sold	

7. REPORTING AND VERIFICATION DETAILS

The project plan and report is prepared in accordance with ISO 14064-2 standard and the GHG CleanProjects® Registry requirements. The methodology that is used, the choice of region specific emission factors and a rigorous monitoring plan allow for a reasonably low level of uncertainty. Eco-credit is confident that the emission reductions are not overestimated and that the numbers of emission reductions that are reported here are real and reflect the actual impacts of the project.

Emission reductions will be verified by an independent third party to a reasonable level of assurance in accordance with ISO 14064-3 standard and the GHG CleanProjects® Registry requirements. Emission reductions are reported here for year 2016, the first year of this second crediting period is also shown. Calculation examples are presented in Appendix I and emissions are detailed in Appendix II.

Table 7.1: Baseline Scenario GHG Emissions for Steel for 2014, 2015 and 2016 by Sources and Total (t CO2e)

	Raw Materials Acquisition (BRAM)				Manufacturing (BM)					Transportation (BT)			Baseline - Steel (BEsteel)			
Year	CO2	CH4	N2O	Sub-total	CO2	CH4	N2O	Sub-total	CO2	CH4	N2O	Sub-total	CO2	CH4	N2O	TOTAL
2014	3672	0	12	3684	86848	24	197	87069	2663	3	24	2690	93183	27	233	93443
2015	4696	0	15	4711	112457	32	255	112744	3448	4	31	3483	12601	36	301	120938
2016	2935	0	9	2944	70289	20	159	70468	2155	2	19	2179	75379	22	187	75588

Table 7.2: Baseline Scenario GHG Emissions for Aggregates for 2014, 2015 and 2016 by Sources and Total (t CO_2e)

	Landfill (BElandfill)				Baseline - Aggregates (BEagg)			
Year	CO2	CH4	N2O	Sub-total	CO2	CH4	N2O	TOTAL
2014	30959	40	281	31280	30959	40	281	31280
2015	26701	34	242	26977	26701	34	242	26977
2016	21273	27	193	21493	21273	27	193	21493

Table 7.3: Project Scenario GHG Emissions for Steel for 2014, 2015 and 2016 by Sources and Total (t CO2e)

	Raw material acquisition (PRAM)				Manufacturing (PM)				Transportation (PT)				Project - Steel (PEsteel)			
Year	CO2	CH4	N2O	Sub-total	CO2	CH4	N2O	Sub-total	CO2	CH4	N2O	Sub-total	CO2	CH4	N2O	TOTAL
2014	1	1	1	3	148	2	2	152	1776	3	17	1796	1925	6	20	1951
2015	1	1	1	3	192	2	2	196	2299	3	21	2323	2492	6	24	2522
2016	1	1	1	3	125	2	2	129	1437	2	14	1453	1563	5	17	1585

Table 7.4: Project Scenario GHG Emissions for Aggregates for 2014, 2015 and 2016 by Sources (t CO_2e)

Year	Virgin Inputs Process (PEvip)				Virgin Inputs Transportation (PEvit)				Recycling Process (PErp)				Landfill (PEstorage)			
	CO2	CH4	N2O	Sub-total	CO2	CH4	N2O	Sub-total	CO2	CH4	N2O	Sub-total	CO2	CH4	N2O	Sub-total
2014	-28244	-37	-257	-28538	-23537	-31	-214	-23782	14221	1	48	14270	12130	16	111	12257
2015	-30659	-40	-279	-30978	-25549	-34	-233	-25816	15436	1	52	15489	6263	9	57	6329
2016	-31610	-42	-288	-31940	-26342	-35	-240	-26617	15915	1	54	15970	201	1	2	15970

Table 7.5: Project Scenario GHG Emissions for Aggregates for 2014, 2015 and 2016 TOTAL (t CO_2e)

Year	Project - Aggregates (PEagg)			
	CO2	CH4	N2O	TOTAL
2014	-25430	-51	-312	-25793
2015	-34509	-64	-403	-34976
2016	-41836	-75	-472	-42383

Table 7.6: GHG Emission Reductions for Steel for 2014, 2015 and 2016 (t CO_2e)

	ERsteel - TOTAL			
	CO2	CH4	N2O	TOTAL
Year	t CO2e	t CO2e	t CO2e	t CO2e
2014	91258	21	213	91492
2015	118109	30	277	118416
2016	73816	17	170	74003

Table 7.7: GHG Emission Reductions for Aggregates for 2014, 2015 and 2016 (t CO_2e)

	ERagg - TOTAL			
	CO2	CH4	N2O	TOTAL
Year	t CO2e	t CO2e	t CO2e	t CO2e
2014	56389	91	593	57073
2015	61210	98	645	61953
2016	63109	102	665	63876

Table 7.8: Total GHG Emission Reductions for 2014, 2015 and 2016 (t CO_2e)

	ER - TOTAL			
	CO2	CH4	N2O	TOTAL
Year	t CO2e	t CO2e	t CO2e	t CO2e
2014	147647	112	806	148565
2015	179319	128	922	180369
2016	136925	119	835	137879

APPENDIX I - CALCULATION EXAMPLES

STEEL

Example for Baseline Scenario - Raw material Acquisition (BRAM)

EnFelec = EnFGJelec * CF

EnFelec = 0.7 GJ / tonne * 2.778 kWh / GJ

EnFelec = 194.444 kWh / tonne of steel

EnFcoal = EnFGJcoal / HHVcoal * CF

EnFcoal = 0 GJ / tonne / 29.82 GJ / tonne * 1

EnFcoal = 0 tonne of coal / tonne of steel

EnFng = EnFGJng / HHVng * CF

EnFng = 0.7 GJ / tonne / 38.32 GJ / m3 * 1

EnFng = 0.018267223 m3 / tonne of steel

EnFoil = EnFGJoil / HHVoil * CF

EnFoil = 0.8 GJ / tonne / 38.78 GJ / kL * 1

EnFoil = 20.6291903 L / tonne of steel

EnFgas = EnFGJgas/ HHVgas * CF

EnFgas = 0.003 GJ / tonne / 34.87 GJ / kL * 1

EnFgas = 0.08603384 L / tonne of steel

Eelec = Qsteel * EnFelec* (EFelec,co2+EFelec,ch4*GWPch4+EFelec,n2o * GWPn2o) * 0.000 001

Eelec = 51148.1530384875tonnes*194.444444444 kWh/tonne of steel*(2.1 +0.0002*25 + 0.0001*298) g/kWh*0.000 001

Eelec = 9 945 474.20 kWh * (2.1 +0.0002*25 + 0.0001*298) g/kWh * 0.000 001

Eelec = 20.89 tCO2+ 0.00*25 tCH4 + 0.00*298 tN2O

Eelec = 20 tCO2e+ 0 tCO2e + 0 tCO2e *rounded down for baseline (in the case of the project, rounded up)*

Eelec = 20 tCO2e

Ecoal = Qsteel *EnFcoal * (EFcoal,co2 + EFcoal,ch4 * GWPch4 + EFcoal,n2o * GWPn2o) * 0.001

Ecoal = 51148.1530384875tonnes*0 tonne of coal / tonne of steel*(2626 +0.03*25 + 0.02*298)g/kg *0.001

Ecoal = 0 tonne of coal * (2626 +0.03*25 + 0.02*298)g/kg *0.001

Ecoal = 0 tCO2+ 0 tCH4 + 0 tN2O *rounded down for baseline (in the case of the project, rounded up)*

Ecoal = 0

Eng = Qsteel * EnFng * (EFng,co2 + EFng,ch4 * GWPch4 + EFng,n2o * GWPn2o) * 0.000 001

Eng = 51148.1530384875 tonnes *0.018267223 m3/tonne of steel* (1887+0.037*25 + 0.033*298)g/m3 * 0.000 001

Eng = 934.33m3 * (1887+0.037*25 + 0.033*298)g/m3 * 0.000 001

Eng = 1.76 tCO2 + 0.00*25 tCH4 + 0.00*298 tN2O

Eng = 1 tCO2e + 0 tCO2e + 0 tCO2e *rounded down for baseline (in the case of the project, rounded up)*

Eoil = 1 tCO2e

Eoil = Qsteel *EnFoil*(EFoil,co2 + EFoil,ch4 * GWPch4 + EFoill,n2o * GWPn2o)*0.000 001

Eoil = 51148.1530384875 tonnes*20.6291903L/tonne of steel*(2753+0.006*25 + 0.031*298)g/L*0.000 001

Eoil = 1055144.98 L*(2753+0.006*25 + 0.031*298)*0.000 001

Eoil = 2904.81 tCO2 + 0.01*25 tCH4 + 0.03*298 tN2O

Eoil = 2904 tCO2e + 0 tCO2e + 9 tCO2e *rounded down for baseline (in the case of the project, rounded up)*

Eoil = 2913 tCO2e

Egas = Qsteel * EnFgas * (EFgas,co2 + EFgas,ch4 * GWPch4 + EFgas,n2o * GWPn2o) * 0.000 001

Egas = 51148.1530384875tonnes*0.08603384L/tonne of steel*(2316+0.068*25 + 0.02*298)g/L*0.000001

Egas = 4400.47 L*(2316+0.068*25 + 0.02*298)*0.000001

Egas = 10.19 tCO2 + 0.000299*25 tCH4 + 0.000088*298 tN2O

Egas = 10 tCO2e + 0 tCO2e + 0 tCO2e *rounded down for baseline (in the case of the project, rounded up)*

Egas = 10 tCO2e

BRAM = Eelec + Ecoal + Eng + Eoil + Egas

BRAM = 20 + 0 + 1 + 2913 + 10 = 2944 tCO2e

The same operation is done for BM, BT, PRAM, PM, and PT.

BEsteel = BRAM + BM + BT

BEsteel = 2944 + 70468 + 2176 = 75588 tCO2e

PEsteel = PRAM + PM + PT

PEsteel = 3 + 129 + 1453 = 1585 tCO2e

ERsteel = BEsteel - PEsteel

ERsteel = 75588 - 1585 =74003 tCO2e

AGGREGATES

Baseline scenario

BEagg = BElandfill BElandfill = BCdiesel * (EFdiesel,co2 + EFdiesel,ch4 * GWPch4 + EFdiesel,n2o * GWPn2o) * 0.000 001

BElandfill= 7908419.12 L * (2690 + 0.14 * 25 + 0.082*298) g/L * 0.000 001

BElandfill = 21273.65 tCO2 + 1.11*25 tCH4 + 0.65*298 tN2O

BElandfill = 21273 tCO2e + 27 tCO2e + 193 tCO2e

BElandfill = 21493 tCO2e

BCdiesel = CFLdiesel * Qaw

BCdiesel = 16.22277067 L / metric tonne of material*487488.81 tonnes of material

BCdiesel = 7908419.12 L

Qaw = QT - Qsteel

Qaw = 538636.96 tonnes of recuperated material - 51148.1530384875 tonnes of steel

Qaw = 487488.81 tonnes of material

CFLdiesel = AEFlandfill,m / (AEFdiesel/1000/1000)

CFLdiesel = 0.044092452 tCO2e /metric tonne of material / (2717.936g/L)

CFLdiesel = 16.22277067 L / metric tonne of material

AEFlandfill,m = AEFlandfill,s / 0.90718474

AEFlandfill,m = 0.04 tCO2e/short ton of material/0.90718474 metric tonne/short ton

AEFlandfill,m = 0.044092452 tCO2e /metric tonne of material

AEFdiesel = EFdiesel,co2 + EFdiesel,ch4 * GWPch4 + EFdiesel,n2o * GWPn2o

AEFdiesel = 2690 + 0.14*25 + 0.082*298 = 2717.936g/L

Project scenario

PEagg = PEvip + PEvit + PErp+ PEstorage

PEagg = -31940 tCO2e + -26617 + 15970 + 204 = -42383tCO2e

PEvip = VIPCdiesel * (EFdiesel,co2 + EFdiesel,ch4 * GWPch4 + EFdiesel,n2o * GWPn2o) * 0.000 001

PEvip = -11 750 883.50 L *(2690 + 0.14 * 25 + 0.082*298) g/L * 0.000 001

PEvip = -31609.88 tCO2 + -1.65 * 25 tCH4 + -0.96 * 298 tN2O

PEvip = -31610 tCO2e + -42 tCO2e + -288 tCO2e

PEvip = -31940 tCO2e

VIPCdiesel = VIPCFdiesel * Qagg

VIPCFdiesel = -24.33415601 L / metric tonne of material* 482896.69 tonnes

VIPCFdiesel = -11 750 883.50 L

VIPCFdiesel = AEFvip,m / (AEFdiesel/1000/1000)

VIPCFdiesel = -0.066138679 tCO2e / metric tonne / 2717.936g/L /1000 /1000

VIPCFdiesel = -24.33415601 L / metric tonne of material

AEFvip,m = AEFvip,s / 0.90718474

AEFvip,m = -0.06 tCO2e / short ton / 0.90718474 = -0.066138679 tCO2e / metric tonne

PEvit = VITCdiesel * (EFdiesel,co2 + EFdiesel,ch4 * GWPch4 + EFdiesel,n2o * GWPn2o) * 0.000 001

PEvit = -9 792 402.92 L * (2690 + 0.14 * 25 + 0.082*298) g/L * 0.000 001

PEvit = -26341.56 tCO2 + -1.37 * 25 tCH4 + -0.80 tN2O

PEvit = -26342 tCO2e + -35 tCO2e + -240 tCO2e

PEvit = -26617 tCO2e

VITCdiesel = VITCFdiesel * Qagg

VITCdiesel = -20.27846334L/tonnes of material*482896.694604 tonnes

VITCdiesel = -9 792 402.92 L

VITCFdiesel = AEFvit,m / (AEFdiesel/1000/1000)

VITCFdiesel = -0.055115566 tCO2e /metric tonne / 2717.936g/L /1000 /1000

VITCFdiesel = -20.27846334L/tonnes of material

AEFvit,m = AEFvit,s / 0.90718474

AEFvit,m = -0.05 tCO2e / short ton / 0.90718474 = -0.055115566 tCO2e / metric tonne

PErp = RPCoil * (EFoil,co2 + EFoil,ch4 * GWPch4 + EFoill,n2o * GWPn2o) * 0.000 001

PEoil = 5780894.883 L * (2753+0.006*25+0.031*298) g/L * 0.000 001

PEoil = 15914.80 tCO2 + 0.03*25 tCH4 + 0.18*298 tN2O

PEoil = 15915 tCO2e + 1 tCO2e + 54 tCO2e

PEoil = 15970 tCO2e

RPCoil = RPCFoil * Qagg

RPCoil = 11.97128692 L/metric tonne * 482896.694604 tonnes of aggregates

RPCoil = 5780894.883 L

RPCFoil = AEFrp,m / (AEFoil/1000/1000)

RPCFoil = 0.033069339 tCO2e/metric tonne / 2762.388 g/L/1000/1000

RPCFoil = 11.97128692 L/metric tonne

AEFrp,m = AEFrp,s / 0.90718474

AEFrp,m= 0.03 tCO2e/short ton / 0.90718474 = 0.033069339 tCO2e/metric tonne

AEFoil = EFoil,co2 + EFoil,ch4 * GWPch4 + EFoil,n2o * GWPn2o

AEFoil = 2753 + 0.006*25 + 0.031*298 = 2762.388 g/L

PEstorage = PCdiesel * (EFdiesel,co2 + EFdiesel,ch4 * GWPch4 + EFdiesel,n2o * GWPn2o) * 0.000 001

PEstorage = 74496.78569 *(2690 + 0.14 * 25 + 0.082*298) g/L * 0.000 001

PEstorage = 200.40 tCO2 + 0.01*25 tCH4 + 0.01*298 tN2O

PEstorage = 201 tCO2e + 1 tCO2e + 2 tCO2e

PEstorage = 204 tCO2e

PCdiesel = CFLdiesel * Quw

PCdiesel = 16.22277067 L / metric tonne of material * 4592.11 tonnes of material

PCdiesel = 74496.78569 L

Quw = QT - Qsteel - Qagg

Quw = 538636.96 - 51148.1530384875 - 482896.694604 = 4592.11 tonnes of material

ERagg = BEagg - PEagg

ERagg = 21493 - (-42383) = 63876 tCO2e

TOTAL

TER = ERsteel + ERagg

TER = 74003 + 63876 = 137 879 tCO2e

APPENDIX II - EMISSIONS DETAILED

Steel - Baseline Scenario

Raw Material Acquisition	Electricity kWh	Coal tonne	Natural Gas m3	Oil L	Gasoline L	
per tonne of material	194.44	0.00	0.02	20.63	0.09	---
Total Consumption	9945474.20	0.00	934.33	1055144.98	4400.47	---
Emissions per gas						TOTAL
Emissions CO2 tCO2	20.89	0.00	1.76	2904.81	10.19	2937.65
Emissions CH4 tCH4	0.00	0.00	0.00	0.01	0.000299	0.01
Emissions N2O tN2O	0.00	0.00	0.00	0.03	0.000088	0.03
Emissions TCO2e						TOTAL
Emissions CO2 tCO2e	20	0	1	2904	10	2935
Emissions CH4 tCO2e	0	0	0	0	0	0
Emissions N2O tCO2e	0	0	0	9	0	9
Emissions TOTAL tCO2e	20	0	1	2913	10	2944

Manufacturing	Electricity kWh	Coal tonne	Natural Gas m3	Oil L	Gasoline L	
Per tonne of material	111.11	0.52	0.14	0.00	0.00	---
Total consumption	5683128.12	26757.59	7341.20	0.00	0.00	---
Emissions per gas						TOTAL
Emissions CO2 tCO2	11.93	70265.42	13.85	0.00	0.00	70291.21
Emissions CH4 tCH4	0.00	0.80	0.00	0.00	0.00	0.80
Emissions N2O tN2O	0.00	0.54	0.00	0.00	0.00	0.54
Emissions TCO2e						TOTAL
Emissions CO2 tCO2e	11	70265	13	0	0	70289
Emissions CH4 tCO2e	0	20	0	0	0	20
Emissions N2O tCO2e	0	159	0	0	0	159
Emissions TOTAL tCO2e	11	70444	13	0	0	70468

Transportation	Electricity kWh	Coal tonne	Natural Gas m3	Diesel L	Gasoline L	
Per tonne of material	0.00	0.00	0.00	15.67	0.00	---
Total consumption	0.00	0.00	0.00	801276.55	0.00	---
Emissions per gas						TOTAL
Emissions CO2 tCO2	0.00	0.00	0.00	2155.43	0.00	2155.43
Emissions CH4 tCH4	0.00	0.00	0.00	0.11	0.00	0.11
Emissions N2O tN2O	0.00	0.00	0.00	0.07	0.00	0.07
Emissions TCO2e						TOTAL
Emissions CO2 tCO2e	0	0	0	2155	0	2155
Emissions CH4 tCO2e	0	0	0	2	0	2
Emissions N2O tCO2e	0	0	0	19	0	19
Emissions TOTAL tCO2e	0	0	0	2176	0	2176

Steel - Project Scenario

Raw Material Acquisition	Electricity kWh	Coal tonne	Natural Gas m3	Oil L	Gasoline L	
Per tonne of material	2.78	0.00	0.00	0.00	0.00	---
Total consumption	142078.20	0.00	0.00	0.00	0.00	---
Emissions per gas						TOTAL
Emissions CO2 tCO2	0.30	0.00	0.00	0.00	0.00	0.30
Emissions CH4 tCH4	0.00	0.00	0.00	0.00	0.00	0.00
Emissions N2O tN2O	0.00	0.00	0.00	0.00	0.00	0.00
Emissions TCO2e						TOTAL
Emissions CO2 tCO2e	1	0	0	0	0	1
Emissions CH4 tCO2e	1	0	0	0	0	1
Emissions N2O tCO2e	1	0	0	0	0	1
Emissions TOTAL tCO2e	3	0	0	0	0	3

Manufacturing	Electricity kWh	Coal tonne	Natural Gas m3	Oil L	Gasoline L	
Per tonne of material	1027.78	0.00	0.14	0.00	0.00	---
Total consumption	52568935.07	0.00	7341.20	0.00	0.00	---
Emissions per gas						TOTAL
Emissions CO2 tCO2	110.39	0.00	13.85	0.00	0.00	124.25
Emissions CH4 tCH4	0.00	0.00	0.00	0.00	0.00	0.00
Emissions N2O tN2O	0.00	0.00	0.00	0.00	0.00	0.00
Emissions TCO2e						TOTAL
Emissions CO2 tCO2e	111	0	14	0	0	125
Emissions CH4 tCO2e	1	0	1	0	0	2
Emissions N2O tCO2e	1	0	1	0	0	2
Emissions TOTAL tCO2e	113	0	16	0	0	129

Transportation	Electricity kWh	Coal tonne	Natural Gas m3	Diesel L	Gasoline L	
Per tonne of material	0.00	0.00	0.00	10.44	0.00	---
Total consumption	0.00	0.00	0.00	534184.37	0.00	---
Emissions per gas						TOTAL
Emissions CO2 tCO2	0.00	0.00	0.00	1436.96	0.00	1436.96
Emissions CH4 tCH4	0.00	0.00	0.00	0.07	0.00	0.07
Emissions N2O tN2O	0.00	0.00	0.00	0.04	0.00	0.04
Emissions TCO2e						TOTAL
Emissions CO2 tCO2e	0	0	0	1437	0	1437
Emissions CH4 tCO2e	0	0	0	2	0	2
Emissions N2O tCO2e	0	0	0	14	0	14
Emissions TOTAL tCO2e	0	0	0	1453	0	1453

Aggregates - Baseline scenario

Baseline scenario - landfill	
Transportation	Diesel mobile L
Per tonne of material	16.22277067
Total consumption	7908419.12
Emissions per gas	
Emissions CO2 tCO2	21273.65
Emissions CH4 tCH4	1.11
Emissions N2O tN2O	0.65
Emissions TCO2e	
Emissions CO2 tCO2e	21273
Emissions CH4 tCO2e	27
Emissions N2O tCO2e	193
Emissions TOTAL tCO2e	21493

Aggregates - Project scenario

Project scenario - recycling and landfill	
Virgin inputs, process	Diésel mobile, L
Per tonne of material	-24.33415601
Total consumption	-11750883.50
Emissions per gas	
Emissions CO2 tCO2	-31609.88
Emissions CH4 tCH4	-1.65
Emissions N2O tN2O	-0.96
Emissions TCO2e	
Emissions CO2 tCO2e	-31610
Emissions CH4 tCO2e	-42
Emissions N2O tCO2e	-288
Emissions TOTAL tCO2e	-31940

Virgin inputs, tranportation	Diésel mobile, L
Per tonne of material	-20.27846334
Total consumption	-9792402.92
Emissions per gas	
Emissions CO2 tCO2	-26341.56
Emissions CH4 tCH4	-1.37
Emissions N2O tN2O	-0.80
Emissions TCO2e	
Emissions CO2 tCO2e	-26342
Emissions CH4 tCO2e	-35
Emissions N2O tCO2e	-240
Emissions TOTAL tCO2e	-26617

Recycling production	Diésel fixe, L
Per tonne of material	11.97128692
Total consumption	5780894.883
Emissions per gas	
Emissions CO2 tCO2	15914.80
Emissions CH4 tCH4	0.03
Emissions N2O tN2O	0.18
Emissions TCO2e	
Emissions CO2 tCO2e	15915
Emissions CH4 tCO2e	1
Emissions N2O tCO2e	54
Emissions TOTAL tCO2e	15970

Storage	Diésel mobiel, L
Per tonne of material	16.22277067
Total consumption	74496.78569
Emissions per gas	
Emissions CO2 tCO2	200.40
Emissions CH4 tCH4	0.01
Emissions N2O tN2O	0.01
Emissions TCO2e	
Emissions CO2 tCO2e	201
Emissions CH4 tCO2e	1
Emissions N2O tCO2e	2
Emissions TOTAL tCO2e	204