BORGARLÍNAN

Borgarlínan Lota 1
Carbon Impact Assessment

June 2023

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Date:	28.06.2023
Version:	1.0
Document ID:	BL100-ENV-IDA-RP-00006

Content

1 Study context

1.1. Study Purpose

Introduction

The purpose of this study is to assess the greenhouse gas (GHG) emissions of Borgarlínan Lota 1, a bus rapid transit construction project. The GHG emissions of the Lota 1 project were assessed for **the construction phase.**

Please note than an assessment of GHGs emissions during operation and a comparison with the baseline scenario are conducted by Mannvitt as part of the EIA.

The aim of the study is to provide quantitative data on GHG emissions for the main emission sources identified within the project (construction phase). Given the current level of definition of the project (Preliminary design is on-going), it is not possible to carry out an exhaustive inventory of all the project's sources of greenhouse gas emissions. The assessments are based on Preliminary Design data. They are likely to change as a result of any changes made to the project by the project owner, technical proposals from contractors, or technical constraints encountered during the works phase. The main emission items identified have therefore been taken into account on the basis of the data available and of their estimated weight in terms of greenhouse gases. In the absence of certain quantitative information, average assumptions have been used to quantify emissions. The GHG assessment carried out does not represent the exact emissions of the final project, but it does provide an order of magnitude of emissions for the main items. Therefore, the assessments allow practical conclusions to arise and can lead to actions aimed at reducing the project's carbon impact.

This report presents the calculation methodology and the main results of the assessment of GHG emissions generated by Borgarlínan Lota 1's construction phase.

Methodology

Carrying out a diagnosis of greenhouse gas emissions, the first stage in a strategy to reduce GHG emissions, can call on several calculation methodologies: the "source approach" and the "product approach".

This study is based on the Bilan Carbone© methodology, which has been associated with a source approach based on the various phases of the project before calculations started.

In addition, emission factors taken from the EcoInvent 3.9 database were used in order to be as close as possible to the reality of the Icelandic context. EcoInvent is an LCA database that can be used for international context and is more suited for this project than the factors present in the Bilan Carbone© which are calculated by the ADEME1 and suit the French context.

« Measure » or « Estimate »

For practical reasons, it is not possible to make a direct measurement of the GHG emissions resulting from a given action. Measuring emissions accurately would indeed require sensors to be fitted to all vehicle exhausts, and dynamic measurement tools to be integrated into each operating system.

The only way to assess GHG emissions without waiting for the action to unfold and resorting to a complex array of devices and tools is to estimate these emissions by obtaining them from other data. The method used by Artelia is the Bilan Carbone© method, developed by ADEME. This method converts a set of data collected directly from the project into GHG emissions using emission factors (expressed in CO2 equivalent). Here, it has been adapted to the Icelandic context by using emission factors from the EcoInvent 3.9 database, an international database containing data on Iceland.

In addition, as most of the method is based on average emission factors, its primary purpose is to provide orders of magnitude that can be used to draw practical conclusions for the implementation of actions.

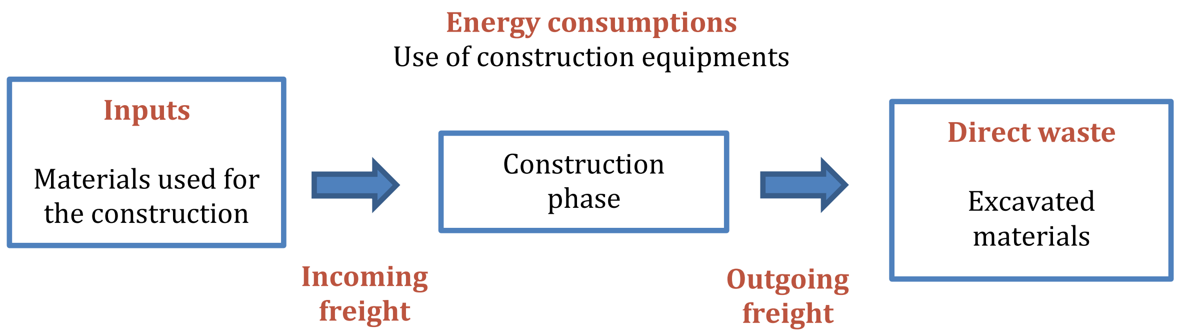
1 ADEME is the French Environment and Energy Management Agency

1.2. Items assessed

Elements taken into account

GHG emissions from the construction phase will be taken into account in our assessment. The scope of the study includes the development and construction of roads and stations for the operation of the BRT (Borgarlínan Lota 1) network.

The diagrams below show the various flows with a potential impact on GHG emissions, as well as the associated GHG emissions assessment methodology (in orange).



Elements not taken into account

The following works have not been taken into account in the calculation of GHG emissions, as experience in other projects has shown that their relative weight is not significant from the point of view of GHG emissions. Hence, it will not change the orders of magnitude derived from this assessment:

- Site installation work (signs, framing, safety, etc.), relatively insignificant in the forecast GHG assessment;
- Road signs and signposts, which have a relatively low weighting in the forecast GHG assessment;
- The creation of green spaces;
- Travel to and from the construction site by construction workers.

Other works that have not been evaluated due to the lack of available and sufficiently detailed data at this stage of the study:

- District heating, snow melting system

In view of the quantity and outcome of the evaluation, the addition of this new activity data (for work not evaluated) once the data is known and consolidated should not, however, be such as to alter the orders of magnitude and the main conclusions of the evaluation.

1.3. Calculating greenhouse gas emissions

GHG measurment unit

As a reminder, there are several greenhouse gases with different levels of harmfulness. In order to compare the impact of these different greenhouse gases (GHGs), the Intergovernmental Panel on Climate Change (IPCC) has defined the Global Warming Potential (GWP). This index expresses the contribution to global warming of a certain quantity of greenhouse gas over a defined period of 100 years compared with that of CO2. Rather than measuring the emissions of each greenhouse gas, the index made the use of a common unit possible: the CO2 equivalent (eqCO2). The CO2 equivalent is the unit created by the IPCC to compare the impact of these different GHGs on global warming and to add up their emissions.

The CO2 equivalent of the various greenhouse gases is measured in relation to the main one, carbon dioxide. In practical terms, the CO2 equivalent involves assigning a different GWP to each gas. It is this indicator that makes it possible to group together the added effect of all the GHGs contributing to the greenhouse effect under a single value. Furthermore, the emission factors likely to be used in the case of Borgarlínan Lota 1 do not always distinguish emissions by type of greenhouse gas, which makes the use of the CO2 equivalent all the more practical.

In this report, it should be noted that the unit used to calculate GHG emissions will be the ton of CO2 equivalent (tCO2eq), and that the carbon assessment takes into account the 3 following emission scopes:

- **Scope 1**, direct GHG emissions: GHG emissions from fixed or mobile sources of greenhouse gases (cars, buildings, warehouses, etc.) controlled by the company.

- **Scope 2**, indirect GHG emissions associated with energy: emissions resulting from the production of electricity, heat or steam imported and consumed by the company for its activities.

- **Scope 3**, other indirect GHG emissions: waste (transport and treatment), manufacture and supply of inputs (materials and materials used in construction).

Calculation methodology

Calculating the project's GHG emissions involves associating each activity with the corresponding emissions factor.

The diagnostic method used consists in analyzing all the physical flows (flows of people, objects, energy, raw materials, etc.) involved in the project, and assigning them an emission factor, which represents the C02eq emissions per unit of flow.

$$\underbrace{\mathit{GHG\ Emissions}}_{\text{In } tC0_2eq} = \underbrace{\mathit{Activity\ data}}_{\text{In ton for example}} * \underbrace{\mathit{emission\ factor}}_{\text{In } tC0_2eq/\text{ quantity}}$$

Most of the information and data used in the study comes from Inception reports and Bills of quantities. This data was then processed and converted into GHG emissions using emission factors from ADEME's carbon database, mainly the EcoInvent 3.9 database, with the help of the Bilan Carbone tool, version 8.7.2.

As the data had not yet been produced for all the sections of the project, it was decided, in agreement with the team in charge of the EIA (*16/03/2023 EIA coordination meeting*), to assess the carbon impact of the most advanced section: for the moment, section 180. A ratio of $tCO2eq/m^2$ of type of surface area was derived from this first assessment and then applied to the other sections to obtain the overall impact of the project.

The Bilan Carbone® methodology defines seven main emissions categories.

For the construction phase, the assessment focuses on four items. Indeed, the following items are not relevant to this work:

- Non-energy item: during the construction phase, no refrigeration production equipment is used that would generate this type of emission.

- Fixed assets: by its very nature, the project is a construction project, with no depreciation of equipment taken into account, as may be the case when preparing annual carbon impact assessment.

- Travel: this is considered negligible, as it is estimated to account for less than 2% of total emissions, based on feedback from similar construction projects.

The results will be presented by differentiating between these items:

- Energy > : Emissions relating to the fuels and electricity used to operate vehicles and site machinery.

- Inputs > : Emissions relating to materials used in the construction of the zone: hydraulic binders, gravel, asphalt, concrete, steel, cast iron, PVC, copper, etc.

- Freight > : Emissions relating to the transport of incoming goods (inputs) and outgoing goods (removal of topsoil, etc.)

- Waste > : Emissions relating to excavated material removed from the area for processing.

Uncertainties

Each GHG emission calculation has its own uncertainty. This uncertainty per elementary calculation combines the estimated uncertainty of the emission factor and the estimated uncertainty of the activity data used for the calculation.

Assuming a Gaussian (normal) distribution of uncertainties, and based on the principle of the propagation of uncertainties, the total uncertainty Ui of the activity is calculated using the following formula:

$$U_i = \sqrt{U_{AD}^2 + U_{EF}{}^2}$$

U_{AD} is the percentage of uncertainty associated with the activity data (AD);

U_{EF} is the percentage of uncertainty associated with the emission factor (EF).

The sum of the uncertainties per emission item determines the overall uncertainty of the project's GHG emissions. The total uncertainty is calculated using the following formula:

$$U_{total} = \frac{\sqrt{(U_1 * x_1)^2 + (U_2 * x_2)^2 + \cdots + (U_n * x_n)^2}}{x_1 + x_2 + \cdots + x_n}$$

Where: U_{total} is the percentage of uncertainty associated with the sum of emissions X_i ;

X_i are the combined emissions of the activities;

Ui are the uncertainties associated with each of the emissions X_i.

This approach is in line with IPCC recommendations on best practice and uncertainty management and is applied in ADEME's Bilan Carbone® tool.

The activity data made available have been classified into two categories, according to their level of uncertainty:

- 30% | Medium uncertainty - for data that has been estimated with medium representativeness or recalculated by conversion (for example: calculation of steel tonnage based on the equipment and components of the technical batches used); an uncertainty range of 30% has been applied for the most part;

- 50% | **High uncertainty** - for data that has been estimated with a low representativeness (for example: assimilation of an activity data to the association with a material, for turnouts assimilated to a steel tonnage); an uncertainty range of 50% has been mostly applied.

The level of uncertainty for each emission factor is defined by ADEME.

2 Details of the greenhouse gas emissions assessment

2.1. Section 180

Since the draft Preliminary Design of section 180 was the first to be completed, this section is used to benchmark the carbon impact of Borgarlínan Lota1. Greenhouse gas emissions were calculated using data from the Preliminary Design, and the results are presented here. The detail is available only for this section in the present study as data on other section was not available at the time the study was performed. The impact of other sections is presented later on in the study and was calculated using ratios based on the results for section 180

Section 180 of the Lota 1 operation is responsible for approximately 2 500 tCO2eq for the Construction phase, estimated with an uncertainty of +/- 300 tCO2eq or approximately 14% according to the uncertainty calculation presented earlier. Using the principle of calculating uncertainties, this means that there is a 95% chance of finding the correct value within the specified range.

Emissions are distributed into "Energy","Freight", "Inputs" and "Waste" in the graphs below.

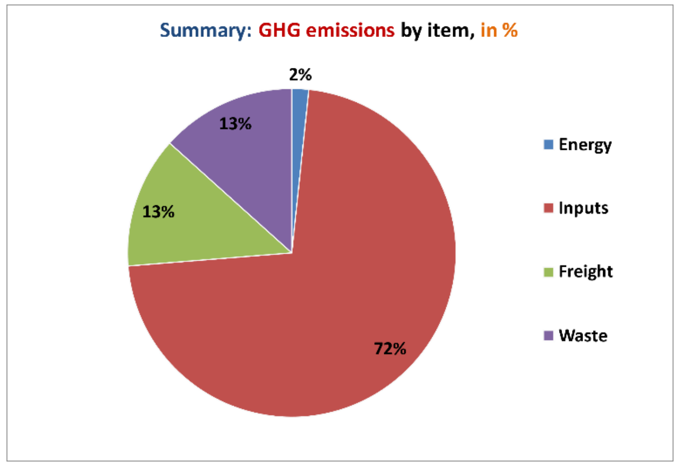


Figure 1: Breakdown of GHG emissions (in %) by emission source (source: Artelia 2023)

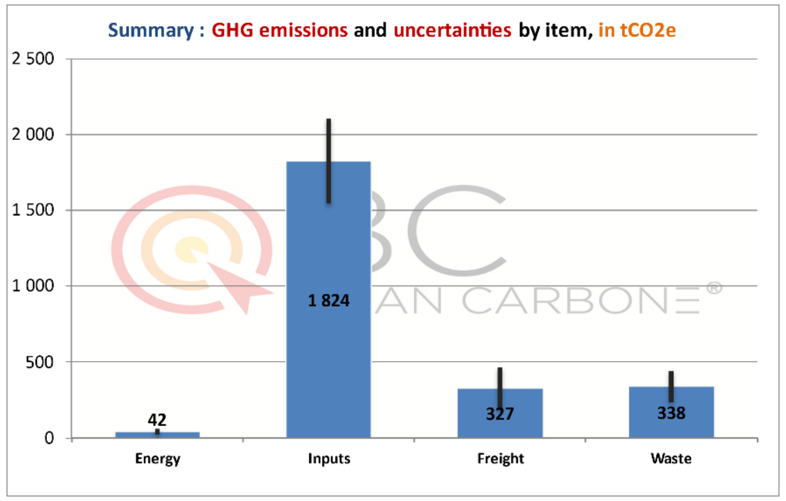


Figure 2: Breakdown of GHG emissions (in tCO2eq) by emission source (Source: Artelia 2023)

Uncertainties associated with the GHG* profile:

- Energy 1: 46%
- Material Inputs 1: 16%
- Freight: 46 %
- Waste: 26%

* In the Bilan Carbone spreadsheet, each calculation result has its own uncertainty, which combines the uncertainty estimated for the emission factor and the uncertainty estimated for the activity data.

The largest percentage of emissions comes from input materials (approximately 1 800 tCO2eq - 72% of the total amount of GHG emissions identified during the construction phase). These are emissions linked to the manufacture of the construction materials required for the project.

This is followed by emissions linked to waste processing, inbound and outbound freight of materials and energy consumption by site machinery.

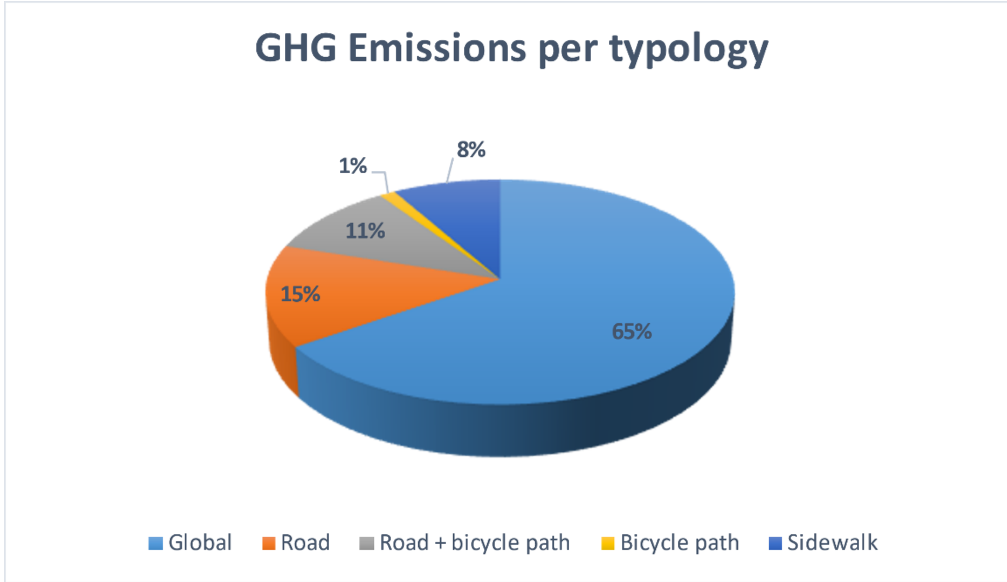


Figure 3 : GHG Emissions per typology (Source : Artelia 2023)

In the figure above, GHG emissions have been represented by distinguishing between:

- Overall impacts (which could not be split between the other categories, for example cut and fill as well as public lighting poles and buried networks)
- Impacts associated with the construction of roads
- Impacts associated with the construction of bike paths
- Impacts associated with the construction of roads and the bike paths that could not be separated
- Impacts associated with the construction of the pavement

This distribution will be useful in order to fix on the ratios used to break down the impacts by surface area for the other sections of the Lota 1 project.

2.1.1 Material Inputs

This item relates to incoming materials (approximately 1 800 tCO_2eq - 72% of the total amount of GHG emissions identified).

These are emissions linked to the manufacture of the construction materials required for the project. To account for the GHG emissions generated by these materials, the cost estimate of the work drawn up for section 180 draft Preliminary Design was used. The method consists in breaking down the quantities per item into physical flows and elementary quantities according to the details and sub-details used for the price studies, in order to quantify the tonnage and volume of the associated materials.

The results for the materials with the greatest impact are presented here.

NB: other 'secondary' materials and/or those present in smaller volumes have been included in the overall assessment but are not presented in detail.

2.1.1.1. Asphalt

In the project, asphalt is used for the base course and surfacing. All the road and bike paths surfaces are surfaced with asphalt, making it one of the project's main materials.

Label	Unit	Quantity	Emission factor (kgCO2 per unit)	Total CO2eq (in tons)
Surface Course Asphalt	t	3 338	122 kgCO2eq/t	408
Binder Course Asphalt	t	5 491	46,5 kgCO2eq/t	255

This quantity corresponds to 22% of the impact of section 180.

2.1.1.2. Filling and Subbase/roadbase

As with any road project, it is necessary to use aggregates as backfill for certain sections. In our case, this has little impact as the aggregates used in street projects will come from local mines (*Preliminary Design information*). The same assumption is made for BRT lanes.

Also considered here is gravel, a type of aggregate used as a base course for road construction.

Label	Unit	Quantity	Emission factor (kgCO2 per unit)	Total CO2eq (in tons)
Gravel	t	42 330	14,5 kgCO2eq/t	614
Backfill	t	13 351	4 kgCO2eq/t	53

2.1.1.3. Copper

The project includes the installation of earth wire, which are made mostly of aluminium and of copper. The worstcase scenario was considered which is the use of only new copper. Using recycledcopper could cause the weight of this item to drop by 10%.

Label	Unit	Quantity	Emission factor (kgCO2 per unit)	Total CO2eq (in tons)
Copper	t	83	1 455 kgCO2eq/t	121

2.1.1.4. Concrete

Concrete is mainly made up of cement, aggregates (crushed quarry stone or aggregates taken directly from a river bed), water, a binder (usually cement) and, potentially, additives. For the production of concrete using traditional cement (CEM II cement taken into account in the EcoInvent 3.9 base), the carbon impact of the concrete is mainly due to that of the cement.

It is used for sidewalks wearing courses and station platforms

Label	Unit	Quantity	Emission factor (kgCO2 per unit)	Total CO2eq (in tons)
Concrete CEM II/B	m^3	1 046	218,19 kgCO2eq/m3	228

2.1.1.5. Steel

Steel is used for reinforcement of foundations and retaining walls. It is also used for light poles. As for copper, it was assumed that only new steel was used. The use of only recycled steel could cause the weight of this item to drop by 50%.

Label	Unit	Quantity	Emission factor (kgCO2 per unit)	Total CO2eq (in tons)
Reinforcing Steel	t	65	2 130 kgCO2eq/t	139

2.1.2 Waste

These are emissions linked to waste sent for recovery (approximately **338 tCO_2eq - 13%** of the total amount of GHG emissions identified).

In order to calculate the volume of waste and its nature, the following were taken into account :

- Non reusable earth materials transferred to reclycling/landfill

- Disposal of excess soil from excavation

In the context of this project, the excavated soil is therefore inert waste. This waste does not decompose or burn, nor does it produce any other physical, chemical or biological reaction that could harm the environment or human health. It will therefore be transported and stored at recycling centres. To calculate the CO_2 emissions due to this excavated material, we have taken into account the emission factors linked to the end-of-life of waste sent to recovery centres (waste sorting/grouping stage).

Label	Unit	Quantity	Emission factor (kgCO2 per unit)	Total CO2eq (in tons)
Waste	t	56 300	Treatment of inert waste 6 kgCO2eq/t	338

2.1.3 Freight

The Freight item corresponds to the supply to the construction site of all the materials required for the site, the manufacture of which has been accounted for under the Inputs item. The methodology used to calculate Freight emissions is based on the tonnage of materials, to which a type of vehicle (for their transport) and an assumption about supply distance is associated

Hypothesis :

- The filling materials and subbase, which represent (in tons) the majority of materials used for the project, are produced locally. Vehicle type : Lorry, 34 to 40t Distance : 20 kms
- For the rest of the materials, it was assumed that they were imported from Europe by boat.
  Vehicle type : Bulk carrier
  Distance : 2 000 kms

The distance used may be different from reality and for information, changing the distance used would lead to a difference of approximately 50tCO2eq/km.

Emissions linked to the transport of materials are estimated at approximately 330 tCO2eq - i.e. 13% of the total amount of GHG emissions identified.

2.1.4 Energy

Within the Construction phase, the Energy item remains difficult to assess at this stage of the study.

Direct energy consumption on the site (approximately 42 tCO2eq - 2% of the total amount of GHG emissions identified for the phase) is evaluated under this heading.

Experience has shown that earthworks are the main sources of energy consumption, due to the use of diesel-powered site machinery. At this stage of the study, however, data on the use of these machines was not available, so consumption ratios were applied according to the surface areas and volumes of materials to be used.

The emission factors are specific and come from a CEREMA2 methodological guide designed specifically for urban development works. These factors are based on feedback from a number of sites. They have been added to the Bilan Carbone spreadsheet. These factors include all the machinery required for all the earthworks. They were calculated using data from the Ecorce v2 software and are presented here:

- Excavation of soil: 0.761 kgCO2eq/m3.
- Construction of a subgrade: 0.711 kgCO2eq/m3.

In view of these factors and the various volumes of earthworks to be carried out, the GHG emissions calculated for the energy item come to 42 tCO2eq; it should be noted that the overall uncertainty for this item remains high, at 50%, i.e. +/- 19 tCO2eq.

2 The CEREMA is the Centre for studies and expertise on risks, environment, mobility and development

2.2. Global emissions of the project

2.2.1 Hypothesis

In order to calculate the overall carbon impact of Borgarlínan Lota 1 (= all the sections) during the construction phase, it was decided in agreement with the team in charge of the EIA to calculate an emissions factor based on the data for section 180, which was already at the Preliminary Design stage. The factor was calculated by surface area (in hectares) and by typology, as presented in the document estimating overall costs from the Inception phase.

These calculations lead to the following results for the ratios obtained:

Ratios based on surface (In ha)	
Global	1 190 tCO2eq/ha
Road	391 tCO2eq/ha
Road + Bicycle path	222 tCO2eq/ha
Bicycle path	128 tCO2eq/ha
Sidewalk	758 tCO2eq/ha

Ratios were calculated on those specific types of surfaces because those surfaces were known for each section, and it was possible to extract the materials used for different typology.

Those ratios were created using the cost estimates, what was used for each is presented afterward :

- Overall : All materials for construction and bridges, surface treatment, utilities, filling materials and subbase.
- Road : Asphalt surface course specified to be used for the road
- Road + bicycle : Bituminous base course used for both road and bicycle, without distinction
- Bicycle path : Asphalt surface course used for bicycle path
- Sidewalk : Concrete used for sidewalks

These ratios were then applied to the surface areas of the different types for each section resulting in the following table.

It is important to note that using surfaces and not ratios per km results in greater accuracy.

For all those sections, the typology of construction is different, some of them reuse existent portions of roads while others involve whole new roads. There are also multiple sections designs, some consider two BRT dedicated lanes and roads, some consider BRT mixed lanes. This leads to a great difference as the surface created for sections with BRT dedicated lines is doubled in comparison to BRT mixed lanes.

2.2.2 Results

The GHG emissions of Lota 1 construction phase is estimated to be approximately 27 200 tCO2eq for the 14,3 km of BRT lanes creation.

		B110	B120	B130	B140	B150	B160	B180	Total
Length	Km	0,65	0,95	3,3	2,5	1,3	3,1	2,5	**14,3**
Surfaces (In ha)	Road	0,85	0,34	2,67	1,2	0,97	2,1	0,91	**9,04**
	Bicycle path	0,29	0,21	0,79	0,27	0,38	0,59	0,23	**2,75**
	Sidewalk	0,35	0,34	0,89	0,53	0,37	0,68	0,27	**3,42**
	Total	1,49	0,88	4,35	1,99	1,72	3,36	1,42	**15,2**
Impact (In tCO2eq)		**2 654**	**1 584**	**7 759**	**3 596**	**3 055**	**6 008**	**2531**	**27 187**

As a side note, this result was calculated using hypotheses as the project is not totally defined. The worst-case scenario was used to have the most realistic impact, but the real impact could be less than anticipated as the project moves forward.

Please note that comparing Borgarlínan Lota 1 to another project is not recommended as the way of calculating the impact is different from project to project and the different hypotheses can lead to significant differences.

2.2.3 Potential reductions

To reduce the impact of the project, the most efficient way is to work on the most emitting items. For example, the use of a cold mixed asphalt could reduce the global impact of the project by approximately 2 800 tCO2eq, ie 10%. Another way could be to use only local materials in order to avoid importations, thus reducing the impact of the project by approximately 1 750 tCO2eq ie 6,4%.

These possibilities also depend on technical opportunities and local conditions.

To conclude, the final goal of such a study is to evaluate the environmental profit of the project. This study cannot conclude on it on its own as it only calculates the impact of the construction phase. This impact needs to be compared to the carbon profit, calculated based on the modal shift caused by the project (reducing the use of cars leads to a reduction of GHG emissions in the future). This is assessed in a separate study.