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# Estimating the Required Global Warming Offsets to Achieve a Carbon Neutral Synthetic Field Turf System Installation

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## 1 Introduction

In 2006, UCC decided to replace its natural grass playing field with a new state-of-the-art, artificial turf surface. The synthetic surface will be easier on the players' joints and is designed to reduce sports-related injuries. Additionally, because the artificial surface won't freeze when temperatures drop, the sports season for both Upper School and Prep students can extend further into the year [10].

As an environmental responsible organization, UCC took the initiative to offset the greenhouse gas (GHG) emissions related to the life cycle (from raw material acquisition through manufacturing, transportation, use and maintenance, and end-of-life disposal) of the artificial turf field. By taking on the challenge of sustainability, UCC has demonstrated leadership in installing a "Carbon Neutral" artificial turf field on their campus. To that end, UCC will plant trees in order to balance the field's carbon footprint, and reuse all the topsoil that is removed from the Oval during construction [10].

The purpose of the study was to estimate of the greenhouse gases emitted during the life cycle of the synthetic turf system as opposed to a natural grass surface. The study also determined the number of trees to be planted to achieve a 10-year carbon neutral synthetic turf installation.

## 2 Greenhouse gas quantification

### 2.1 Project System Boundaries

A life cycle approach was followed to determine the boundaries and elements attributable to each of the synthetic and baseline natural turf systems. This procedure allows for the identification of all life cycle phases that may be contained within the system.

The main phases in the UCC project life cycle are as follows:

- Production of the main components of the artificial turf system
- Use and maintenance
- Disposal phase (recycling)
- Transportation

The main stages are further defined at the project element level (symbol P) and shown in the system boundary in Figure 1.

There are five main components used to construct the synthetic turf field – the synthetic turf itself, primary backing material ("Thioback Pro"), a secondary elastomeric coating, rubber granule infill and PVC piping to provide field drainage [6], [8], [11]. The rubber infill granules are derived from recycled tires and can be reused indefinitely [7]. The other turf components have an estimated life of 10 years, which is assumed to be the study period.

The primary backing material itself is made up of three materials (i.e., non woven fiberglass layer, a woven polypropylene/polyester blend layer and a fiber fleece layer (likely tufted polypropylene)). The secondary elastomeric coating is primarily a polyurethane product.

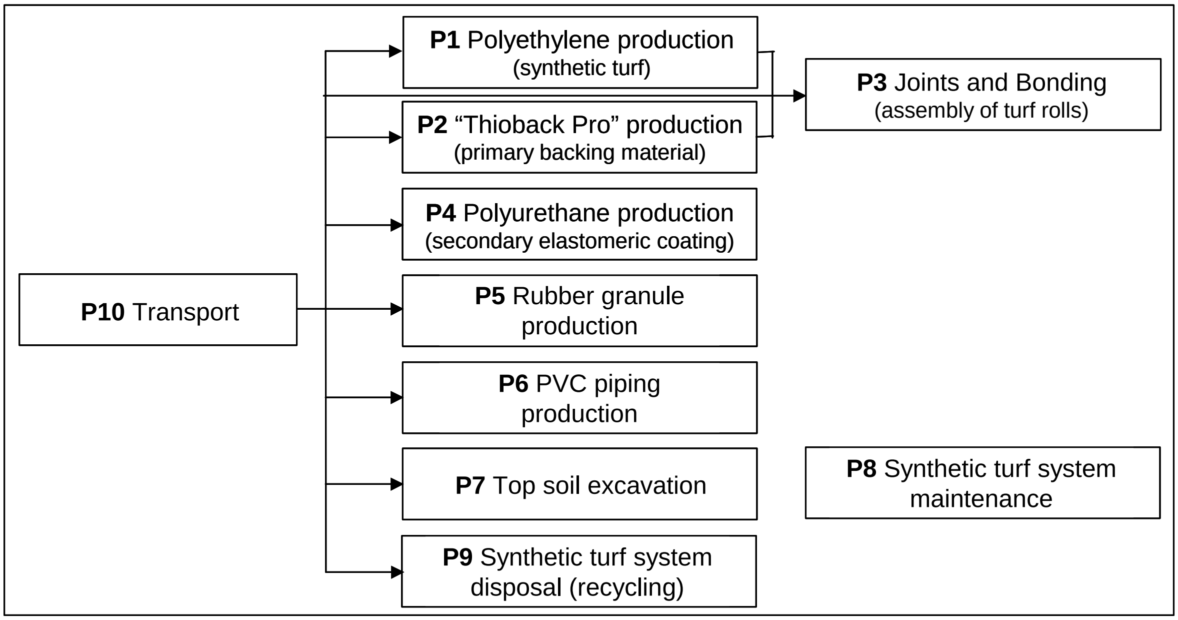


**Figure 1** Project system boundaries

## 2.2 Natural Grass Baseline System Boundaries

The baseline is the most appropriate and best estimate of GHG emissions and removals that would have occurred in the absence of the project. The baseline was broken into elements (symbol B) as identified and numbered in Figure 2.

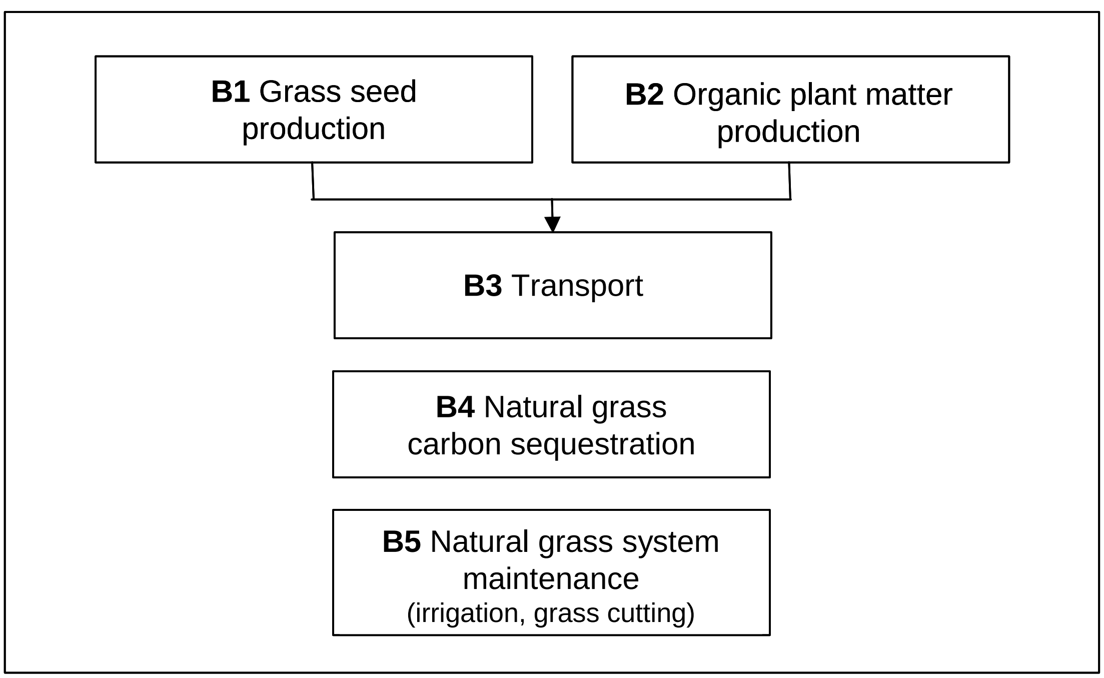


**Figure 2** Baseline system boundaries (business as usual, in absence of artificial turf system)

Comparison between baseline and project systems is made on the basis of the same reference unit, a 9,000-$m^2$ field over a 10-year period.

## 2.3 Element description

The elements in the baseline and project systems are described in Table 1.

**Table 1** Element overview

| Element Identifier | Element Name | Description | Included and quantified in scope of study |
|---|---|---|---|
| **BASELINE- Natural Grass System** | | | |
| B1 | Grass seed production | Includes the GHG emissions released during the production of the grass seed. | Yes |
| B2 | Organic plant matter production | Includes the GHG emissions released during the production of the organic plant matter. | Yes |
| B3 | Transport | Includes the GHG emissions released during the on-road (from supplier to UCC) and off- road transportation of the grass seed and organic plant matter. | Yes |
| B4 | Natural grass carbon sequestration | Includes the GHG emissions savings (captured by the natural grass). | Yes |
| B5 | "Natural grass system maintenance | Includes the GHG emissions released during the grass cutting and irrigation. | Yes |
| **PROJECT- Synthetic Turf System** | | | |
| P1 | "Polyethylene production (synthetic turf)" | Includes the GHG emissions released during the production of polyethylene. | Yes |
| P2 | “Thioback Pro” production (primary backing material) | Includes the GHG emissions released during the production of primary backing material. | Yes |
| P3 | Joints and Bonding (assembly of turf rolls) | Includes the GHG emissions released during the assembling of turf rolls. | Yes |
| P4 | Polyurethane production (secondary elastomeric coating) | Includes the GHG emissions released during the production of polyurethane. | Yes |
| P5 | Rubber granules production | Includes the GHG emissions released during the production of rubber granules infill. | Yes |
| P6 | PVC piping production | Includes the GHG emissions released during the production of PVC piping. | Yes |
| P7 | Top soil excavation | Includes the GHG emissions released during the topsoil excavation. | Yes |
| P8 | Synthetic turf system maintenance | Includes the GHG emissions released during the maintenance of synthetic turf system. | Yes |

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| Element Identifier | Element Name | Description | Included and quantified in scope of study |
|---|---|---|---|
| P9 | Synthetic turf system disposal. | Includes the GHG emissions savings related to recycling of synthetic turf system after 10 years. | Yes |
| P10 | Transport | Includes the GHG emissions released during the transportation (includes all project transportation roads). | Yes |

Transportation for the UCC project was considered in detail. The logistics, modes and distances involved are unique and significant when measured in GHG terms [7], [8]. The basic summary of the transportation is illustrated in Figure 3. Details, with calculations and emissions factors [2], are provided in the spreadsheet.

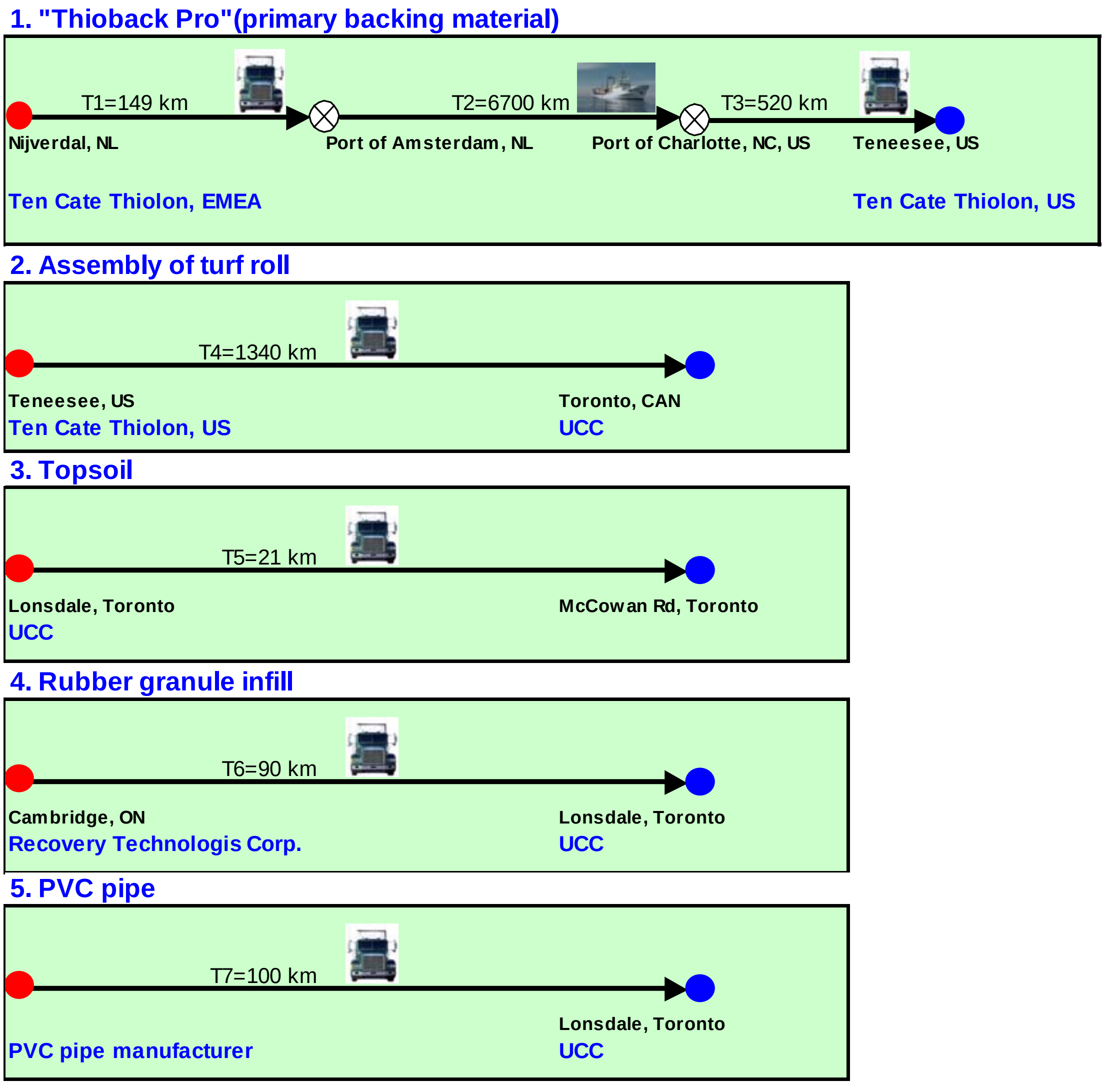


**Figure 3** UCC project transportation routes

## 2.4 General GHG quantification procedure

GHGs are quantified at the element level. This approach generally requires two pieces of information. One describes the **level of activity** of an element (e.g. the quantity of the synthetic turf manufactured in tonne) and the other defines the **GHG emission factor** associated with the element (e.g. emission factor of polyethylene production in tonne $CO_2$e/tonne).
Emissions are reported in the results as much as possible to differentiate each greenhouse gas ($CO_2$, $CH_4$ and $N_2O$). Once emissions or removals of individual GHGs have been calculated, they are expressed in terms of tones of $CO_2$e and summed for an overall measure of GHG emissions for each element. Then the GHG results for all elements in a system (project and baseline) are "rolled up".
Lastly, the flux in GHGs for the baseline natural grass and the synthetic turf project is calculated, thus providing the quantification of total GHG emissions to be offset within a 10-year period.

*Activity Levels:*
In general, inputs, outputs and level of activity data can be obtained by:

- Direct measurement such as continuous or periodic sampling
- Performing mass and energy balances on the system
- Manufacture/supplier specification documents (e.g. quantity of polypropylene used in the manufacture of "Thioback Pro")
- Professional estimation using published data or information collected from external similar sources.

*Emissions factors:*
An emissions factor may be specifically determined in the project through monitoring and/or sampling of the element; or it may be secondary, derived from published or private sources (e.g. SimaPro LCA Software).
When using emission factors for the individual greenhouse gases ($CO_2$, $CH_4$, and $N_2O$), the equation for estimating the $CO_2$ equivalent emission for the elements is:

$$CO_2e = \sum_{i=1}^{n} EF_i \times GWP_i \quad (1)$$

Where:
- $CO_2e$ = emissions of $CO_2$ equivalent in kg
- i = greenhouse gas type
- n = total number of greenhouse gases emitted by the element
- $EF_i$ = emissions of greenhouse gas i in kg
- $GWP_i$ = Global Warming Potential of greenhouse gas i: 1, 21 and 310 are respectively the GWPs of CO2, CH4 and N2O [3]

## 2.5 General quantification assumptions

- Whenever relevant and possible, Canadian GHG emissions factors are applied per each element of the baseline and project systems.
- US emissions factors per element P1, P3, P4 and P6 (artificial turf system's components made in US) are estimated by using Franklin 98/01-update Life Cycle Inventory database, SimaPro 7 LCA Software 2006.

- European emissions factors per element P2 ("Thioback Pro" materials made in the Netherlands) are estimated by using the best European Life Cycle Inventory database-EcoInvent Library v.1.2, SimaPro 7 LCA Software 2006.
- Element activity data for the baseline and project systems were basically compiled with support of UCC Toronto and IC Improvements Inc.
- Natural grass carbon sequestration factor of 0.95 tonne Carbon/ha/year is applied-see http://agron.scijournals.org/cgi/content/abstract/94/4/930.
- Based on the FIFA 2001 Guide [1], GHG emissions factor of the maintenance (P8) of "Artificial turf system" are assumed as high as 30% of the "Natural grass system" maintenance (B5).
- On-road transportation fuel combustion GHG emission factors are based on Environment Canada final report, 2004 [2], Franklin 98/01-update and EcoInvent Library v.1.2 LCI database [9].
- Finally, it's assumed that after 10 years, the artificial turf system's components (P1, P2, P4 and P6) with be 100% recycled. The GHG emissions factor for plastic recycling is based on the ICF Consulting final report, 2005.

## 3 Uncertainty analysis

Sources of uncertainty in the quantification of emissions include:

- Scientific uncertainty: related to incomplete knowledge of emission processes – or example global warming potentials (GWPs). These uncertainties are common to every project and can be excluded from the uncertainty analysis.
- Parameter uncertainty: related to the measured or estimated data used in the quantification methodology (e.g. activity of an element; GHG emission factor associated with the element). Uncertainty of the activity level and GHG emission factors is expected/assumed to be low to medium for measured and estimated data.
- Model uncertainty: associated with the quantification methodology.
- Uncertainty propagation: occurs when the uncertainties associated with the parameters are propagated through the quantification and consolidation process.

Based on the operational experience and professional judgment, the overall uncertainty was estimated and reported for each element. Once the uncertainties are estimated, they are combined to provide uncertainty estimates for the whole project and baseline, based on "Methods for combining uncertainties" according to IPCC 2000 [4] as follows,

- **Rule A:** Where uncertain quantities are to be combined by addition, the standard deviation of the sum will be the square root of the sum of the squares of the standard deviations of the quantities that are added with the standard deviations all expressed in absolute terms.

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

Where:

$U_{total}$ is the percentage uncertainty in the sum of the quantities (half the 95% confidence interval divided by the total (i.e. mean) and expressed as a percentage);

$x_i$ and $U_i$ are the uncertain quantities and the percentage uncertainties associated with them, respectively.

The same principles are applied to estimate the uncertainty for GHG emissions Offset (see spreadsheet).

## 4 Sensitivity analysis

The sensitivity analysis attempts to determine the influence of variations in assumptions, methods and data on the results [5]. Mainly, the sensitivity of the most significant issues identified is determined.

In sensitivity analysis, typically the influence on the results of varying the assumptions and data by some range, e.g. change of the GHGs factor of the B4 element- Natural grass carbon sequestration by (-5%), is checked (see Table 2). Both results are then compared. Sensitivity is expressed as the percentage of change or as the absolute deviation of the results.

Table 2 summarizes the sensitivity analysis for the GHGs factor of B4 element in the baseline system of this project. Sensitivity analysis shows that a change of (-5%) of the GHGs factor (3.3 tonne CO2e/ha/yr) results in a change of (-2%) for number of trees to be planted to achieve a 10-year carbon neutral synthetic turf installation.

**Table 2 Sensitivity analysis on GHG emissions factor for element B4**

| **1. Changes to the B4 (GHG emissions factor 3.3 tonne CO2e/ha/yr is applied (-5%): Baseline;** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SSR identifier<br>SSR name | | B1<br>Grass seed production | B2<br>Organic plant matter production | B3<br>Transport | B4<br>Natural grass carbon sequestration | B5<br>Natural grass system maintenance (Irrigation, grass cutting) | **TOTAL**<br>BASELINE | **GHGs Offset**<br>**BASELINE-PROJECT** | **Number of trees** |
| Base case | t CO2e | 0.003 | 0.11 | 0.83 | **-31.3** | 13.4 | -16.9 | -72.6 | **1861** |
| Altered assumption | t CO2e | 0.003 | 0.11 | 0.83 | **-29.7** | 13.4 | -15.3 | -71 | 1820 |
| Deviation | t CO2e | 0.0 | 0.0 | 0.0 | 1.6 | 0.0 | 1.6 | 1.6 | -41.3 |
| Deviation | % | 0% | 0% | 0% | -5% | 0% | -10% | -2% | -2% |
| Sensitivity | % | 0% | 0% | 0% | 5% | 0% | -10% | 2% | 2% |

## 5 Results

A spreadsheet was developed and is separately available. It documents all the estimations and calculations performed. A summary of the results is presented in Table 3 to Table 5. Results have been scaled according to the reference unit 9,000-$m^2$ field and over a 10-year period.

Because the values and results of this report are based on information and quantities that were not independently verified, Athena's responsibility for the results and conclusions expressed herein are limited to the methods used and the processing of provided data.

Total GHG emissions factor of the baseline and project are estimated respectively to (-16.9)[1] and (55.6) tonnes $CO_2$e. GHG emissions offset is estimated to be (-72.6) tonnes $CO_2$e.

As per U.S. DOE, 1998, a medium growth coniferous tree, planted in an urban setting and allowed to grow for 10 years, sequesters 23.2 lbs of carbon, equivalent to 0.039 metric tonnes $CO_2$ [12]. The tree planting offset requirements to achieve a 10-year carbon neutral synthetic turf installation is estimated to be **1861** trees (±23%).

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[1] Results tables use the following accounting convention: (1) Negative values: reflect "savings" of GHG emissions, which means a "reduction" in emissions; (2) Positive values: reflect "release" of GHG emissions, which means an "increase" in emissions.

**Table 3** Summary of the elements in the UCC BASELINE "Natural grass" System

| Reference | 9,000 m2 | | Timeline: | 10 | years | | |
|---|---|---|---|---|---|---|---|
| Element identifier<br>Element name | | B1<br>Grass seed production | B2<br>Organic plant matter production | B3<br>Transport | B4<br>Natural grass carbon sequestration | B5<br>Natural grass system maintenance (Irrigation, grass cutting) | TOTAL<br><br>BASELINE |
| Scaling factor | | 0.02 | 1 | 250 | 9,000 | 9,000 | 9,000 |
| | Units | tonnes | tonnes | liters | m2 | m2 | m2 |
| CO2 | t CO2e | 3.E-03 | 2.E-02 | 0.80 | -31.3 | 13.4 | **-17.1** |
| CH4 | t CO2e | 0.E+00 | 8.E-04 | 4.8E-04 | 0 | 0 | **0.0** |
| N2O | t CO2e | 0.E+00 | 9.E-02 | 2.9E-02 | 0 | 0 | **0.1** |
| **Total GHGs** | **t CO2e** | **0.003** | **0.1** | **0.8** | **-31.3** | **13.4** | **-16.9** |
| Uncertainty (+/-) | % | 5 | 10 | 20 | 5 | 20 | **18.4** |

**Table 4** Summary of the elements in the UCC PROJECT "Artificial Turf System"

| Reference | 9,000 m2 | | Timeline: | 10 | years | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Element identifier<br>Element name | | P1<br>Polyethylene production (synthetic turf) | P2<br>"Thioback Pro" production (primary backing material) | P3<br>Joints and Bonding (assembly of turf rolls) | P4<br>Polyurethane production (secondary elastomeric | P5<br>Rubber granules production | P6<br>PVC piping production | P7<br>Top soil excavation | P8<br>Synthetic turf system maintenance | P9<br>Synthetic turf system disposal | P10<br>Transport | TOTAL<br><br>PROJECT |
| Scaling factor | | 15.9 | 1.2 | 0.0 | 8 | 105 | 4 | 4,500 | 9,000 | 29 | 9,000 | 9,000 |
| | Units | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | m2 | tonnes | m2 | m2 |
| CO2 | t CO2e | 28 | 2.6 | 0 | 32 | 10.5 | 8 | 1.8 | 4 | -53 | 16 | **50** |
| CH4 | t CO2e | 2 | 0.2 | 0 | 3 | 0 | 0.54 | 0.025 | 0 | 0 | 3.7E-02 | **5** |
| N2O | t CO2e | 1.9E-03 | 4.6E-02 | 0 | 8.7E-02 | 0 | 0.01 | 0.019 | 0 | 0 | 8.4E-02 | **0** |
| **Total GHGs** | **t CO2e** | **29.8** | **2.9** | **0.0** | **34.7** | **10.5** | **8.1** | **1.8** | **4** | **-52.6** | **16.4** | **55.6** |
| Uncertainty (+/-) | % | 20 | 10 | 0 | 20 | 30 | 20 | 20 | 20 | 25 | 20 | **30.1** |

**Table 5** GHG emissions Offsets (Baseline- Project)

| Element identifier<br>Element name | | **GHGs Offset**<br>BASELINE-PROJECT | **GHG emissions can be offset in 10 years by planting the following number of trees:** |
|---|---|---|---|
| Scaling factor | | **9,000** | **1861** |
| | Units | **m2** | |
| CO2 | t CO2e | -67 | Source: http://www.usctcgateway.net/tool/<br>A medium growth coniferous tree, planted in an urban setting and allowed to grow for 10 years, sequesters 23.2 lbs of carbon. For each year, the sequestration rate (in lb per tree) is multiplied by the survival factor to yield a probability-weighted sequestration rate. These values are summed for the 10-year period, beginning from the time of planting, to derive the estimate of 23.2 lbs of carbon per tree.<br>To convert to units of metric tons CO2 per tree, we multiplied by the ratio of the molecular weight of carbon dioxide to that of carbon (44/12) and the ratio of metric tons per pound (1/2203).<br>23.2 lbs C/tree *(44 units CO2 / 12 units C) * 1 metric ton / 2203 lbs = 0.039 metric ton CO2 per urban tree planted |
| CH4 | t CO2e | -5 | |
| N2O | t CO2e | 0 | |
| **Total GHGs** | **t CO2e** | **-72.6** | |
| Uncertainty (+/-) | % | 23 | |

## 6 References


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