TAF

TA13.13

TAF's GHG Quantification Methodology

November 2016

Introduction

Greenhouse gas (GHG) emissions are one of the key metrics used to assess human impact on climate change. In order to understand and reduce our impact on the environment, it is crucial to estimate existing emissions and the potential for reducing those emissions. There are numerous approaches and factors to consider when quantifying GHG emissions. This document provides a summary of The Atmospheric Fund's (TAF) GHG quantification methodology. It is intended to provide stakeholders with an understanding of TAF's GHG quantification approach as well as to provide resources and best practices for the broader community. This document will elaborate on core principles, key concepts, a general approach, key outputs, additional considerations for quantification, and operational practices.

Summary

Quantifying GHG emissions as accurately as reasonably possible is critical to identifying and prioritizing interventions to reduce emissions. TAF strives to inform all major investments with rigorous GHG quantification, and to report annually on the GHG performance of its investments.

This document attempts to share some of TAF's practices to inform other parties, to improve TAF's transparency, and to stimulate GHG quantification discussions and activities.

Although procedures and techniques for quantification differ from case-to-case, they should all be transparent, consistent, rigorous, accurate, and use reliable data. These essential principles should be followed to ensure higher quality results when calculating emissions and emissions reductions.

TAF's general approach of establishing a purpose, determining a boundary, collecting activity/resource use data, applying emissions factors, and checking reasonableness is described in this document and is broadly applied to all quantification activities.

Considerations while quantifying emissions include additionality, double counting, interactive effects, the time value of carbon reductions, and cost effectiveness. Keeping these matters in mind will help improve GHG estimates and the prioritization of potential GHG reduction actions.

TAF assesses the GHG emissions and reductions in order to evaluate grants and investments; explore new areas of potential reductions; and inform policy decisions. Each purpose has various considerations and procedural differences which are explained below.

Core Principles

GHG quantification approaches can vary based on the objectives and constraints of each project. In spite of this the underlying values and principles of GHG quantification should remain consistent. TAF strives to apply the following core principles to all GHG quantification efforts:

Transparency

- The process, data, calculations and sources used should be clearly presented and ultimately enable a reader to replicate the results. Clearly and explicitly stating the methodology increases the trustworthiness of the results. It also allows third parties to identify any errors or improvements possible thus refining the quantification.

Consistency

- A key function of GHG quantification is to allow the comparison of values from year-to-year, between projects or between sectors. Using consistent approaches, assumptions and data sources helps the comparability between different GHG emissions values. By enabling good comparison trends can be observed, areas for intervention can be prioritized and/or projects can be assessed based on their GHG reduction potential.

Credible and Timely Data

- Data should be obtained from recognized, reliable and current sources. Poor quality data will result in poor quality estimates of GHG emissions and emissions reductions.

Accuracy

- Inaccurate GHG estimates can be worse than having no estimate at all because they can engender a false sense of confidence in the results leading to misdirection of resources and effort. All calculations should be double checked and, where possible, results should be cross-referenced with other sources. If a reasonable degree of accuracy cannot be achieved, an estimate should not be provided.

Rigor

- Attempt to consider the significant factors which might influence the GHG emissions being quantified. Generally, the more considerations made the more robust the quantification probably is. However, caution should be taken if considering an additional factor requires the use of poor data.

Key Concepts

This section describes key GHG quantification concepts necessary to understanding emissions calculations.

Fundamental Unit

There are numerous GHGs such as nitrous oxide, methane, and carbon dioxide which absorb and radiate heat back to the Earth's surface. In order to simplify and enable comparisons these various gases are all converted to a common unit for measuring GHG emissions: carbon dioxide equivalents (CO_2eq). GHGs are converted by their global warming potential (GWP) which is based on their ability to absorb and radiate back to the earth's surface relative to carbon dioxide (CO_2). CO_2 serves as the baseline and has a GWP of 1. Lastly, GHGs are measured by their mass (i.e. megatonnes, tonnes, kilograms, or grams of CO_2eq).

Emissions Factors

Emissions factors are ratios between an activity or the use of a resource and the associated amount of CO_2eq released (or not released) as a result. The most commonly used emissions factors are for the consumption (or conservation) of fossil fuels and electricity. TAF presently uses the below emissions factors, primarily sourced from the 2016 National Inventory Report (NIR 2016). Other emissions factors are sometimes required, for example for waste diversion, and are generated on an as needed basis based on best available data.

Resource	Factor	Unit	Source
Natural Gas	0.001899	tCO_2eq/m^3	NIR 2016
Electricity (Average)	0.000050	tCO_2eq/kWh	NIR 2016
Electricity (Marginal)	0.000146	tCO_2eq/kWh	TAF
Water[1]	1.9	kWh/m^3	TAF
Gasoline	0.0023	tCO_2eq/L	NIR 2016
Diesel	0.0028	tCO_2eq/L	NIR 2016

Table 1 - Common Emissions Factors for Ontario

Electricity Emissions Factors: Marginality and Time-of-Use

Emissions factors for electricity are typically more complex than emissions factors for direct fossil fuel combustion. Firstly, the carbon intensity of grid-supplied electricity fluctuates significantly over time, varying based on time-of-day, seasonally, and year-over-year. Additionally, average emissions factors (such as the Ontario factor from NIR 2016) do not accurately represent the emissions reduction potential of electricity conservation or renewable energy generation, even if an average factor is weighted for time-of-use. This is because average emissions factors do not take into account the response of the grid to marginal changes in electricity demand.

At any given point in time one specific generating resource is ‘on the margin’, meaning it will respond to any incremental increase or decrease in demand. A marginal emissions factor considers the source of electricity that is on the margin. By using a marginal emissions factor, a more accurate representation of the emissions reduction potential of conservation, renewable generation, or electricity storage can be gained. The marginal emissions factor can be calculated in numerous ways and differs between electricity systems. Based on publically available information from the IESO, TAF has developed marginal emissions factors for electricity.

As a general rule, when estimating the carbon footprint of an entity — whether it is a city, and organization, or a building — TAF uses an average emissions factor sourced from NIR. When estimating the emissions reduction potential of specific projects or policies, TAF uses a marginal emissions factor developed internally. If the electricity conservation/generation measure(s) being quantified has a known temporal profile, a time of use weighted marginal emissions factor can be used. In the absence of such information, an annual marginal factor provides a good

[1] This value was developed based on energy consumed by Toronto water operations and may not be applicable to other jurisdictions. Further refinement of this value is being undertaken.

approximation of emissions reduction potential. Average and marginal electricity emissions factors for future years can be found in Appendix B.

General Approach

TAF's fundamental approach to GHG quantification follows the below process:

Figure 1 – TAF's General GHG Quantification Process

A previous TAF quantification is provided in appendix C for reference.

Establishing a Purpose

The purpose of the quantification should be determined as a first step so that the results meet the needs. Below are some common reasons for GHG quantification and some considerations to be made based on the identified needs.

Purpose	Consideration
Identify opportunities for reduction	Granularity and context required to identify actions that can lead to significant reductions
Track emissions between years	Consistency of methods and data in order to compare between years and foresight of potential future changes
Meet regulatory requirements	Ensuring the process and output follow stipulations made in the regulations
Quantifying the reduction potential	Establishing a fair and consistent baseline and alternative scenario.

Table 2 - Common Purposes and Related Considerations for GHG Quantification

Boundary and Scope

When quantifying GHG emissions it is important and useful to create a boundary within which the emissions will be calculated. The boundary can be physical, organizational, jurisdictional or some other reasonable limit. Boundaries can be set in order to focus on specific emissions sources, to encompass a specific responsible party or to serve another purpose of the quantification.

Part of establishing a boundary is also establishing a scope which usually refers to the type of emissions to be quantified. Below are descriptions of conventional scopes as established by the Greenhouse Gas Protocol, an internationally recognized guide for quantifying GHG emissions.

Scope	Description	Example
1 - Direct	Emissions produced from when the activity is undertaken.	The gasoline used to operate a vehicle

2 – Indirect Electricity	Emissions from the generation of electricity used during the activity.	The electricity used for lighting in a building
3 – Other Indirect	Emissions which occur downstream or upstream of the activity.	The manufacturing emissions produced elsewhere associated with goods consumed in a city

Table 3 - Scopes According to the GHG Protocol

Generally, only scope 1 and 2 emissions are calculated as part of standard municipal GHG inventory protocols. This is because influence over scope 3 emissions is considered to be largely beyond municipal spheres of control. Also, assessing scope 3 emissions is more difficult and quantification methodologies for this area are less developed. However, recent studies have shown that scope 3 emissions from cities can be significant – even doubling a city's emissions profile – and so TAF will monitor international work addressing this challenge. If a GHG reduction potential is being calculated then the boundary and scope between the baseline and alternative scenario should be consistent unless there is a sound reason for them to be different.

Usage/Activity Data

Once the boundary and scope are established then the next step to quantification is identifying the fundamental activity or resource use which generates emissions. If the organization is seeking to reduce its emissions then it might be more useful to gather contextual data such as how much electricity is used to power computers or that air travel contributes to half of the organization's total emissions. If an organization is simply reporting its GHG emissions then it might be sufficient to convert the gasoline, electricity and natural gas consumption of that organization directly into GHGs without the detailed activity information.

If a potential reduction in emissions is being quantified then activity/usage data for the baseline and alternative scenarios need to be obtained. The alternative scenario could be a completely different activity/resource use or less of the same activity/resource use. An example of this would be estimating the GHG difference between different ways to get from home to work. If someone is currently driving a gasoline vehicle and considering driving an electric vehicle instead then driving with the gasoline vehicle would be considered the baseline while driving an electric vehicle could be the alternative. The main difference between the two would be the emissions produced per distance travelled.

Applying Emissions Factors

Multiplying the activities or resource usage by their corresponding emissions factors produces a final GHG emissions number. For example, if 1000 L of gasoline is consumed by an organization in a year then multiplying that value by the gasoline emissions factor of 0.0023 tCO_2eq/L results in a total GHG emissions of 2.3 tCO_2eq from gasoline consumption in that year.

If a potential reduction in emissions is being quantified then the difference between the baseline and alternative emissions is the potential reduction. Additionally, special attention should be paid to ensuring consistent units and timeframes are used.

Check Reasonableness

If possible, the resulting GHG quantity should be compared to another established GHG quantity to check if the value is sensible. For example, if a building is estimated to reduce its GHG emissions by 50% simply by installing a new chiller then the calculations might warrant revisiting, as experience shows that this level or reduction is not generally associated with implementation of updated chiller equipment.

Key Outputs

The output of TAF's GHG quantification analyses is usually an estimated impact on carbon emissions but, depending on purpose of the analysis, it may be an annual impact or a cumulative impact over a defined time horizon. Generally, TAF's primary focus in quantification is on the Cumulative GHG Reduction Potential. Below is a list of GHG metrics that are commonly generated as part of TAFs quantification activities.

Cumulative GHG Reduction Potential

- An assessment of the total GHG reduction potential associated with a project, policy, technology, or other initiative over a time horizon of up to twenty years. Assessment is based on a scenario incorporating assumptions on how quickly the initiative could take effect and scale up to its maximum potential. For some projects, a discount rate of 5% per year is applied to future GHG reductions and then summed into a value that TAF refers to as a Carbon Net Present Value or CNPV.

Average Annual GHG Reduction Potential

- An average of the annual GHG reduction potential quantified for a project, policy, technology or other initiative. This is equivalent to the Cumultative GHG Potential divided by the number of years in the time horizon.

Cumulative Direct GHG Reduction

- Where relevant, the direct GHG impact is quantified over a time horizon of up to twenty years. For example, with investments in energy retrofit projects, renewable energy projects, etc, the project will lead directly to GHG reductions. Time horizon is established based on the expected life of the project. The project may or may not also have a scale up potential that is separately assessed. A CNPV may also be calculated for these types of GHG reductions.

Average Annual Direct GHG Reduction

- An average of the annual Direct GHG reduction estimate for a project. Equivalent to the Cumulative Direct GHG Reduction divided by the number of years in the time horizon.

Additional Considerations

GHG quantification can be complex to perform. Understanding the concepts in this section can help inform the process and also improve the utility of the GHG emissions values produced.

Additionality

When considering the GHG reduction potential of an alternative it is important to consider what changes in the baseline might have occurred without the alternative. It might be the case that a certain amount of change would have happened without intervention due to other interventions or the general trend in that area. For example, it would be unreasonable to estimate that installing 100 new electric vehicle charging stations accounted for all of the increases in electric vehicle usage afterwards since electric vehicle usage is generally increasing year-to-year due to other factors such as reductions in vehicle cost. The new charging stations may be responsible for a percentage of the increase in electric vehicle usage.

Double Counting

Double counting is when calculations of emissions are added together despite them having some overlap. One potential cause of this is emissions activities which cross boundaries or organizations setting scopes which overlap. For example, if someone drove from Mississauga to Toronto and both cities counted the entire drive as part of their emissions then those emissions were double counted. It may be useful to do in this case since both cities can probably influence the choice of that decision but if the two cities' GHG inventories were added up to get a regional GHG inventory then that number may be overestimated.

Interactive Effects

It is important to consider the impacts that multiple related emissions reductions interventions have on each other. If a building installed more efficient water fixtures and a more efficient water heater then water is heated more efficiently and less water needs to be heated. Simply combining each individual measure's reductions to obtain the collective impact would result in an overestimation of savings in this case. Accounting for such interactive effects will produce more accurate GHG estimates.

Time Value

It is critical to consider the urgency of emissions reductions due to the increased difficulty and the diminished impact of reducing emissions in the future. Making decisions today which create emissions may increase the difficulty and/or cost of implementing an alternative in the future which could have resulted in reduced emissions. For example, it is far easier and cheaper to initially construct an efficient home than it is to construct an inefficient home and then retrofit it later on to become efficient. Further, by delaying emissions reduction actions, the impacts of climate change may intensify to a point where reducing a similar amount of emissions may not result in a similar reduction in climate change intensity. This can be observed by warming temperatures that reduce reflective snow and ice cover which in turn result in warmer temperatures and a positive feedback loop. As a result, reductions that can be achieved more quickly are more valuable – assuming they do not preclude the opportunity to achieve deeper subsequent reductions.

Cost Effectiveness

One factor that can be helpful in evaluating various GHG reduction strategies is the cost effectiveness of each strategy. Cost effectiveness is typically evaluated as $/t$CO_2$eq reduced.

Generally, such analysis should include the cumulative GHG reductions over the life of the project/measure, as well as the cumulative utility cost savings (if applicable) over the same time frame. The 'cost' per tonne of some emissions reduction strategies can be negative since reducing emissions typically means reducing resource consumption which in the long run can result in net savings.

Time Horizon and Scale-up Pathway

Depending on the purpose of the quantification, a time horizon is selected for the analysis. Most commonly, TAF applies a twenty year time horizon. If the purpose of the analysis is to quantify potential emissions reductions, assumptions must also be made about how a climate change mitigation measure, and the resulting GHG impact, could scale over time. For example, the scale up pathway for a policy reform initiative would reflect assumptions about when the policy might take effect, whereas the scale up pathway for a new technology would reflect assumption about market adoption potential.

Operational Practices

Below are descriptions of some specific considerations and approaches to GHG quantification based on the purpose.

Grants

TAF provides grants to projects which demonstrate a significant cumulative GHG reduction potential. Based on the information a grantee provides and additional research performed by TAF an emissions reduction potential is determined for each year of the project's lifetime up to a maximum of 20 years and a CNPV is calculated. The CNPV is then converted to a score out of 20 for a standard grant[2] and a score out of 25 for a concept development grant. A CNPV of 1,000,000 tCO_2eq or more is given the highest score possible while lower CNPVs are scored proportionally. The GHG score is then provided along with other scores which assess other aspects of the grant proposal to the Grants and Programs Committee to inform their decision making.

Key Performance Indicator

In order to track organizational progress towards the goal of combating climate change TAF tracks the GHG reduction potential of the projects it pursues as one of TAF's key performance indicators. The cumulative GHG reduction potential from all grants, direct investments, and other projects initiated in a given year are summed to create the GHG KPI for that year.

Direct Investments

Part of TAF's GHG reduction strategy is to fund or finance projects with direct emissions reductions. Direct investments typically aim to reduce an explicit quantity of resource consumption (such as cubic metres of natural gas) and the reduction can be fairly accurately calculated prior to pursuing the project. This reduction potential is assessed along with financial

[2] As part of the score of a standard grant, the external probability of success is scored out of 5 and added to the GHG score.

parameters and a plan to measure the actual savings in order to determine if the investment should be made. After an investment is approved, a measurement and verification plan is typically implemented and savings are continuously monitored to ensure the investment objectives are met. In some cases, direct investments also have a scale up potential that is also assessed (e.g. seed funding to a renewable energy cooperative that is expected leverage that investment by raising private capital in the marketplace).

Exploratory Research

New areas, technologies, methods and policies for GHG reduction are constantly sought out by TAF. GHG quantification for exploratory research generally results in a coarse estimate of emissions most likely accurate on an order of magnitude scale and often uses assumptions to fill in gaps in data. However, exploratory research can uncover significant areas of emissions and reduction potentials previously unknown or undetermined and thus is a valuable effort worth pursuing. Further analyzing the impacts of scope 3 emissions is one example of emissions which could be significant and have a high reduction potential.

Internal Projects

TAF also pursues GHG reduction projects which it internally cultivates and manages. Direct and potential emissions impacts of these internal projects are assessed similarly to direct investments.

Policy Impacts

Many internal projects and grants funded by TAF focus partly or wholly on policy solutions to climate change. Historical analysis of TAF's performance shows that the biggest reductions supported by TAF have come from policy-related outcomes. Some policies pursued locally mimic existing policies in other jurisdictions so consequently the emissions reductions can also be modelled based on the existing policies' impacts. However, differences between the economic, political and social climate of different jurisdictions may affect the transferability of impacts. Policy impacts are often broad and can affect a large portion of a jurisdiction's emissions so the scale-up potential, breadth of impact and depth of impact need to be given careful consideration.

Historical GHG Impact Potential

TAF reports the total Cumulative GHG Reduction Potential of all TAF supported initiatives each year as part of our annual report, as well as historical figures for comparison. The table below illustrates the reported Cumulative GHG Reduction Potential of TAF supported initiatives in a variety of historical periods. Bear in mind that the numbers represent the total cumulative potential impacts estimated for all TAF supported initiatives in that time period, over the lifecycle of those projects (up to 20 years). The annualized average Cumulative GHG Reduction Potential over TAF's history is 6.1 MtCO_2eq, meaning that in a typical year TAF supports initiatives with estimated 20 year reduction potential of 6.1 MtCO_2eq. With the additional resources provided by the Province, we would expect to better that average in future years. However, one must also bear in mind that much of the lowest hanging fruit has already been picked, and as GTHA GHG emissions continue to decline, further reductions may be increasingly challenging.

Historical Period	Cumulative GHG Reduction Potential from TAF supported Projects	
	Total Cumulative GHG Reduction Potential during period	Average Cumulative GHG Reduction Potential per annum
1991-2006	70.3 $MtCO_2eq$	4.4 $MtCO_2eq$
2007-2010	34.8 $MtCO_2eq$	8.7 $MtCO_2eq$
2011-2015	47.5 $MtCO_2eq$	9.5 $MtCO_2eq$
1991-2015	152.6 $MtCO_2eq$	6.1 $MtCO_2eq$

Appendix A - Terms and Abbreviations

Baseline scenario: a theoretical situation intended to reflect what would occur without any GHG reduction interventions.

Carbon Dioxide (CO_2): a molecule consisting of a carbon atom and two oxygen atoms. Carbon dioxide is a common greenhouse gas.

Carbon Dioxide Equivalent (CO_2eq): a common unit various greenhouse gases are converted to based on their global warming potential.

Carbon Net Present Value (CNPV): The quantity of carbon produced or reduced during the project lifetime discounted to the present in order to account for the reduced impact in the future.

Emissions Factor (EF): A ratio of greenhouse gas emissions to the use of a resource, typically the burning of a fossil fuel.

Greenhouse Gas (GHG): a gas which absorbs and reradiates infrared radiation which contributes to the greenhouse gas effect.

Global Warming Potential (GWP): A factor applied to greenhouse gases based on their greenhouse gas effect potency relative to CO_2.

Marginal Emissions Factor (MEF): A ratio of greenhouse gas emissions to the use of a resource which attempts to reflect the actual emissions reduced by accounting for factors such as the time of consumption.

Project Lifetime: A duration encompassing when a project produces and/or reduces emissions up to a maximum of 20 years.

Appendix B – Future Electricity Emissions Factors

Year	Average Electricity Factor (tCO_2eq/kWh)	Annual Marginal Electricity Factor (tCO_2eq/kWh)
2016	0.0000321	0.000149
2017	0.0000266	0.000151
2018	0.0000245	0.000153
2019	0.0000218	0.000156
2020	0.0000239	0.000158
2021	0.0000254	0.000160
2022	0.0000261	0.000162
2023	0.0000297	0.000165
2024	0.0000240	0.000167
2025	0.0000332	0.000169
2026	0.0000269	0.000172
2027	0.0000276	0.000174
2028	0.0000260	0.000176
2029	0.0000274	0.000179
2030	0.0000266	0.000181
2031	0.0000314	0.000183
2032	0.0000278	0.000186
2033	0.0000290	0.000186
2034	0.0000314	0.000186
2035	0.0000359	0.000186

TAF

Appendix C – Quantification Example

When the City of Toronto was contemplating an energy reporting benchmark bylaw for large buildings (>50,000 ft^2) TAF estimated the policy's GHG reductions potential. The purpose of the quantification was to demonstrate the contribution this policy would have on reducing Toronto's GHG emissions. The boundary was large buildings within the City of Toronto and scope 1 and 2 emissions were included in order to maintain comparability to the City of Toronto's emissions inventory.

The data required was energy use by type for buildings in Toronto over 50,000 ft^2. Based on a Halsall report, there was approximately 17,309,742 m^2 of such buildings in the commercial sector. It was assumed that residential buildings over 4 storeys were at least 50,000 ft^2 and StatsCan data showed there were 545,840 dwellings in buildings over 4 storeys. Natural gas and electricity energy use intensity for commercial buildings were determined from NRCan's Comprehensive Energy Use Database[3] to be 13.27 m^3/m^2/year and 125.03 kWh/m^2/year, respectively. The same database showed each apartment unit > 4 storeys had an average natural gas and electricity consumption of 1067.7 m^3/year and 3493.62 kWh/year, respectively.

Another piece of information required was the potential energy reduction from this type of policy. Energy Star Portfolio Manager is an online platform that enables the tracking of building energy use on a voluntary basis and thought to be a reasonable comparison. A three year study[4] of Portfolio Manager showed an annual average energy savings of 2.4% from the buildings using the platform and was assumed to be the impact of the energy reporting and benchmarking bylaw. TAF felt it was unrealistic for savings to persist at the same level, a 5% reduction in savings was assumed each year going forward.

The emissions factor for natural gas was obtained from the National Inventory Report[5] as 0.001891 tCO_2eq/m3 and assumed to remain constant into the future. The emissions factors for electricity was taken from Ontario's Independent Energy Systems Operator's Long-Term Energy Plan[6] and was 0.0000916 tCO_2eq/kWh in 2012 with it generally decreasing into the future.

One additional consideration made was that New York had implemented a similar policy (Local Law 84) and demonstrated a 84% compliance rate which was applied to this calculation.

The resulting calculation showed an average annual emissions reduction of 227,707 tCO2eq/year over the next 20 years. This is approximately 2.3% of Toronto's buildings emissions in 2012 which seemed like a reasonable estimate given the portion of buildings included, growth in reductions, and scale of such a policy.

---

[3] http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm
[4] https://www.energystar.gov/sites/default/files/buildings/tools/DataTrends_Savings_20121002.pdf
[5] http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php
[6] http://www.ieso.ca/Documents/LTEP/LTEP_2013_Consolidated_Figures_and_Data_Tables.pdf