WHITE PAPER

MEASURING UP TO GLOBAL WARMING

TORONTO, ONTARIO

WHITE PAPER

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SUBMITTED TO

Michael Singleton
Sustainable Buildings Canada
33 Longboat Avenue
Toronto, Ontario M5A 4C9
mike-singleton@rogers.ca

SUBMITTED BY

Mike Williams
Principal, Sustainability
mike.williams@rwdi.com

Chris Frankowski
Sustainability Consultant
chris.frankowski@rwdi.com

Greg Allen
Senior Associate, Rivercourt Engineering Inc.
greg.allen@rivercourt.ca

RWDI
600 Southgate Drive,
Guelph, Canada, N1G 4P6
T: 519.823.1311
F: 519.823.1316

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1 FOREWARD

This study was undertaken for Sustainable Buildings Canada as part of a series of research activities that are intended to advance the science and understanding of energy use and greenhouse gas emissions as they may be impacted by building design and operations, equipment specification and market operations. Any errors and omissions, conclusions and recommendations are purely the responsibility of the project team.

2 ABSTRACT

The intention of this white paper is to summarize the current landscape of CO_2e emission factors, to describe how these factors were calculated and what they represent, and to identify issues in the current methods of deriving these emission factors. This white paper can be used to inform building design teams and energy modellers in the selection of an appropriate emission factor, as well as to show program designers and regulators the implication that their choice of CO_2e emission factor will have on building sector GHG emissions.

A selection of emissions factors, including the current Ontario Building Code (OBC) emission factors, the proposed changes to the OBC, and additional marginal and average emission factors, are reviewed and applied to an archetype energy model to compare the implications these factors have on decision making in new building design.

2.1 Key Findings

1. GHG emissions from the combustion of natural gas are likely significantly underestimated by allocating upstream emissions to the industrial production of natural gas rather than end use combustion.

2. There is a 10 times range in the electricity CO_2e emissions factors that are referenced by various calculation methodologies, leading to confusion in the design community and the potential for misdirection. This should be a point of caution and concern in the adoption and development of CO_2e performance targets.

3. Using the OBC 2012 CO_2e methodology, which is a marginal electricity factor, encourages the use of natural gas fueled systems, while using the OBC 2017 methodology, which is an average methodology, heavily favours electric systems.

4. There is a need for the development of a CO_2e calculation methodology that is sufficiently comprehensive while balancing the need for simplicity in ease of use.

3 INTRODUCTION

In an effort to begin to curb the impacts of climate change, ambitious Green House Gas (GHG) reduction targets have been established nationally, provincially, and in many municipalities. The graph below summarizes the current targets in Canada, Ontario, and Toronto. The red bars represent the established baseline year from which reductions are measured; the pink bars represent the result of the latest inventory; with the green bars representing future targets.

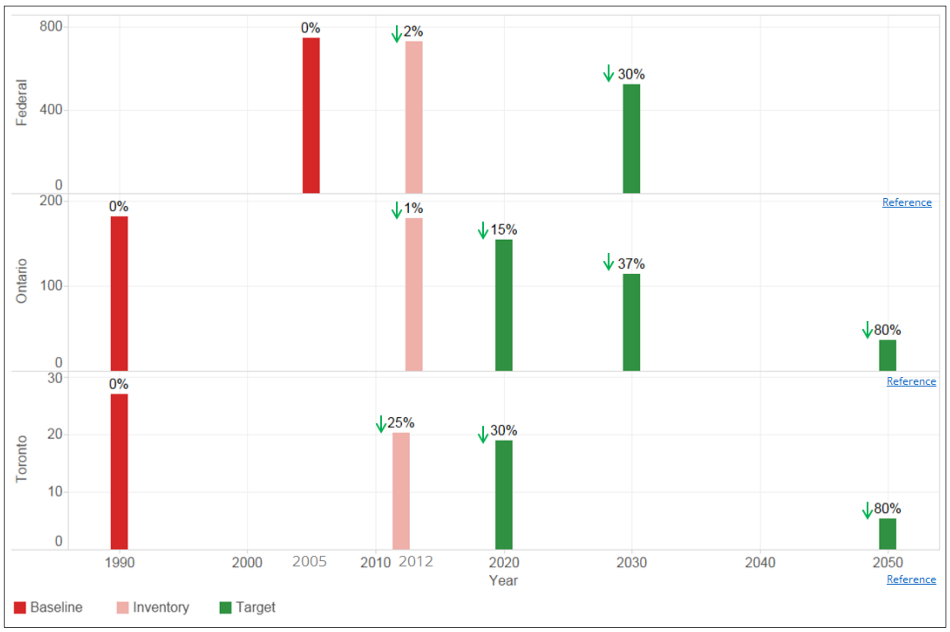

Figure 1: GHG Emission Baselines, Inventories, and Targets

It is widely acknowledged that buildings are responsible for a large portion of reported emission inventories. To date green building rating systems, building codes and incentives have primarily encouraged reductions in energy use or energy cost. However, it is known that a reduction in energy use does not equate directly to a reduction in GHG or equivalent carbon emissions (CO_2e).

Programs such as the OBC and the Toronto Green Development Standard (TGS) have identified this important difference and are now requiring that new building developments estimate their CO_2e footprint. These efforts are laudable; however, the variance in calculation methodologies supported by each of these programs is a point of caution and potential concern.

The pursuit of financial incentives or the need to meet regulatory requirements will impact choices made by design teams in the types of systems that are considered in early design stages. Depending on the CO_2e calculation methodology that a program decides to reference, certain technologies and features may be deployed in new building construction and these choices will impact the actual amount of CO_2e emissions from buildings for decades to come.

The intention of this paper is to compare various methodologies for calculating a building's annual GHG emissions, and will specifically examine the impact of CO_2e emission factors for grid delivered electricity on calculated GHG emissions of various building designs.

The selection of the methodology that most accurately reflects reality, while still being simple enough for industry adoption, will assist designers to make choices that minimize the actual GHG emissions of new buildings.

4 CALCULATING BUILDING GHG EMISSIONS

GHG emissions are typically calculated by multiplying a constant GHG emission factor for each source type by the annual consumption of each energy source required by a building to meet energy demands. This methodology assumes that the GHG emissions resulting from electricity generation are constant at all hours of the day, and at all times of the year. Since the GHG emissions of electricity generation is dependent on the supply mix of the electricity grid, and the supply mix fluctuates throughout the day and year; this simplification neglects some of the realities of the impact of the electricity grid as a system. Even using this simplified methodology, there is a wide range of CO_2e emission factors that are currently being used in Canada. This paper compares the results of using these varying emission factors as well as some more detailed methods that estimate the hourly emission factors.

The hourly CO_2e emission factors will be combined with hourly energy use by fuel type from an energy model of an archetype building. This reflects the process that is followed during new building design when considering various energy and carbon efficiency options. The archetype design and the two system types that were considered are described in the next section.

5 EMISSIONS FROM NATURAL GAS COMBUSTION

There are 2 key issues with respect to the CO_2e emission factor for the combustion of natural gas that is commonly used today. The first problem is that the emission factor does not comprehensively consider the upstream emissions associated with natural gas, which current research suggests are significant. The second problem is caused by the choice of Global Warming Potential (GWP) time period that is used for methane. Currently the 100-year value is used, which misses the significant impacts that methane emissions will have on climate change in the shorter term.

The CO_2e emission factor for natural gas combustion specified in the OBC is 191 g / kWh, while a more comprehensive value that includes upstream emissions and uses the more appropriate 20 year GWP triples (U.S. Environmental Protection Agency, 2011) the emission factor to 602 g / kWh. Research on the methane emissions associated with hydraulic fracturing and shale gas development calculate the GHG emissions of shale gas as 965 g / kWh (Howarth, 2015), using the mean of likely methane emissions. Resolving this issue will be critical for the accurate accounting of GHG emissions and abatement strategies. Buildings designs that reference a lower emission factor for natural gas use will clearly have a lower GHG outcome.

As all of the methods reviewed in this report assume that there are no emissions associated with non-fossil fuel forms of electricity generation (In Ontario, all emissions are caused by natural gas combustion), changing the natural gas emission factor would equally affect natural gas combusted in a building or at an electricity generation facility. Put another way, changing the emission factor will scale the results, but will not change the relative positions of the results. In order to review and compare the existing CO_2e emission methodology, the current OBC CO_2e emission factor for natural gas will be used throughout this paper. However, this simplification should not detract from the underlying issue that CO_2e emissions from natural gas consumption may be underestimated; a matter that requires immediate attention and revision in the development of a more comprehensive approach to the calculation of CO_2e emissions from buildings.

6 CATEGORIZING EMISSION CALCULATION METHODOLOGIES FOR GRID DELIVERED ELECTRICITY

The CO_2e emission calculation methodologies for grid delivered electricity can be categorized by two different characteristics, what they are meant to represent (the existing system or changes to the system), and their time scale (an hourly value or a constant value). These categorization methods are explained below, followed by a review of a selection of CO_2e emission methodologies.

6.1 Average and Marginal Emission Factors

There are two general categories of methodologies for determining the GHG emissions of electricity generation; average and marginal. The “average emission” factor can be calculated by dividing the GHG emissions of electricity generation facilities by the amount of electricity they produce. The average emission factor represents the emissions of the combined electric system, as is. Alternatively, a variety of methods can be used to try to estimate the way generating facilities are dispatched to reflect the impact of adding or removing load from the electric grid. These methods produce “marginal emission” factors, which are intended to reflect the emissions associated with a load, for example a new building, being added to the electrical grid. The factors considered in this report are labelled with a trailing (M) and (A) to identify them as marginal or average, respectively.

6.2 Constant and Time Variable Emission Factors

The most prevalent CO_2e emission calculation methodologies are constant, meaning they are a single value meant to be applied for all energy use. The benefit of using a constant emission factor is that it provides a straightforward calculation of annual GHG emissions once annual fuel consumption has been estimated. This ease of use comes at the expense of accuracy and the failure to recognize peak shifting and other demand side management activities that can significantly alter the generation mix.

In Ontario, the Independent Electricity System Operator (IESO) is responsible for balancing supply and demand for electricity and directing transmission. The GHG emissions of an electricity generation facility are dependent on the energy source, and therefore the collective GHG emissions of the electricity grid are dependent on the total supply mix. As the supply mix is constantly changing in response to the system demand, the actual CO_2e emission factor is also constantly changing. Accordingly, the time that electricity is consumed affects the GHG emissions that are associated with its generation. A time variable emission factor is a series of values that better reflect the variability of the electricity system supply mix. The factors considered in this report are labelled with a trailing (C) and (V) to identify them as time constant or variable, respectively.

7 CURRENT CO_2e CALCULATION METHODOLOGIES

7.1 Electricity from Natural Gas in Ontario (A, C)

The emission factor for electricity generated through natural gas combustion can be calculated from the values included in the National Inventory Report (NIR) (Environment and Climate Change Canada, 2016). In the NIR, Table A13-7 *Electricity Generation and GHG Emissions Details for Ontario* includes the annual electricity generation from natural gas and the associated GHG emissions. The emission factor for 2013 (latest non-preliminary result available) is calculated as 506 g / kWh. This value does not include unallocated energy (transmission line losses, metering differences and other losses) or SF_6 emissions (the electric utility sector's share of emissions from electrical equipment).

7.2 OBC 2012 (M, C)

The Ontario Building Code includes energy efficiency requirements as well as CO_2e emission factors for various fuel types that are required to be used in calculating a building's annual CO_2e emissions when applying for a building permit. The emission factor for 'Grid Delivered Electricity' is 400 g / kWh, and includes the label *"marginal based on natural gas".* It is not clear which specific method was used in determining the marginal emission factor, however, if it is intended to represent marginal generation being entirely supplied by natural gas, it is ~20% lower than the emissions reported in the NIR.

7.3 TAF 2015 (M, V)

The Toronto Atmospheric Fund (TAF) undertook an effort to develop a marginal emission factor for Ontario that is intended to more accurately represent how the province's generating facilities are dispatched by reviewing various published methods. Their report, *Marginal Electricity Emissions Factors for Ontario* concluded that the

Dalhousie method best reflected the hourly fluctuations in marginal emissions and produced reasonable values, and is included in our review.

7.4 TAF 2032 (M, V)

In addition to the historic data, TAF also projected the marginal emission factor for the year 2032 following the same methodology. Their report considered the IESO's Long Term Energy Plan (LTEP), and assumed that the 30 TWh currently labelled as being provided by conservation measures is instead provided by natural gas power plants. This would approximately double the current marginal emission factor for electricity in Ontario by 2032.

7.5 IESO Generator Output (A, V)

The IESO publishes their hourly electricity generation for each facility that has a capacity of more than 20MW. The fraction of total electricity supply from natural gas can be applied to the emission factor of electricity from natural gas to determine the average hourly emission factor. A representative daily load profile was found by averaging each hour of a day from the annual hourly data. The averaging was performed to remove randomness from the data caused by weather and other irregularities, such as maintenance of generation facilities. Attempts to maintain greater data granularity, for example, calculating a daily load profile for each season, found that too much randomness was carried into the analysis. The results between years were inconsistent, and the additional granularity failed to provide a benefit. This is also the methodology that was followed by Provident Energy in their white paper *CO_2 Emission Analysis of Air Source Heat Pump Systems*.

7.6 OBC 2017 (A, C)

The updates to OBC that went into effect January 1, 2017 substantially change the CO_2e factor to be used for electricity from that found in OBC 2012. By changing from a marginal to an average emission factor, the value has been reduced by a factor of 8, from 400 g / kWh to 50 g / kWh. The significant change is interesting and could be a response to changes on the supply or demand side of the electricity grid, or a reconsideration of the appropriateness of the methodologies.

Figure 2 provides a summary of the CO2e emissions factors associated with each calculation methodology considered in this review.

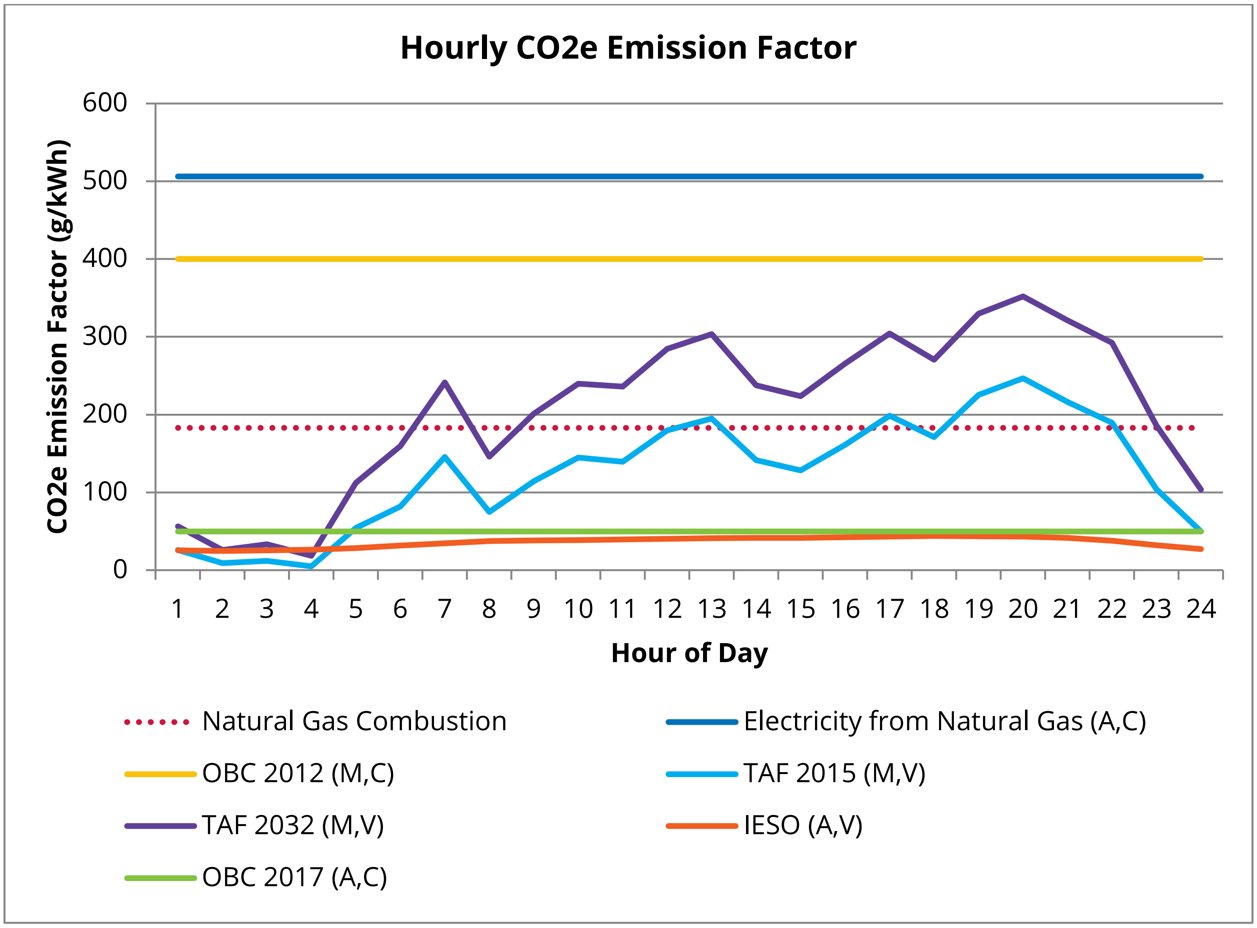

Figure 2: Summary of Hourly CO_2e Emission Factors

8 EXAMPLE APPLICATION OF CALCULATION METHODS

To illustrate the significance of the differences between the various CO_2e calculation methodologies, the methodologies were used to calculate the GHG emissions of a modelled building. An energy model was developed for an archetype building. An archetype is a building intended to represent a typical example from a select class of buildings. The archetype building considered two typical mechanical system configurations that are commonly used in new construction of this type of building. Both of these systems would be considered high performance systems from an energy efficiency perspective. Maintaining system equivalence was necessary to isolate the impact of the choice of emission factor on calculated GHG emissions.

Annual energy simulations were then conducted to estimate the annual fuel consumption profiles and totals. The results of the simulations for the two modelled systems are summarized in Figure 3.

8.1 Archetype Description

The archetype design is a 33-storey 45,000 m^2 multi-unit residential building (MURB) located in Toronto. The two system configurations that were considered are described in further detail as follows. System 1, the electric option (EO), is based on a water sourced Variable Refrigerant Flow – Heat Recovery (VRF-HR) system with in-suite Energy Recovery Ventilators (ERVs) for outdoor air ventilation, as well as electric domestic hot water heaters. System 2, the natural gas heating option (NGHO) includes a Dedicated Outdoor Air System (DOAS) for ventilation, while four pipe fan coils provide heating and cooling for the suites, and domestic hot water is supplied by natural gas boilers.

The energy use profiles for the two systems are shown in Figure 3. The archetype building with the NGHO system uses natural gas for space heating and hot water, (NGHO Natural Gas), with the remainder of the building loads, such as lighting, plug loads, and fans are supplied by electricity (NGHO Electricity). The sum of the electricity and natural gas loads for the archetype with the NGHO system is labelled NGHO Total. The archetype building with the electric option system uses only electricity for all building loads (EO Electricity). The shapes of the profiles are typical of a residential building in a heating dominated climate: energy use declines during the day when residences are usually unoccupied and solar gains reduce heating loads, which are the largest of the building loads.

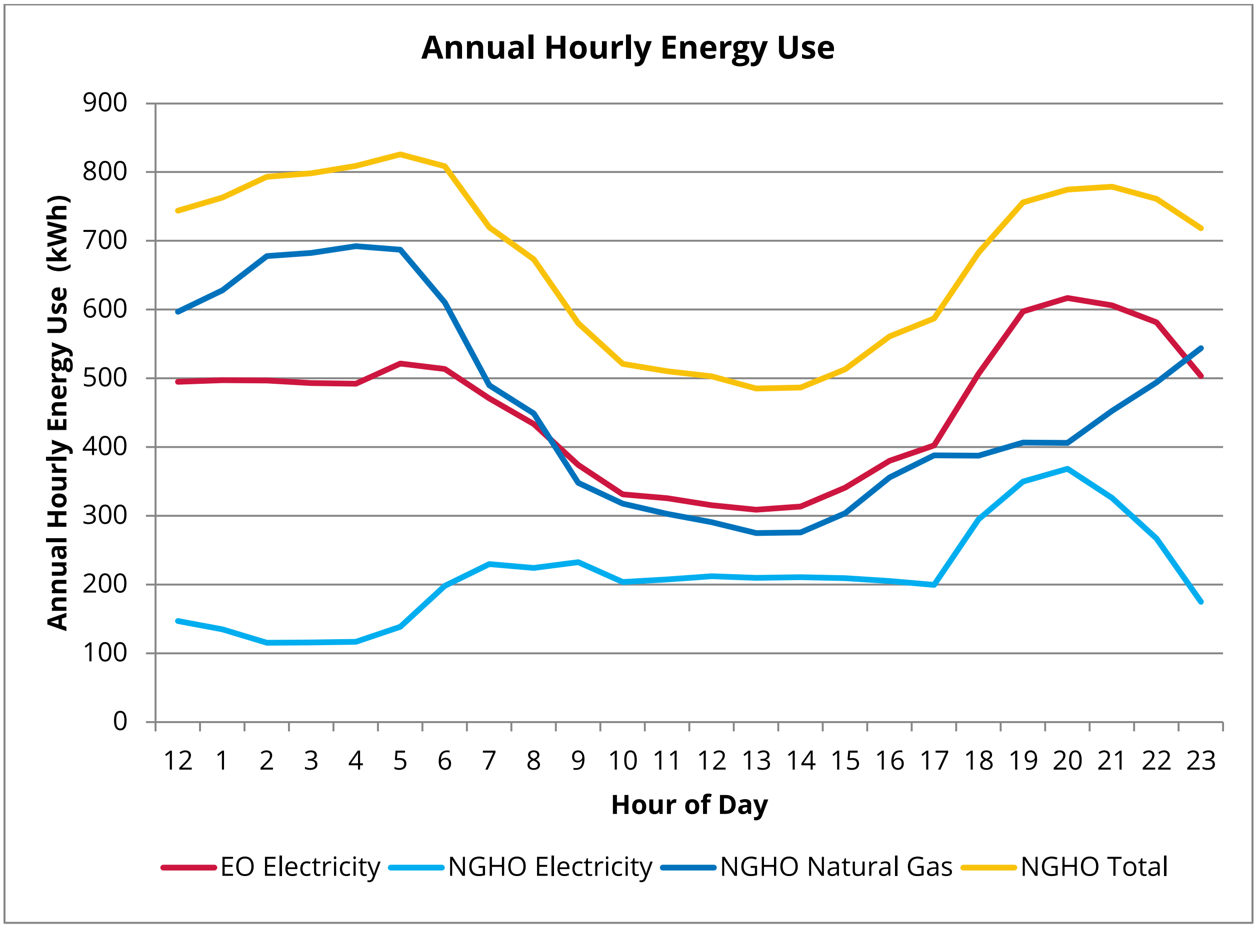

Figure 3: Hourly Energy Use of Archetype Designs

9 RESULTS

Combining the hourly energy use profiles from the energy models with the CO_2e factors for grid delivered electricity reviewed in Section 7 calculates annual CO_2e emissions for the two building system configuration options, presented in Figure 4.

The results show that depending on the CO_2e calculation methodology used, the calculated GHG emissions vary by a factor of more than 10. Another significant conclusion is that depending on the CO_2e factor that is used for grid delivered electricity, the building system design that would be selected to minimize GHG emissions could change. Put another way, a design team using the OBC 2012 method would select a natural gas heating system and using the OBC 2017 method would select an electric heating system.

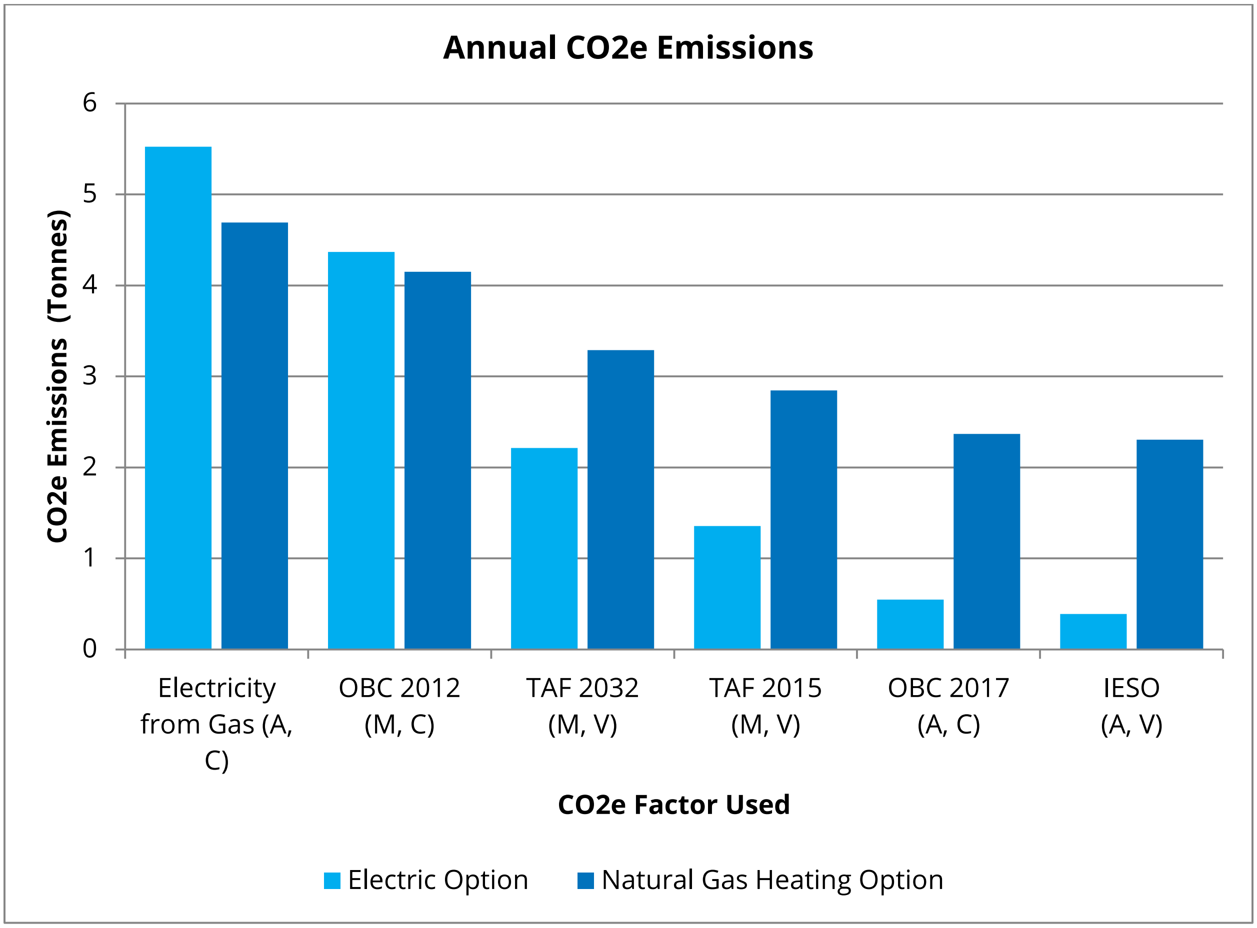

Figure 4: Calculated Annual CO_2e Emissions

Some would argue that the current OBC 2012 (M, C) calculation method is misleading design teams to the construction of buildings with natural gas systems by overestimating the CO_2e emission factor for electricity, leading to higher actual GHG emissions. While others could argue that the OBC 2017 (A, C) methodology does not sufficiently consider the marginal impact of additional load from new buildings on the electricity grid. However, following the changes to the OBC, the results fall in line with the results of the other CO_2e methodologies that were reviewed, which suggest that electricity is the preferred fuel from a GHG emissions perspective in Ontario.

10 REQUIREMENTS FOR THE DEVELOPMENT OF A STANDARD PROCEDURE FOR GHG ACCOUNTING

As the foregoing analysis illustrates, current methods of calculating GHG emissions of buildings are deficient and inconsistent. GHG accounting is important to building energy practitioners as regulations, programs, and emissions trading are increasingly calling for creditable calculations. There is a need for authoritative directives to be developed. Based on a comprehensive review of best practices, relevant research, and Ontario's circumstances, the following recommendations of approach are offered.

To be useful, simplified methods of GHG accounting needs to be developed. Larger projects will warrant more precise calculations, likely employing hourly energy models. Smaller projects may use simpler averaging factors. For electricity, IESO's system modeling will be required to determine marginal emissions factors that are sufficiently accurate and rigorous. Trial application of the tools for a range of building types and scenarios should then be tested against the detailed electrical system model results.

10.1 Adopt the Greenhouse Gas Protocol for Project Accounting

To develop standardized procedures and factors for calculating emissions, it is necessary to establish protocols that are appropriate for applications to buildings. The World Resources Institute and the World Business Council for Sustainable Development have spearheaded the Greenhouse Gas Protocol initiative and developed the Greenhouse Gas Protocol for Project Accounting (World Resources Institute & World Business Council for Sustainable Development, 2006) and other supporting documents (World Resources Institute & World Business Council for Sustainable Development, 2007). These are the most widely used international standards for GHG accounting and have formed the basis of ISO 14064-1 and the Climate Registry for North American jurisdictions. These represent creditable approaches that might be applied in the Ontario context.

10.2 Include Upstream Emissions of Ontario's Fuel Imports

Consistent with the protocols referenced above, the indirect emissions of GHG's should be included when calculating the reductions due to a project's GHG mitigation activity. These emissions are included in national inventory reporting but Ontario's inventory only includes emissions within its borders. For buildings, these would apply to both direct fuel usage and electricity generated by fossil fuels.

10.3 Base Upstream Emissions on Current Research

Several studies, based on satellite and aerial measurements, offer considerable improvement to estimates of North American fossil fuel production and delivery. The US-Canada Joint Action to Reduce Methane Emissions sets out a target of 45% reduction of fossil fuel fugitive methane by 2025 but skepticism of achieving this goal has been expressed by producers. Updated accounting of fugitive emissions are provided by Dr. Howarth in *Methane emissions and climatic warming risk from hydraulic fracturing and shale gas development* (Howarth, 2015).

10.4 Apply 20-Year GWP for Methane

As recommended in the Ontario Environment Commissioner's reports, *Facing Climate Change* and *Conservation: Let's Get Serious* (Environmental Commissioner of Ontario, 2016a, 2016b), the Ontario government should apply the most current IPCC published GWP for 20 years, not 100 years as has been the convention. Climate model projections indicate that a 1.5 C rise in global temperature will occur within the next 10 years if aggressive methane mitigation is not undertaken (Allen, 2015); hence, the shorter term impact is more relevant. This places methane as greater source of potential GHG than CO2 for Canada's GHG emissions.

10.5 Base Accounting on New Generation Marginal Emissions

Efforts to refine GHG factors for electricity through marginal accounting have relied on analysis of hourly generation mix over previous periods. This approach attempts to interpret what IESO dispatch protocols are for fossil fuel generators and the various techniques of data analysis result in wide variability of operating margin estimations. The actual dispatch response to load variation is particular to each regional utility and IESO has modeling capability to predict operations under differing load scenarios. This is the only way to match up building energy modeling with marginal GHG emissions.

10.6 Account for Current and Future Emissions Reductions

What is of concern is not what emission reductions would have occurred under previous utility operations but what reductions are achieved proceeding into the future. Ontario's electricity system has exhibited large variability on an annual basis and is projected to undergo substantial changes over the next several years. Since a GHG accounting method for buildings, the dominant load sector, is intended to effect changes on the demand side, the supply side will adapt accordingly. The ability to change building energy characteristics that will result in lowering GHG emissions by the utility is the purpose. In the nomenclature of the GHG Protocols, this is called the Build Margin. Since Climate Action policy and Cap and Trade directly affect operations and planning of the IESO, the role that demand-side activities require a hand-in-hand approach.

10.7 Account for Displacement of System Services That Use Natural Gas

Combined cycle gas turbines (CCGT), which dominate Ontario's gas generation, must run at a minimum loading point of around 50% of their peak capacity in order to be available for ramping (load following). At times, the power delivered displaces zero-emitting generation that is available. Since a building can be enabled to have load or supply dispatched, this attribute contributes ramping capacity and, when aggregated across many buildings, allows CCGT's to be turned off thus avoiding emissions and increasing wind, hydraulic, and solar utilization. Demand dispatch aggregation is viewed by IESO as a valuable and underexploited resource.

Ancillary services such as voltage and frequency stabilization and spinning reserve may be met by a variety of building-level measures such as batteries and PV invertors. To the extent that ancillary services currently provided by natural gas plants can be replaced by such distributed assets, there will be reductions in GHG emissions even though the energy quantities are negligible.

10.8 Account for Transmission and Distribution Losses

Line and transformer losses average about 8% of the energy generated. The power losses are proportional to the square of the current so that during peak periods, the losses are much greater, reaching more than 20% at times. Since gas-fired generation increases during these periods, there are very significant GHG reductions to be achieved with load management and conservation. The losses also vary by location but this may not be as significant an issue as time-of-use, in GHG emission factors for delivery loss reductions.

10.9 Engage and Inform Stakeholders

Building owners and design professionals, utilities, climate change analysts, and government should be represented in an initiative to develop the specific accounting standards outlined above. The Provincial Government's climate change initiatives would benefit directly from standardized accounting of avoided emissions and should provide direction and support for its development.

11 REFERENCES

Allen, M. (2015). *Short-Lived Promise? The Science and Policy of Cumulative and Short-Lived Climate Pollutants*. Retrieved from http://www.oxfordmartin.ox.ac.uk/downloads/briefings/Short_Lived_Promise.pdf

Environment and Climate Change Canada. (2016). *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada*. Retrieved from http://unfccc.int/files/national_reports/annex_i_ghg_inventories/national_inventories_submissions/application/zip/can-2016-nir-14apr16.zip

Environmental Commissioner of Ontario. (2016a). *Conservation: Let's Get Serious Annual Energy Conservation Progress Report - 2015/2016*. Retrieved from http://docs.assets.eco.on.ca/reports/energy/2015-2016/ECO_Conservation_Lets_Get_Serious.pdf

Environmental Commissioner of Ontario. (2016b). *Facing Climate Change Greenhouse Gas Progress Report 2016*. Retrieved from http://docs.assets.eco.on.ca/reports/climate-change/2016/2016-Annual-GHG-Report-EN.pdf

Howarth, R. W. (2015). Methane emissions and climatic warming risk from hydraulic fracturing and shale gas development: implications for policy. *Energy and Emission Control Technologies*, *3*, 45–54. https://doi.org/10.2147/EECT.S61539

IESO. (2016). *MODULE 2: Demand Outlook*. Retrieved from http://ieso.ca/Documents/OPO/MODULE-2-Demand-Outlook-20160901.pdf

U.S. Environmental Protection Agency. (2011). *Inventory of U.S. greenhouse gas emissions and sinks: 1990-2009*.

World Resources Institute, & World Business Council for Sustainable Development. (2006). *The GHG Protocol for Project Accounting*. Retrieved from http://www.ghgprotocol.org/standards/project-protocol

World Resources Institute, & World Business Council for Sustainable Development. (2007). *Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects*. Retrieved from http://wbcsdpublications.org/project/guidelines-for-quantifying-ghg-reductions-from-grid-connected-electricity-projects/.

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