TAF The Atmospheric Fund

A Clearer View of Ontario's Emissions

Updated electricity emissions factors and guidelines

2021 EDITION

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TAF The Atmospheric Fund

About The Atmospheric Fund

The Atmospheric Fund (TAF) is a regional climate agency that invests in low-carbon solutions in the Greater Toronto and Hamilton Area and helps scale them up for broad implementation. We are experienced leaders and collaborate with stakeholders in the private, public and non-profit sectors who have ideas and opportunities for reducing carbon emissions. Supported by endowment funds, we advance the most promising concepts by investing, providing grants, influencing policies and running programs. We're particularly interested in ideas that offer benefits beyond carbon reduction such as improving people's health, creating local green jobs, boosting urban resiliency, and contributing to a fair society.

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Ontario TORONTO

Content

Executive Summary

Accurate emissions factors are the backbone of climate action strategy

Regulation of carbon emissions and investment in climate solutions are gaining momentum worldwide, which is why it’s more important than ever to practice accurate emission quantification. Only with precise emissions calculations can we properly identify, prioritize, and monitor climate change mitigation strategies.

Conventional methods to quantify emissions can oversimplify and distort the data. Looking specifically at electricity systems, outdated and inaccurate emissions factors can result in poor decision-making such as underinvesting in conservation, grid improvements, the shift to renewables, or underestimating the climate impacts of carbon-intensive electricity generation like natural gas.

Each jurisdiction has a unique electricity mix, but most provinces and territories count on at least some natural gas generation. In Ontario, more than 90% of electricity is produced carbon-free (hydro, nuclear, renewables), but the remainder comes from natural gas, especially during peak hours. While natural gas supplies a small share, they are disproportionately likely to be the generating resource that responds to changes in demand.

Quantifying the carbon impact of projects, programs, and policies that affect electricity consumption or generation require an in-depth understanding of Ontario’s electricity emissions and appropriate emissions factors. These best practices in quantification methodology are crucial to decarbonizing the electricity sector.

The Atmospheric Fund (TAF) has developed a range of electricity emissions factors for different purposes. This guideline summarizes those factors, outlines the methodology and data sources used, and provides guidelines for which emissions factor to apply for different purposes.

This edition provides an update to our 2019 release, containing data for 2019 and 2020, seasonal emissions factors, and an improved methodology based on further research and valuable feedback received from other practitioners. Major updates include multipliers to estimate lifecycle emissions for all electricity emission factors (EFs) and a Build Margin EF.

The emissions factors and this guide will be especially helpful for Ontario’s provincial and municipal policymakers, engineers, scientists, electricity industry professionals, and non-profit organizations involved in the quantification of carbon emissions.

TAF recommends that the federal government track and report on marginal electricity emissions factors across Canada, to enable and encourage better decision making and prioritization of climate action.

Guidelines

Quantifying carbon emissions fulfils one of two purposes:

- Understand current or historical emissions (for example, a carbon[1] inventory for an organization or city);
- Evaluate the carbon impacts of an actual or potential change (for example, a project, policy, or infrastructure decision).

Quantifying current or historical emissions related to electricity involves determining the quantity of energy consumed and multiplying it by the average carbon intensity of the electricity supply. Quantifying the carbon impact of a change (real or proposed) is more complex. In addition to understanding the quantity of electricity consumed, conserved, or generated as a result of the change, quantifying the carbon impact requires taking into account the marginal impact on the electricity system. In other words, it requires consideration of which generating source (hydro, nuclear, renewables, or natural gas) is expected to respond to the change in electricity demand.

Although the resource in question is the same (electricity), different electricity emissions factors should be used for different quantification purposes:

- **To prepare an inventory:** When quantifying current or historical emissions resulting from electricity consumption (such as for a building, company, or whole city), an Average Emissions Factor (AEF) is recommended. An annual AEF is sufficient for most purposes, although hourly AEFs can be applied where more precision is desired and hourly consumption data is available.
- **To quantify impact:** When estimating the carbon impact of a change (e.g., an energy efficiency or renewable energy project), a Marginal Emissions Factor (MEF) is recommended. Changing the demand for grid electricity results in specific facilities increasing or decreasing electricity production, and this change is not evenly distributed across all generating resources. An annual MEF is sufficient for most purposes, however, the use of hourly, seasonal, or peak/off-peak MEFs will provide more accurate results. Evaluating energy storage or load shifting initiatives should be done with either hourly or peak/off-peak factors.
- **To forecast:** Estimating future carbon emissions is recommended with either a Forecasted AEF or Forecasted MEF. The electricity system evolves over time and the Independent Electricity System Operator (IESO) provides regularly updated forecasts of future generation sources. Generally, estimating future emissions is done when looking at the impact of a change, and therefore a forecasted MEF is recommended for most cases. Based on the latest available forecasts from IESO, electricity emissions factors are expected to trend upwards over time and should be accounted for when estimating long-term impacts. However, there is significant uncertainty on the forecasted factors, as policy decisions and technological developments can impact forecasts.

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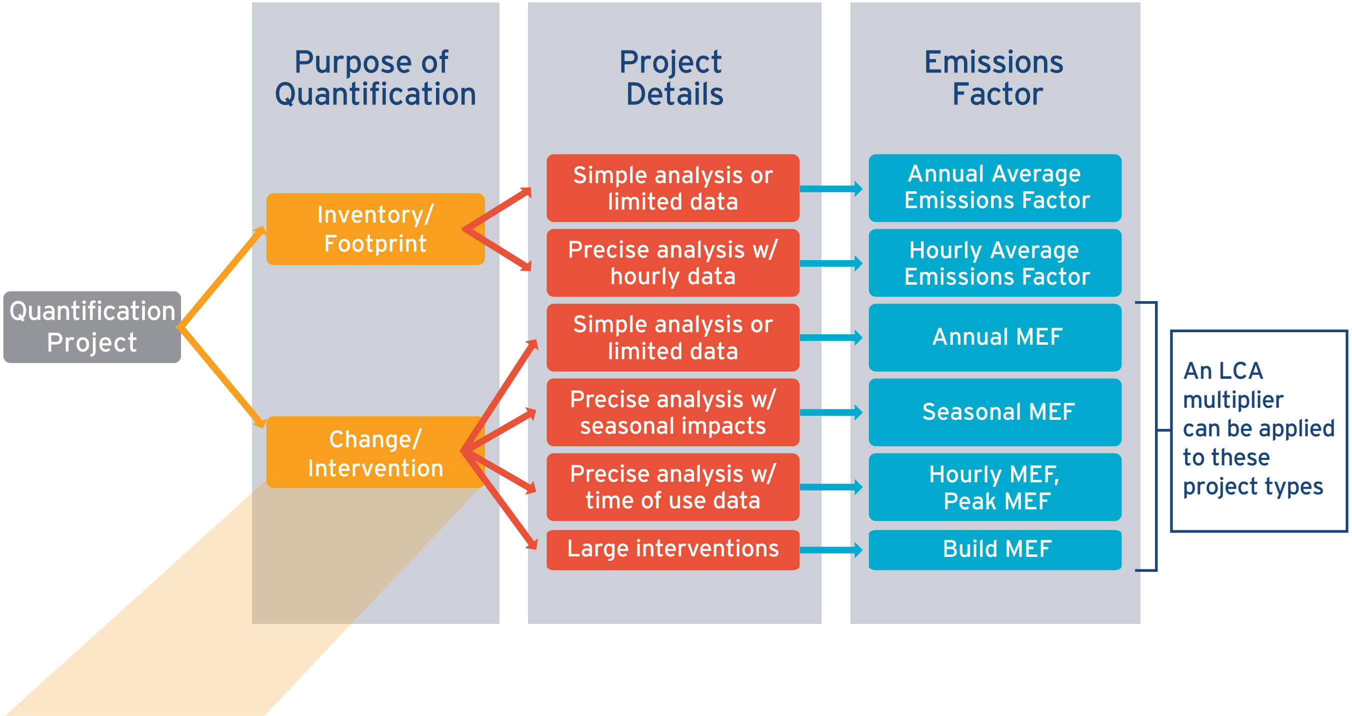
[1] TAF uses the term *Carbon* to refer to *CO_2 equivalent*, regardless of the specific greenhouse gases involved.

Decision Aids

The factors presented in this guideline account only for direct (combustion) emissions, and thus can underestimate the global impact of interventions. To address this, TAF has introduced a lifecycle multiplier and explains how to consider the **full life cycle assessment (LCA) emissions** of electricity generation. The following decision tree and table can assist in determining which specific emissions factors should be used in common scenarios[2]:

Important:
AEFs and MEFs should never be mixed in the same quantification calculation.



Type of Intervention	Examples	Preferable emissions factor	Backup emissions factor
Electricity efficiency	Lighting retrofit	If the lights are only on overnight: Off Peak MEF	If the lights are on all day, or it is unknown: Annual MEF
Electricity storage	A battery that can be charged off peak and then used to supply electricity during peak hours	If the specific hours are known: Hourly MEF	If the specific hours are unknown: Peak / Off Peak MEF

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[2] This update introduces a new Build Margin factor to quickly estimate large, transformative interventions. If a more detail analysis is needed, review GHG Protocol Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects

Load shifting	Shifting use of appliances such as laundry machines and dishwashers to off-peak times	If the specific hours are known: Hourly MEF	If the specific hours are unknown: Peak / Off Peak MEF
Renewable electricity generation	Installing solar photovoltaic (PV) panels	If the hourly production data is available or can be estimated: Hourly MEF	Simple analysis or hourly data unknown: Peak MEF
Increase in electricity-consuming activities	Increasing deployment of Electric vehicles	If predominately charged overnight: Off-Peak MEF	Charging time unknown or random: Annual MEF
Large projects (impact over 100 MW)	New clean energy supply from a solar energy project	Combination of Annual MEF and Build MEF	Build MEF only
Forecast-related interventions	Predicting impact of any project over the next 10 years	For inventories: forecasted AEF For interventions: forecasted peak and/or off peak MEFs	For inventories: forecasted AEF For interventions: forecasted MEF

Methodology Overview

All data used to generate the electricity emissions factors comes from publicly available data from the IESO or the National Inventory Report. The forecasted emissions factors are based on the latest IESO forecasts for electricity supply and demand. There is significant uncertainty around these forecasts, as they will be impacted by future policy decisions and technological developments. A more detailed description of the sources of information and methodology is presented in the Appendix.

Limitations

Apart from the LCA EFs, the emissions factors in this guideline exclude the impacts of:

- **Emissions associated with the construction, maintenance, and eventual decommissioning of power plants or renewable energy facilities;**
- **Location of the consumption or generation of electricity and thus the effect that transmission bottlenecks might have on emissions;**
- **Upstream emissions from natural gas production and transmission as well as uranium mining and processing; and**
- **Emissions generated from imported electricity**[3]**.**

Major changes in province-wide electricity consumption or production, like a dramatic expansion in renewable energy generation, will affect the MEF once implemented. The methodology applied to obtain most of the factors presented in this guideline allows for the accurate use of MEF values below 100 MW of change in demand or generation. For large-scale transformative interventions beyond that size, the Build Margin EF or a more detailed customized modelling approach is recommended.

Updates from the previous version include:

- **Updated forecast factors, including the IESO's latest supply and demand forecasts.**
- **A new Build Margin emissions factor to predict impacts of projects over 100 MW.**
- **An LCA multiplier that can be applied to every emissions factor.**
- **Emissions factor tables expanded for 2019 and 2020.**

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[3] 96% of 2020 **Ontario's imports** came from Quebec and Manitoba; sources with very low or zero emissions associated.

Emissions Factor		Methodology
Average	Annual	The total emissions from electricity production in Ontario divided by the total electricity produced in any given year.
	Hourly	The total emissions from electricity production in Ontario divided by the total electricity produced in a specific hour of the day, averaged over the year.
Marginal	Annual	The emissions generated by changes in generation divided by the changes in electricity production in any given year.
	Hourly	The emissions generated by changes in generation divided by the changes in electricity production in a specific hour of the day, averaged over the year.
	Peak/Off Peak	Similar to Annual MEF but calculated separately for peak and off-peak hours.
	Seasonal	Similar to Annual MEF but calculated separately for each season of the year.
Forecast	Annual AEF	Forecasted Annual AEFs for 2021-2040.
	Annual MEF	Forecasted Annual MEFs for 2021-2040.
	Peak/Off-Peak MEF	Forecasted Peak and Off Peak MEFs for 2021-2040.
	Build Margin	Estimated by analyzing the structural impact of large changes in demand or generation on the grid.

Emissions Factors and Their Applications

Average Emissions Factors (AEFs)

Annual Average Emissions Factor (Annual AEF)

The Annual AEF is a measure of the average amount of carbon pollution produced per kWh of electricity consumed in Ontario and is reported annually in Canada's National Inventory Reports (NIR) as a consumption intensity. Annual AEFs are intended for calculating emissions from current or historical electricity consumption (e.g., for an inventory).

2020 Value
Annual AEF
31
(g CO_2eq/kWh)[4]

Example

When calculating the emissions generated by a specific building over a year. The total kWh of electricity consumption will be multiplied by the AEF value. For example:

150,000 kWh x 31 gCO_2eq per kWh = 4,650,000 gCO_2eq or 4.65 TCO_2eq.

Reminder: Do not combine different emissions factors in a single calculation or metric. For example, either an AEF or MEF (but not both) should be used when calculating a reduction in emissions compared to a baseline value.

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[4] Since the 2021 NIR only includes data up to 2019, TAF has calculated the 2020 AEFs using 2020 IESO data and our internal methodology.

Hourly Average Emissions Factor (Hourly AEF)

The Hourly AEF is like the Annual AEF but reflects the average carbon intensity of electricity consumed in Ontario in any given hour. It can be used to calculate emissions from current or historical electricity consumption when a greater degree of precision is needed, or where hourly data is available or can be estimated.

Values, Hourly AEFs[5]

Hourly AEF (gCO_2eq/kWh)							
Hour	**2020**	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**
1	14	15	14	12	27	34	29
2	13	14	13	12	26	33	29
3	14	14	13	12	26	33	29
4	16	16	15	12	27	35	31
5	19	19	18	14	29	38	33
6	23	22	23	15	32	41	36
7	26	26	27	17	35	44	39
8	28	30	30	18	37	47	42
9	31	32	32	19	40	48	43
10	34	34	34	20	41	50	44
11	36	35	36	21	42	51	46
12	38	36	37	22	44	53	47
13	39	37	38	23	44	53	47
14	41	37	39	24	46	54	48
15	42	38	40	25	47	55	48
16	43	38	41	26	49	56	49
17	43	40	43	27	50	57	50
18	43	41	44	28	51	58	50
19	42	41	43	27	51	58	50
20	40	39	42	26	51	57	49
21	36	36	39	24	49	56	47
22	30	31	32	21	44	50	43
23	23	23	23	17	36	43	37
24	17	17	16	13	30	38	31

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[5] In addition to presenting 2019 and 2020 data, previous years have been adjusted and included. These small adjustments are due to changes in the gas-fired generation portion of the emission factor.

Marginal Emission Factors (MEFs)

Annual Marginal Emissions Factor (Annual MEF)

In Ontario, while electricity generation is predominantly nuclear (60%) and hydro power (25%)[6], conserving electricity is expected to largely reduce natural gas-fired generation. Because of its ability to rapidly increase and decrease production, natural gas power plants are frequently used to respond to changes in demand (in other words, they are 'on the margin'). On the other hand, nuclear power plants are rarely on the margin, because they have very limited ability to adjust output.

As there are no commonly accepted Ontario-specific MEFs, TAF has developed them.

2020 Value
Annual MEF
123
(g CO_2eq/kWh)[7]

When estimating lifecycle emissions, multiply this value by 1.83 = **225 gCO_2eq/kWh**

The Annual MEF is an estimate of the change in carbon emissions resulting from an actual or proposed change in electricity consumption in Ontario. These changes can either increase or decrease consumption. The Annual MEF is also applicable to renewable energy projects, as these reduce demand for grid-supplied electricity.

An annual MEF is sufficient for many quantification purposes. However, estimates can be refined by applying hourly, seasonal, peak, and off-peak MEFs. When quantifying impacts of energy storage or load shifting initiatives, specifically, either hourly or peak/off-peak factors need to be used.

Example

Lighting retrofits illustrate the importance of using MEFs to estimate the impact of changes in electricity consumption. Installing more energy efficient lights will have an impact on heating and cooling systems. Since inefficient lights produce a lot of waste heat, upgrading to LEDs can increase heating energy-use during the winter and reduce cooling energy-use in the summer. Using Ontario's current AEF, energy efficient lighting upgrades will result in a net increase in carbon emissions. But, using the Annual MEF will show that the actual impact of lighting retrofits is a net reduction in carbon emissions, even when accounting for the increased heating demand.

The review of a feasibility study provided the following results:

- Savings from change in lighting: 94,249 kWh/year
- Increase in natural gas consumption for heating: 6,116 m^3/year
- Reduction in electricity consumption for cooling: 2,495 kWh/year

Carbon reductions = A - B + C

A: Reductions in lighting emissions with efficient bulbs

B: Increase in emissions due more heating needed in winter

C: Reduction in emissions due less energy needed for cooling in the summer

If we just use the AEF (31), the project will result in an increase of 8.62 TCO_2e/year:

(94,249 kWh/year x 31gCO_2e/kWh x 0.000001) – (6,116 m^3/year x 0.001899 tCO_2eq/m^3) + (2,495 kWh/year x 31gCO_2e/kWh x 0.000001) = – 8.62 TCO_2eq/year (increase in carbon emissions)

But, if we use Annual MEF (123), the project will result in a reduction of 0.29 TCO_2e/year:

(94,249 kWh/year x 123gCO_2e/kWh x 0.000001) – (6,116 m^3/year x 0.001899 tCO_2eq/m^3) + (2,495 kWh/year x 123gCO_2e/kWh x 0.000001) = 0.29 TCO_2eq/year (decrease in carbon emissions)

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[6] https://www.ieso.ca/en/Corporate-IESO/Media/Year-End-Data

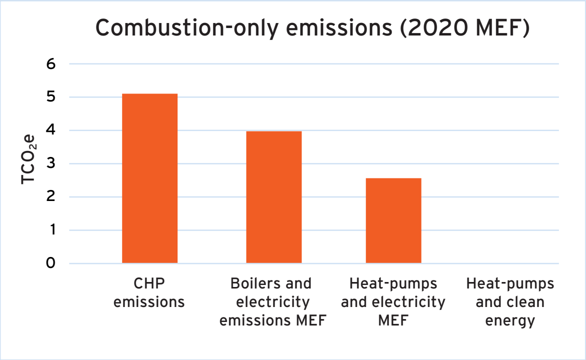
[7] Calculated with 2020 IESO data and TAF's internal methodology.

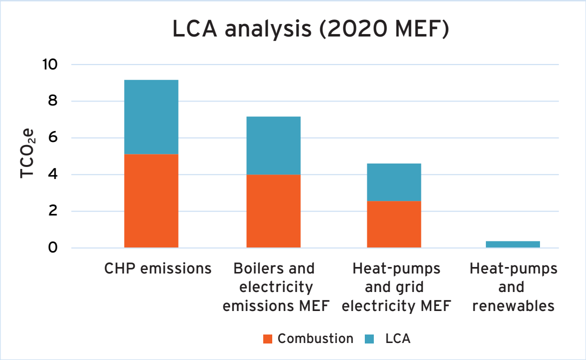
Example: Interventions with fuel switching to grid electricity using life cycle assessment (LCA)

More information on the forecasted EFs is provided later in this guideline. The methodology behind the LCA assessment can be found in the Appendix.

Consider the comparison between four heating systems producing the same amount of heating and electricity:

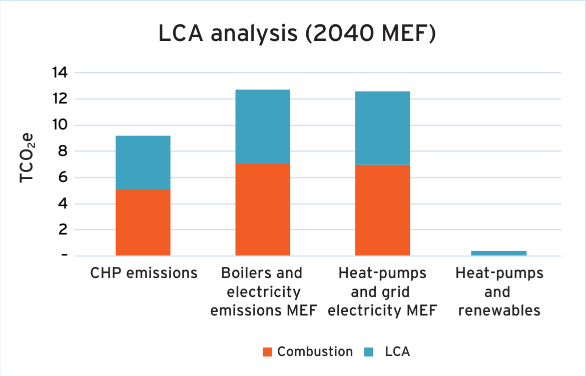
- **System 1:** Combined heat and power (CHP) generator with natural gas[8]. Total generation 100 GJ (50% of energy generated is electricity, 30% is heat, 20% is wasted).
- **System 2:** Traditional boilers and grid electricity. 70% Boiler efficiency, 2020 MEF for electricity.
- **System 3:** Heat pumps and grid electricity. Coefficient of Performance (COP) 2, 2020 MEF for electricity.
- **System 4:** Heat pumps and renewable generation. COP 2, Average for electricity renewable generation (14 gCO_2eq/kWh).





While using an LCA analysis does not change the rank of the four systems, it shows that the emission differences between Scenarios 1 and 4 are *much larger* than in a combustion-only analysis. The combination of heat pumps and renewables is the only transformative solution that can be adopted at scale to have a heating system close to net zero.

Forecasted marginal emission factors paint a different picture if natural gas generated electricity is left unchecked. By 2040, this will cause emissions generated by heat pumps connected to the grid to exceed CHP emissions. In keeping with our climate goals, it is critical to curtail natural gas generated electricity by massive adoption of renewable generation, storage solutions, and conservation measures. This will open much needed capacity for the continued electrification of transportation and heating.



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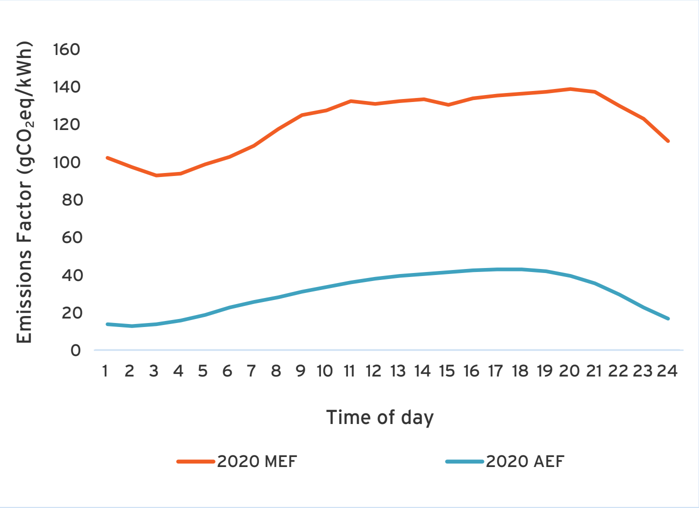
[8] While a CHP system consuming RNG could have low emissions, it is not a structural transformative solution given the resource availability limitations.

Hourly MEFs

Hourly MEFs are typically larger than the Annual MEF and reflect the change in carbon emissions resulting from a change in electricity consumption in Ontario at any given hour.

Hourly MEFs enable additional precision and customization when calculating the emission impacts of electricity interventions. Hourly factors can be applied to interventions where specific hourly changes in electricity generation or consumption are known or can be estimated. Examples include switching electric appliance usage to off-peak hours, adding solar PV generation, and battery storage. The differences in hourly MEFs throughout the day are not as significant over the weekend when total demand is lower.



Example

EV charging will have different impacts on the grid depending on the hours when they are charged. If a vehicle charges at a speed of 6 kWh and needs 3 hours for a full charge, we can compare the following scenarios:

1. **The vehicle is charged right after arriving from work, between 6 p.m. and 8 p.m.:**

   Total emissions = 6 kWh x 137 gCO_2eq/kWh + 6 kWh x 138 gCO_2eq/kWh + 6 kWh x 139 gCO_2eq/kWh = 2,486 gCO_2eq

2. **The vehicle is connected to a timer and charged between 2am and 4am:**

   Total emissions = 6 kWh x 98 gCO_2eq/kWh + 6 kWh x 93 gCO_2eq/kWh + 6 kWh x 94 gCO_2eq/kWh = 1,710 gCO_2eq

- **Carbon reductions** = 2,486 gCO_2eq – 1,710 gCO_2eq = 776 gCO_2eq
- **Carbon reductions %** = 776 gCO_2eq / 2,486 gCO_2eq = 31% reduction

A change in charging times generates a **31% reduction in emissions**, which would result in a very significant reduction of emissions once EVs are adopted at scale.

Values, Hourly MEFs[9]

Hourly MEFs (gCO_2eq/kWh)

	2020	2019	2018	2017	2016	2015	2014
1	103	99	102	53	90	120	92
2	98	98	98	47	80	111	82
3	93	94	97	47	74	111	81
4	94	96	100	47	76	114	80
5	99	100	103	48	83	117	88
6	103	109	115	53	96	123	100
7	109	124	126	64	107	124	115
8	118	132	138	73	121	130	131
9	125	136	141	76	126	135	137
10	128	139	144	82	129	136	143
11	133	138	144	85	126	139	144
12	132	138	142	86	126	139	147
13	133	139	140	88	127	139	148
14	134	139	139	87	129	138	145
15	131	139	139	90	126	139	148
16	134	139	144	90	131	143	151
17	136	145	148	91	137	145	160
18	137	151	155	100	144	141	161
19	138	150	158	103	149	145	165
20	139	149	163	100	151	144	167
21	138	143	153	99	143	142	156
22	130	137	145	84	133	141	143
23	124	124	131	70	121	135	124
24	112	110	114	59	106	127	105

When estimating lifecycle emissions, multiply the values in this table by 1.83

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[9] In addition to presenting 2019 and 2020 data, previous years have been adjusted and included. These small adjustments are due to changes in the gas-fired generation portion of the emission factor.

Peak and Off-Peak MEFs

Peak and Off-Peak MEFs measure the carbon impacts of changes in electricity consumption during peak and off-peak times. They are simpler to apply than hourly MEFs, but still provide greater precision than an Annual MEF. Peak hours are defined as weekdays 7 a.m. to 7 p.m., following IESO's definition[10]. Like Hourly MEFs, Peak and Off-Peak MEFs can be used to measure energy savings from shifting the time of consumption. These MEFs are recommended when there is not enough information about the exact hours of the day when the precise hours of the time shift are unknown, or when an approximate calculation is needed. The IESO defines peak hours as weekdays 7 a.m. to 7 p.m. [10]

Values: Annual, Peak and Off-Peak for 2014-2020[11]

	MEF (gCO_2eq/kWh)						
	2020	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**
Peak MEF	133	141	148	91	134	141	157
Off Peak MEF	114	119	123	66	108	127	113
Annual MEF (as comparison)	123	129	134	77	120	133	131
When estimating lifecycle emissions, multiply the values in this table by 1.83							

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[10] The definition of peak is the same for all years, following IESO's criteria. For some years, a high Hourly MEF can be observed also at 8 p.m. – 9 p.m., increasing the Off-Peak MEF.

[11] In addition to presenting 2019 and 2020 data, previous years have been adjusted and included. These small adjustments are due to changes in the gas-fired generation portion of the emission factor.

Example: Load Shifting

As with the hourly MEF, when applying marginal emissions factors to energy storage or load-shifting strategies, Peak and Off-Peak MEFs should be applied to both the consumption (e.g., energy drawn from the grid to charge a battery) and avoided electricity consumption (e.g., energy drawn from a battery instead of the grid). The quantities of electricity that would have been consumed with and without the strategies in place should be multiplied by their respective MEFs. The net difference in emissions is the impact of the strategy.

If a household decides to shift the 3 kWh consumption of their electric clothes dryer from Peak to Off Peak, the avoided emissions in 2020 would equal:

3 kWh x 3 loads/week x 52 weeks/year x Peak MEF 133 gCO_2eq/kWh = 62,244 gCO_2eq

And the generated emissions would equal:

3 kWh x 3 loads/week x 52 weeks/year x Off-Peak MEF 114 gCO_2eq/kWh = 53,352 gCO_2eq

Net difference = 8,892 gCO_2eq, a 14% carbon reduction over the year.

Example: Renewable Generation

One of the positive attributes of solar energy is that it is peak-coincident, meaning the panels produce energy primarily during peak hours. When installing solar panels, the avoided emissions would be equal to the total energy generated by the panels. If the panels generated 15,000 kWh over the year, and assuming that this energy is not stored (avoiding Peak emissions), the Carbon emissions savings in 2020 would result in:

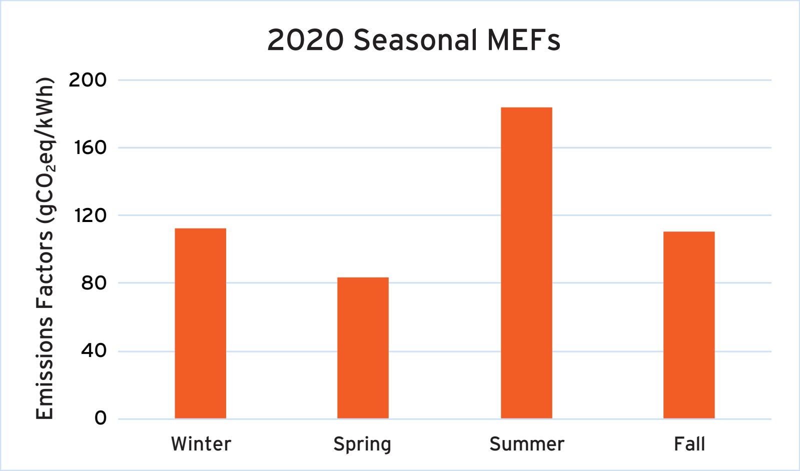
Carbon reductions = 15,000 kWh x 133 gCO_2e/kWh = 1,995,000 gCO_2e = 2 TCO_2eq

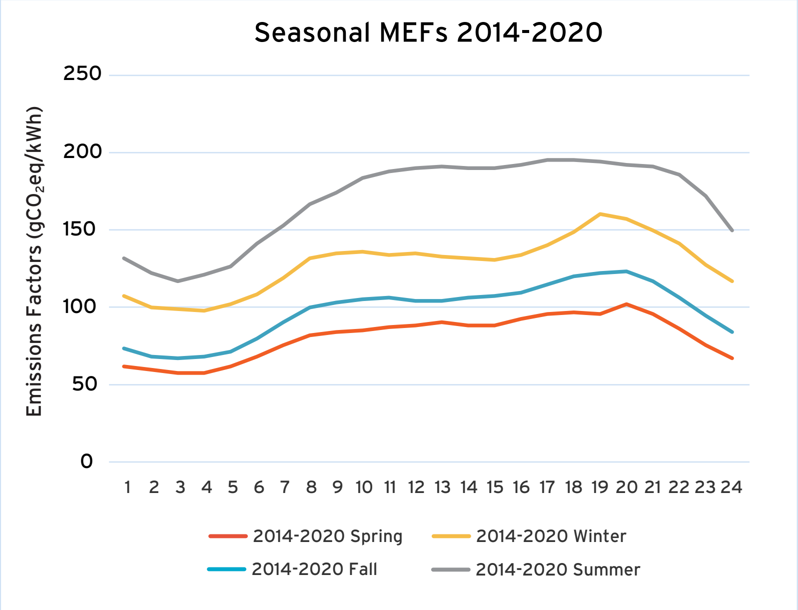
While Hourly MEFs could provide a more accurate estimation of carbon reductions by better tracking hourly changes in natural gas on the margin, a Peak MEF provides a reasonable approximation because it averages the highest usage and is far simpler to apply.

Seasonal Marginal Emissions Factor

Electricity demand and generation both vary seasonally. Seasonal MEFs[12] provide a measure of the carbon impact of changes in electricity consumption in any given season. These MEFs can be used to calculate emissions when an intervention impacts electricity consumption in a specific time of the year. For example, a winter MEF can be used for heating interventions and a summer MEF for cooling.

Seasonal MEFs are not forecasted since they are highly dependent on extreme temperatures and weather patterns each year, and thus difficult to accurately predict.





The MEF is lowest in spring, with relatively low demand due to mild temperatures and high availability of hydro generation enhanced by the snow thaw. Fall also has low demand, but not the same availability of hydro generation, which accounts for an increased MEF compared to spring. Winter has a higher MEF due to higher consumption from electric heating systems, but a similar trend to the shoulder season, with more noticeable peaks around 8 a.m. and 8 p.m. Summer is characterized by the highest MEF, and notable spike during the middle of the day, both associated with the higher cooling loads resulting from higher daytime temperatures in the summer.

MEF values for summer and winter are highly influenced by the temperature. For example, the MEF curve in a year with extremely high temperatures in summer can be expected to show higher values than a mild winter.

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[12] Winter: December 21 to March 20; Spring: March 21 to June 20; Summer: June 21 to September20; Fall: September 21 to December 20.

Example

If a building installs a more efficient chiller, the electricity savings will occur primarily over the summer, therefore a summer MEF is recommended to better estimate the real impact of the improvement. Replacing a chiller with a full load efficiency of 0.83 kW/tonne for one with 0.6 kwh/Tonne, for 500 Tonnes capacity, which runs for 2,000 hours over the summer, would result in:

Reduction in electricity consumption =

(0.83 – 0.6) kW/Tonne x 500 Tonnes x 2,000 hours

= **230,000 kWh**

Carbon emissions reduction =

230,000 kWh x 184 gCO_2eq/kWh

= **42,320,000 gCO_2eq = 42.32 TCO_2eq**

Values: Seasonal MEFs

	2020 Seasonal MEFs (gCO_2eq/kWh)			
Hour	**Winter**	**Spring**	**Summer**	**Fall**
1	109	57	153	91
2	102	53	152	84
3	102	49	140	82
4	101	49	147	79
5	104	56	149	86
6	108	58	153	94
7	108	62	161	105
8	114	73	174	112
9	116	81	187	117
10	119	88	191	115
11	121	93	199	117
12	114	95	201	116
13	115	99	198	120
14	118	99	199	119
15	110	95	203	115
16	115	98	206	118
17	112	107	208	118
18	111	108	204	125
19	123	102	200	127
20	115	112	199	130
21	120	104	199	128
22	119	91	196	116
23	113	84	187	111
24	108	66	170	102
Seasonal Average	**113**	**84**	**184**	**110**

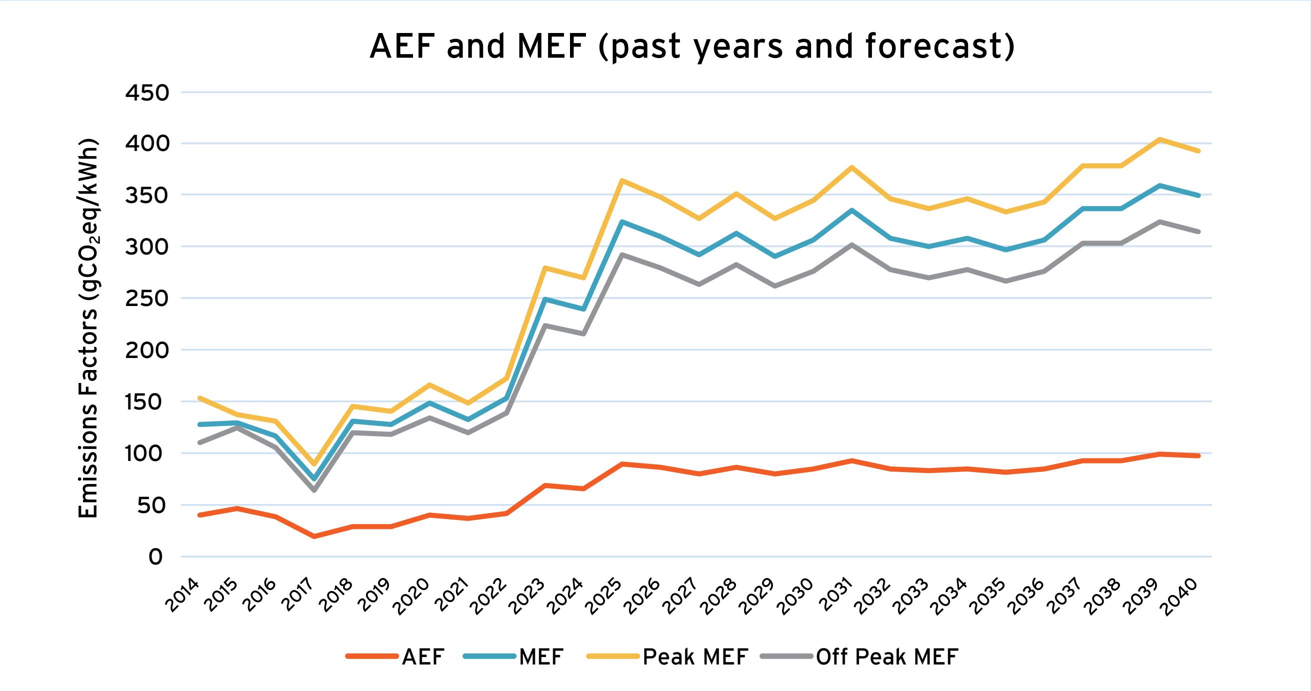
When estimating lifecycle emissions, multiply the values in this table by 1.83

Forecasted Emissions Factors from 2021-2040

In many cases, we want to understand the impact of changes in electricity consumption well into the future (e.g., over the expected life of a renewable energy project). It is common practice to use the most recent year's emissions factor and simply carry it forward. However, it is possible to forecast future emissions factors, based on published IESO data, and the use of forecasted factors is likely to be more accurate. TAF has forecasted most emissions factors to 2040. In order to forecast the MEF for future years, TAF has used the total and natural gas generation values presented in the last IESO's Annual Planning Outlook (IESO, Technical Planning Outlook, 2020).

There is an expected increase in natural gas electricity generation over the next 20 years in the province, which is the reason for the increase in both AEFs and MEFs. Emissions are forecasted to gradually increase from 5.4 MT CO_2eq in 2020 to 14.2MT CO_2eq in 2040. The forecasted emissions factor will help to avoid underestimating the effects of interventions in the future, since any increase or reduction in consumption will have a progressively bigger impact.

IESO's forecast changes over time, with any new policy decisions and technological developments, and there is considerable uncertainty about the forecasted factors, becoming more significant as the forecasts go further into the future. While changes may result in material variations to the forecasts, the most up-to date and accurate information available is used to generate the projected factors in this guideline.



Values: Forecasted Emissions Factors

	Emissions Factors (gCO_2eq/kWh)			
Year	**AEF**	**MEF**	**Peak MEF**	**Off-Peak MEF**
2021	37	134	150	121
2022	43	156	175	140
2023	70	251	281	226
2024	67	242	272	218
2025	91	327	367	295
2026	87	312	350	281
2027	82	294	330	265
2028	88	316	355	285
2029	81	293	329	264
2030	86	310	348	279
2031	94	338	379	305
2032	86	311	349	280
2033	84	303	340	273
2034	86	311	349	281
2035	83	299	336	270
2036	86	309	347	278
2037	94	340	382	307
2038	94	340	381	306
2039	101	362	407	326
2040	98	352	396	318
When estimating lifecycle emissions, multiply the values in this table by 1.83[13]				

Note on COVID-19:

IESO has modelled two short-term scenarios with impacts from COVID-19 in its July 2021 update. Scenario 1 is a shallow recession for the 2021-2026 period, while Scenario 2 is a deep recession. COVID-19 impacts (and modeled scenarios) are not considered in this guideline but will be in future updates once the reasons for these impacts become clear. While Ontario experienced a reduction in electricity demand in 2020, natural gas electricity generation increased compared to 2019. It is still unclear if this is due a hot Summer in 2020[14] requiring additional generation from peaking natural gas fired plants (particularly the first half of July) or because of reduced nuclear generation due to plant refurbishments.

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[13] This LCA value is highly influenced by methane leaks, which are supposed to decrease significantly between now and 2030. Any significant updates related to this variable will be captured in future editions of this guideline.

[14] June - August 2019 had a total of 310 Cooling Degree Days (CDD), while the same months for 2020 reported 438 CDDs (41% more).

Forecasting impact of large transformative projects

The EFs presented earlier are designed to capture the impact of interventions under 100 MW. Larger interventions can include significant increases in demand (e.g., cumulative new construction, large EV charging projects), significant reductions in demand (e.g., provincial conservation programs, large behind-the-meter generation projects), or significant increases in generation (e.g., new large-scale wind or solar generation).

To estimate the impact of larger projects, it is important to look at potential structural changes in the grid. Since the current forecast assumes any increase in demand is met by increasing natural gas generation, we recommend using the EF for natural gas generation. This reflects that those large projects will mainly impact this resource.

Build MEF = 472 gCO_2eq/kWh

When estimating lifecycle emissions, use 864 gCO_2eq/kWh (multiplying 472 gCO_2eq/kWh by 1.83).

Every project can impact the operational and structural nature of the grid. If a more detailed analysis is desired, we recommend following the GHG protocol guideline for Quantifying GHG reductions from Grid Connected Electricity Projects[15]. When using this protocol, the recommended values to apply for operating and build margins are:

- **Operating Margin (OM):** All sets of MEFs described in this methodology
- **Build Margin (BM):** Build MEF for large projects

One key function of natural gas generators is to provide grid flexibility and respond to fluctuation in demand, providing ancillary services as spinning reserve or regulation services. When evaluating large systems that have potential to replace these specific functions for natural gas generators (e.g., a battery system that provides the same flexibility at the same or lower price), detailed analysis is required beyond what current methodology can provide. To simply prove the GHG additionality of the replacement system, the natural gas generation EF (472 gCO_2eq/kWh) should be used to estimate the impact of the project.

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[15] http://pdf.wri.org/GHGProtocol-Electricity.pdf

Appendix: Methodology

Electricity Generation

The electricity market is highly complex, and there are multiple variables that determine which resource is on the margin at any given point of time. Different approaches can be applied to determine the MEF of electricity generation such as total generation, changes in generation, and market price. Most of the time, the availability of data is the factor that determines which methodology can provide better results. IESO makes several sets of data available to the public (including a series of public reports[16] and a data directory[17]), but this data is not enough to accurately determine marginal values (this has been confirmed by the IESO).

For our purposes – using MEFs to better reflect the change in emissions associated with increasing or decreasing demand at any given moment – is a good proxy to determine if the marginal resource would be the type of generator that sets the market clearing price, but unfortunately the IESO does not generate a report on marginal resources.

The best available source of information is the **Generator Output and Capability Report** (IESO, Generator Output and Capability Report, 2018 III) which presents the energy output and capability for generating facilities in the IESO-administered energy market with a maximum output capability of 20 MW or more. For variable generation only, forecast values are published instead of capability, as these provide a more accurate view of how much energy these units could be expected to produce.

Using this data carries certain limitations:

- "Behind-the-meter" generation in Ontario is not captured by IESO's generation data, which only reports distribution connected and contracted generators. This guideline is not intended to provide information or emissions factors for this type of electricity generation.
- As of August 2021, there are 3,285 contracts[18] with an output capability of 20 MW or less that account for 2,455 MW. Only 24 small generators run on natural gas, with a capacity of 119 MW. Those small contractors, many of which are clean energy, would most certainly lower the amount of natural gas on the margin.

The electricity generation on an average day follows a similar pattern as demand, with a small peak around 9 a.m. and one more significant around 7 p.m. The two main sources that changes generation over the day to meet demand are hydro and natural gas, making them the most prominent resources in marginal electricity generation.

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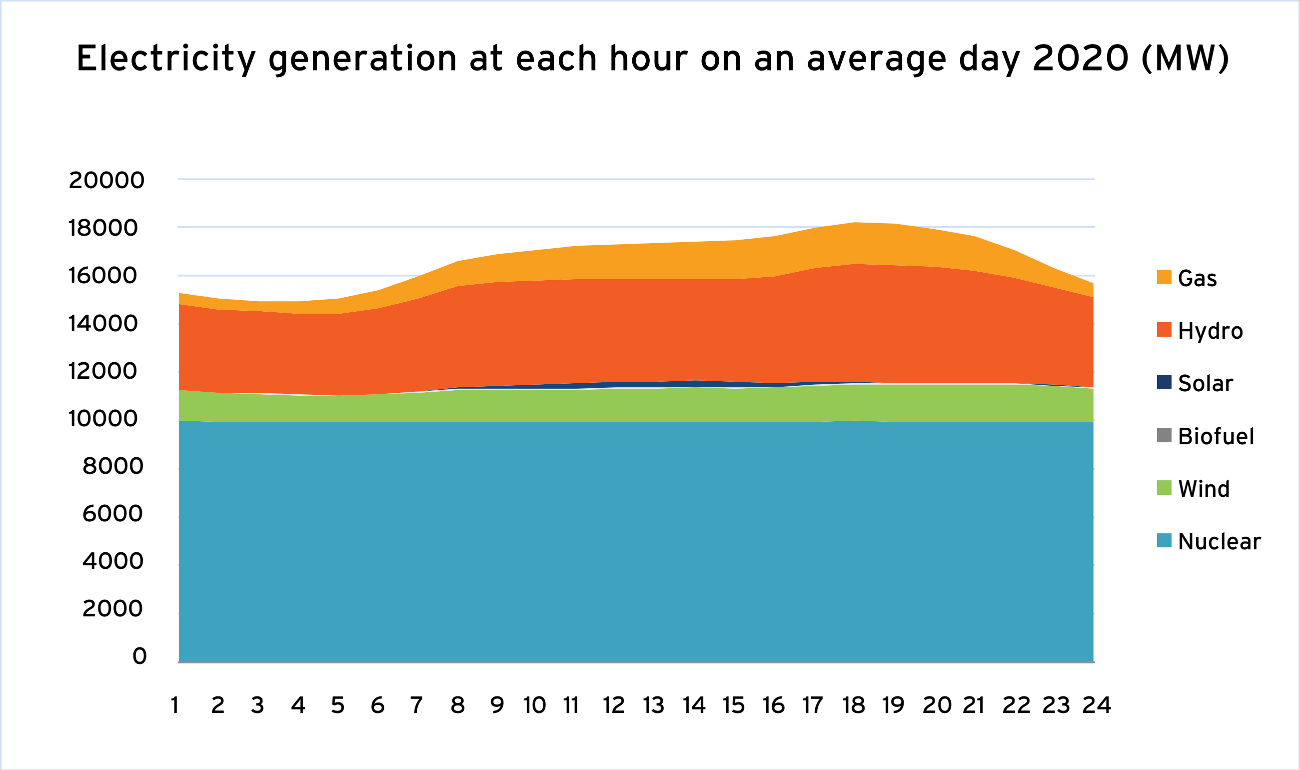
[16] Available at **http://reports.ieso.ca/public/**.
[17] Available at **http://www.ieso.ca/Power-Data/Data-Directory**.
[18] Available data at the **IESO Active Contracted Generation List**

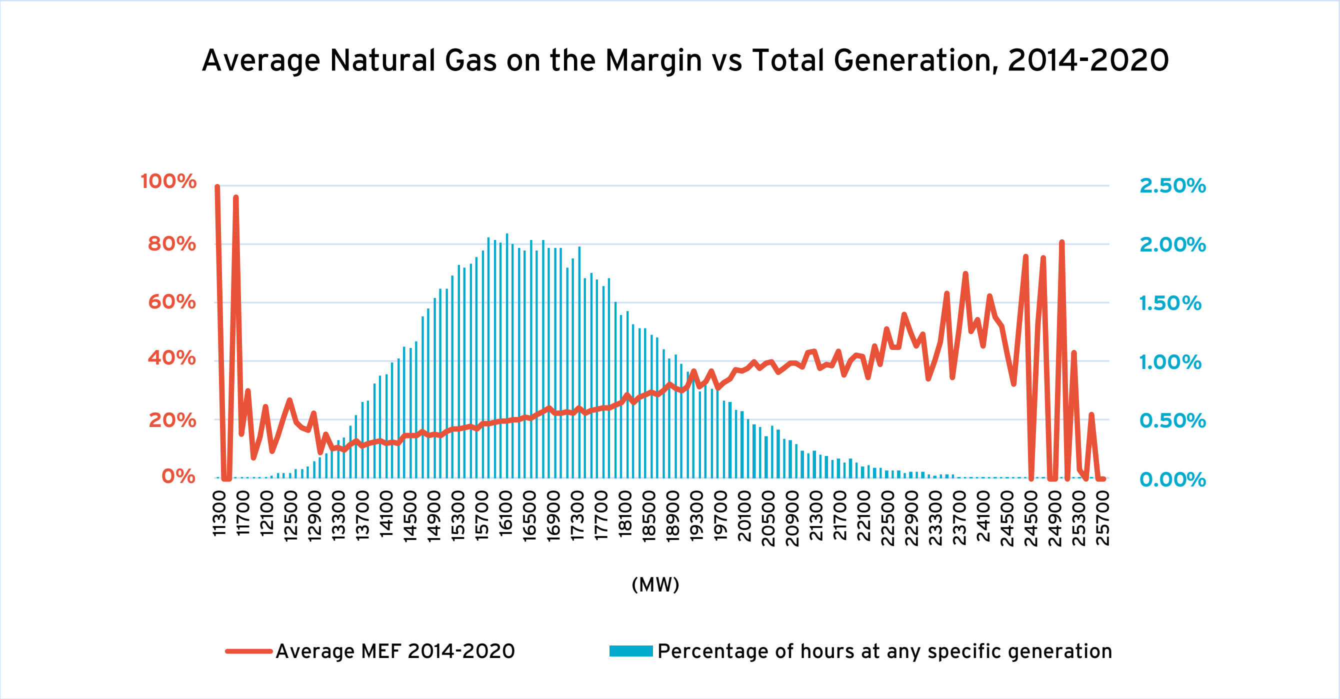


Natural Gas Generation

The only source of carbon emissions in Ontario's electricity generation is natural gas (biofuel consumption is negligible). To determine the MEF, the goal is to determine the proportion of natural gas on the margin.

Electricity generated with natural gas is an expensive resource, and it is used to provide flexibility to the system and increase supply in periods of high demand. But these are not the only variables that influence natural gas generation. For example, an important part of natural gas generation is the combined cycle plants, which require long periods of time to start and need to run for at least four hours, excluding this generation from short-term changes in demand. Natural gas generators also run at night to carry capacity and other tests. There are also generators running under contracts signed before the market implementation, which generate electricity regardless of demand.

The best indicator to determine the amount of natural gas as a marginal resource is total electricity demand. As total demand increases, the proportion of natural gas on the margin also increases. This can be observed in the figure below.


Average Natural Gas on the Margin vs Total Generation, 2014-2020

The amount of natural gas on the margin has highly oscillating values at very low (under 13,000 MW) or very high (over 21,000 MW) demand. This is because the sample size for these extreme values is not large enough to cancel the effect of the variability of the system (like wind and hydro generation, and system constraints). It would be reasonable to expect a very low gas generation value (but not zero) when demand is very low, and a very high generation value when demand is very high (probably close to 80-100% of marginal generation). As a result of the lack of enough good quality data, this methodology probably overestimates natural gas on the margin at low demand and underestimates it at high demand values, but those errors are minimized when the average MEF is calculated for each hour, given that very high or low demand values are less frequent.

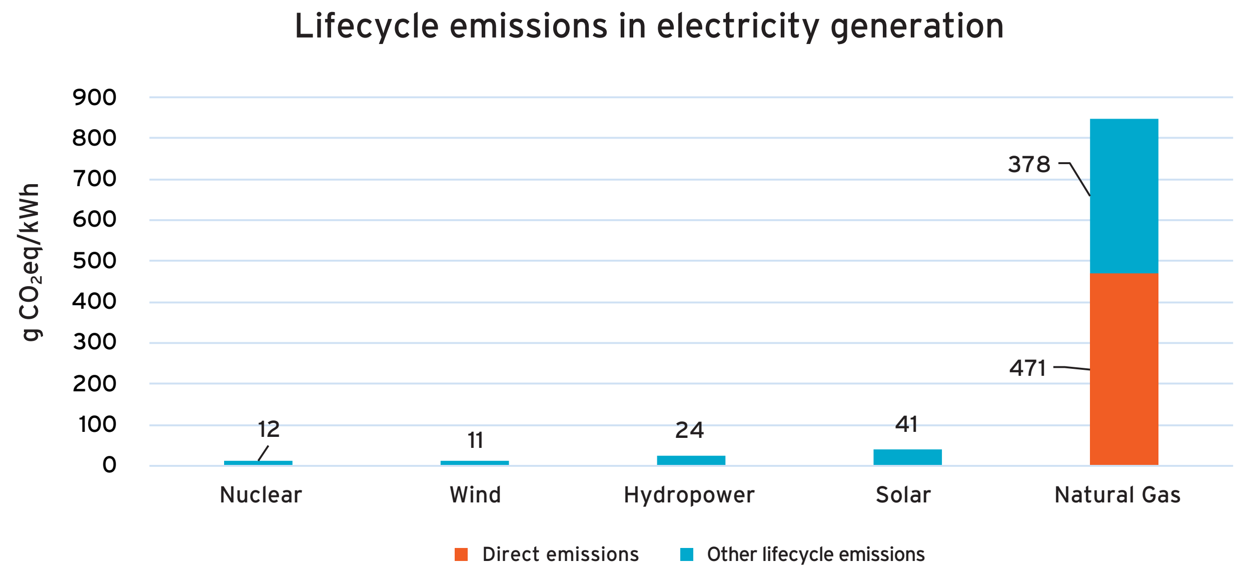
The other main factors that affect the amount of natural gas on the margin (closely related to the previous one) are extreme temperatures, which increases general and peak demands, and the availability of other resources – solar and hydro being the ones with most significant seasonal variations. The increase of natural gas as a marginal resource displays a different correlation with the increase in generation for each season of the year. The main variables are the availability of hydro or solar energy and the expected peak demand. Given the characteristics of some natural gas facilities (long periods needed to start and the need to function for several hours), when peak demand is expected to be high, those facilities start before the system reaches peak demand.

To estimate the MEF addressing this variable, the proportion of natural gas as a marginal resource was calculated as a function of total generation, for each season, and was finally applied to every hour.

LCA Approach

Combustion emissions are most often used to estimate the carbon intensity of the grid, however, a full Life Cycle Assessment (LCA) will provide a more accurate understanding of the full intervention impacts. LCA EFs for electricity should be used in scenarios where alternative solutions (other fuels, etc.) are also expressed in terms of their LCA emissions. The easiest way to transform MEFs into lifecycle MEFs is to **multiply the MEFs based on combustion by 1.83**. This guideline provides conversion examples for each type of emissions factor.

While most of Ontario's energy sources generate zero emissions at a local level, their life cycle has an impact at climate change, as can be seen in the next figure (*note renewable sources data is based on IPCC*[19] *Hydro Quebec*[20] *and others*[21]).



While solar generation is the second highest generator in emissions intensity, it's role as marginal resource is very minimal based on our methodology:

	Marginal generation						
Year	**Nuclear**	**Gas**	**Wind**	**Other**	**Biofuel**	**Hydro**	**Solar**
2014	10.0%	28.7%	11.2%	1.8%	0.0%	48.3%	0.0%
2015	7.7%	29.3%	15.0%	0.0%	0.9%	46.6%	0.6%
2016	6.6%	26.7%	23.2%	0.0%	1.0%	41.1%	1.5%
2017	8.7%	16.6%	23.6%	0.0%	1.1%	47.8%	2.1%
2018	3.1%	29.2%	21.4%	0.0%	1.2%	43.2%	1.9%

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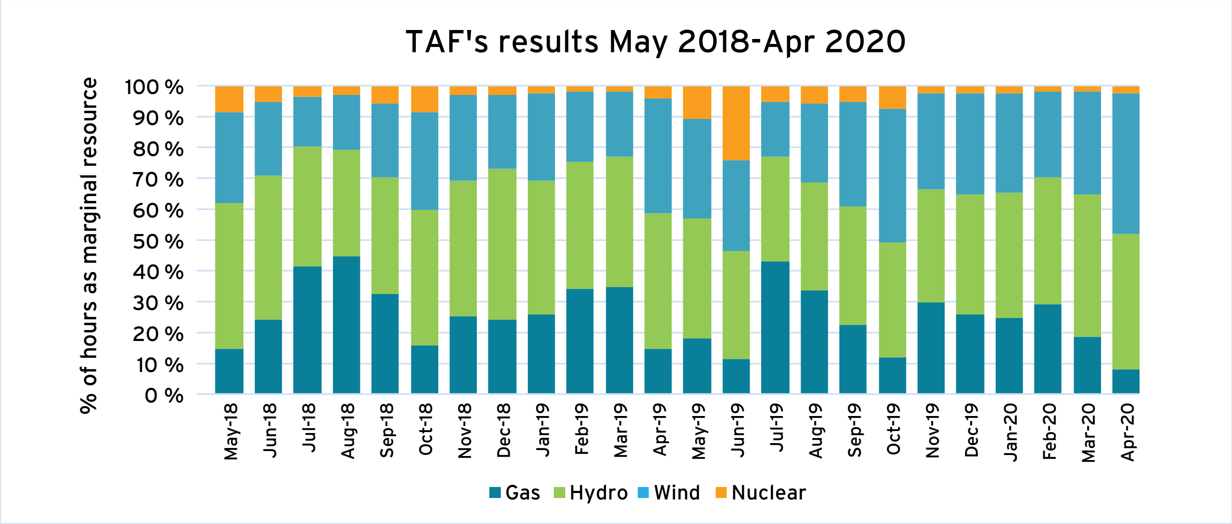
[19] https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf all sources from here except for natural gas (TAF data)
[20] https://www.hydroquebec.com/data/developpement-durable/pdf/ghg-emissions.pdf
[21] https://www.nrel.gov/docs/fy13osti/56487.pdf

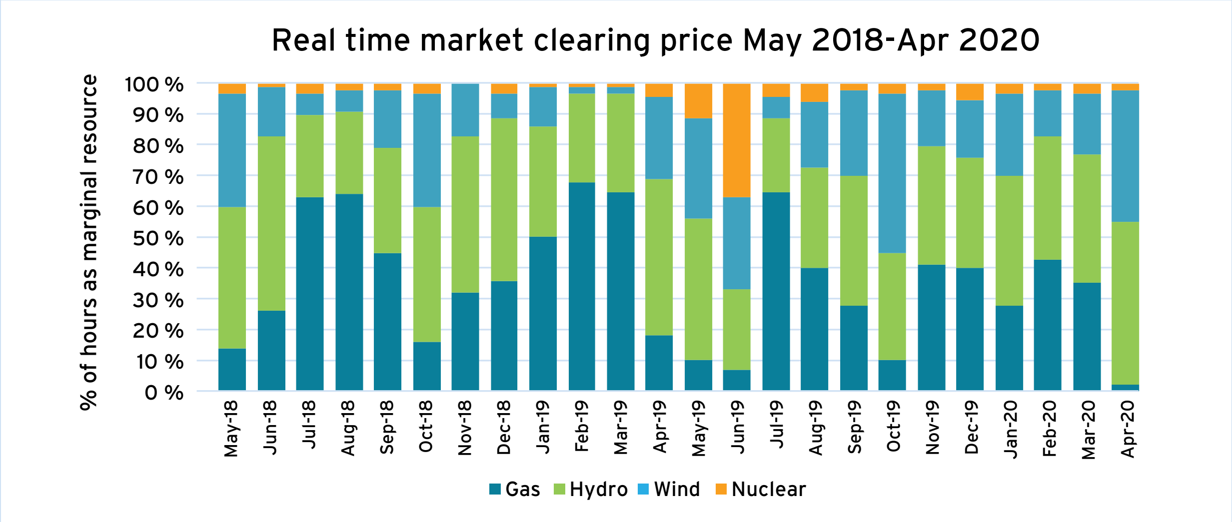
The most significant LCA impact comes from upstream methane emissions associated with natural gas extraction, transmissions, and distribution. TAF has estimated that 2.3% of the natural gas is lost in the process of bringing it to generation facilities (potential post-metering fugitive emissions not accounted). The current LCA is calculated converting these methane emissions with GWP20.

Looking at the full LCA emphasizes the importance of increasing investment in solutions like renewables, storage, demand response, and peak shifting to reduce forecasted increases in natural gas generated electricity.

Results Evaluation

IESO provides information related to the type of generator that sets the market clearing price. The Market Surveillance Panel of the Ontario Energy Board uses this information. It has several reports with data regarding the proportion each generator sets of the market clearing price. The most recent report[22], contains information covering the period from May 2018 to April 2020, which was used to evaluate the accuracy of the current methodology.





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[22] Available at **https://www.oeb.ca/sites/default/files/msp-monitoring-report-202101.pdf.**

The current methodology doesn't capture the high variability in wind and hydro generation and underestimates the amount of gas on the margin when wind generation is particularly low.

The chart below shows the comparison between TAF's percentage of gas on the margin and the CMP for each month from May 2018 to April 2020, and the specific temperature for each month and the historical average temperature. As discussed in previous versions of this guideline, the larger differences take place when temperatures diverge from monthly averages. It is also worth mentioning that in April 2020, during the most strict lockdown measures, natural gas electricity generators only were the marginal resource 2% of the time (the lowest value in our records). This is likely due to high hydro availability and lower electricity demand during that time.

This comparison shows that TAF's methodology captures the trends in natural gas marginal generation. Lack of data means it underestimates the MEF for exceptionally high demand levels and extreme temperatures. We look forward to enhancing the methodology over time.