CALCULATION AND APPLICATION OF HOURLY EMISSION FACTORS FOR INCREASED ACCURACY IN SCOPE TWO EMISSION CALCULATIONS

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ABSTRACT

The accepted method of calculating GHG emissions from the consumption of grid-purchased electricity, otherwise known as scope two emissions, is limited to one emission factor that represents an annual average. The emission intensities of large-scale electrical grids change by the hour, therefore requiring hourly precision in emission calculations for optimal accuracy. For the power market of Ontario, Christian Gordon and Alan Fung of Ryerson University have developed a method of generating hourly emission factors to better measure the impact of renewable technologies. Although calculations using this method demonstrate improvement from the e-grid average, results can be further improved through the use of facility-specific emission factors and consistent units of measurement. This paper recommends a modified methodology that yields more accurate hourly emission calculations and provides opportunity in quantifying scope two emissions with a high degree of precision.

Keywords: emission intensity; electricity grid; carbon footprinting.

MÉTHODE DE CALCUL ET SON APPLICATION POUR LES FACTEURS D'ÉMISSION DE SCOPE 2 PAR HEURE POUR UNE PLUS GRANDE PRÉCISION DES CALCULS

RÉSUMÉ

La méthode acceptée de calcul des émissions de GES, connu sous le nom de " émissions de scope 2 ", de la consommation d'électricité achetée d'un réseau, est limitée à un facteur d'émission qui représente une moyenne annuelle. L'intensité des émissions des réseaux électriques à grande échelle changent à toutes les heures, par conséquent, il est nécessaire pour avoir une efficacité optimale d'avoir un calcul des émissions à l'heure. Pour le marché de l'énergie de l'Ontario, Christian Gordon et Alan Fung, de l'Université Ryerson, ont développé une méthode de calcul des facteurs d'émission par heure pour mesurer plus efficacement l'impact des technologies renouvelables. Bien que les calculs utilisant cette méthode démontrent une amélioration sur les moyennes *e-grid*, les résultats peuvent être davantage perfectionnés par l'utilisation de facteurs de coefficient d'émission d'une source spécifique et des unités de mesures régulières. La présente étude recommande une modification de la méthodologie qui produirait des calculs d'émission par heure plus précis et fournirait l'occasion de chiffrer les " émissions de scope 2 " avec un degré plus élevé de précision.

Mots-clés : intensité des émissions; réseau électrique; empreinte carbone.

1. INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) states that efficiency and mix of fuels varies dramatically from country to country. As a result, general emission factors cannot be given [1]. For a given study year, one emission factor (EF) is released for Ontario in the National Inventory Report published by Environment Canada [2]. The accepted method of calculating CO_2e emissions from the use of grid-purchased electricity in Ontario is as follows:

$$\begin{aligned} CO_2e\ Emissions\ (g) = {} & Consumption\ of\ Grid\ Purchased\ Electricity\ (kWh) \\ & \times Provincial\ Average\ EF\ (g/kWh)\,. \end{aligned} \tag{1}$$

Colin High of Resource Systems Group (RSG) stresses the importance of tracking and analyzing the emission intensity of the electrical grid on an hourly level. Developing and applying hourly emission factors allows for monitoring of emission reductions from energy efficiency and renewable energy ("EERE") investments with a high degree of accuracy [3]. Christian Gordon and Alan Fung have recognized this concept as well, and have completed a related study entitled "Hourly Emission Factors from the Electricity Generation Sector – A Tool for Analyzing the Impact of Renewable Technologies in Ontario". This study recommends the use of hourly emission factors to more accurately measure emission reductions from the use of EERE technologies in Ontario [4]. By taking the actual hourly grid emission intensity into account, the temporal nature of electricity consumption is reflected in emission calculations. The accuracy of emission calculations is inevitably improved when compared to using Ontario's provincial average emission factor. Building on the scope two quantification innovations proposed by Gordon and Fung, further modifications need to be implemented. In addition, hourly emission factors provide opportunity in accurate scope two emission calculations for carbon footprinting purposes. To date, this application has not been recognized. The identified shortcomings have been addressed, and recommendations for improvement have been provided.

2. IMPROVEMENTS TO GORDON AND FUNG'S METHODOLOGY

The work completed by Gordon and Fung contributed to advances in accurate emission quantification. However, it has the two following drawbacks.

One GHG emission factor was applied to all power generation facilities of the same type – When calculating hourly emissions per generation facility, Gordon and Fung grouped generation facilities by fuel source [4]. For example, an average emission factor (amount of CO_2 per unit of electricity generated) was determined for coal powered generating facilities using data from Ontario Power Generation's (OPG) 2006 Sustainable Development Report [5]. Total hourly power generation by coal facilities was then applied to this average emission factor to calculate total emissions by coal facilities during that hour. Emission intensity calculations are therefore limited through the assumption that all facilities using the same fuel source are equally efficient, therefore dismissing variables such as age and combustion technology. In our study, based on 2009 data from the Ontario power market, the efficiency of natural gas facilities varied by as much as 326 grams of CO_2e per kilowatt hour generated. The variable efficiencies can be accurately accounted for by developing Facility-Specific Emission Factors (FSEF) for each facility that generates emissions during power generation. The FSEFs can then be applied to facility-specific generation data to achieve emission values with increased accuracy.

The formula for calculating a facility-specific emission factor is as follows:

$$FSEF\ (g/kWh) = \frac{Annual\ GHG\ Emissions\ (g)}{Annual\ Generation\ Total\ (kWh)}\,. \tag{2}$$

Although FSEFs for CO_2e are the most practical for carbon accounting, the above formula can be applied to any individual greenhouse gas with adequate data available. If a CO_2e footprint is calculated by applying Global Warming Potential (GWP) values to the corresponding GHGs, it is recommended that the IPCC database of GWPs be consulted [5]. These values will allow the calculation of a carbon dioxide equivalent. When calculating FSEFs, data for the study year should be used. If this data is unavailable, the best available data should be used.

The units for CO_2/CO_2e calculations are inconsistent – Non-carbon dioxide GHGs were excluded from coal-fired facility emission factor calculations in Gordon and Fung's study. That is, CO_2 values – and not CO_2e – were employed in the development of the coal-fired facility emission factor. In contrast, Gordon and Fung used CO_2e for the development of the natural gas facility emission factor. Standard GHG accounting protocols, such as the GHG Protocol, recommend that a carbon footprint be measured in CO_2e [6], and the inconsistent units would make reported values less accurate.

3. METHODOLOGY

Through this study, building on the innovative approach taken by Gordon and Fung, a new methodology has been developed to greatly increase the accuracy of scope two emissions quantification. The methodology attempts to amend the inaccuracies identified in Gordon and Fung's methodology. The steps to calculate a CO_2e hourly emission factor have been provided below:

1. Total emissions for each power generation facility that supplied the grid for the particular hour was calculated by multiplying total hourly generation by the facility (in kWh) by the FSEF (in g/kWh). The facility-specific emission factor was 0 g/kWh for facilities that do not generate GHG emissions during power generation (nuclear, hydro, wind).
2. All facility-specific emissions for the hour were summed to generate "total hourly emissions".
3. Hourly generation values were summed for all facilities supplying the grid during that hour to generate "total hourly generation".
4. Total hourly emissions (in grams) were divided by total hourly generation (in kWh) to generate the **hourly emission factor** in grams of CO_2e/kWh.

Therefore,

$$Hourly\ EF\ (g/kWh) = \frac{Total\ Hourly\ Emissions\ (g)}{Total\ Hourly\ Generation(kWh)}\ . \tag{3}$$

Once the hourly emission factor has been established, it can be multiplied by an electricity consumption value for that particular hour to determine accurate Scope Two hourly GHG emissions. Hourly emissions are to be summed to represent a desired timeframe, such as a month or a year.

4. COMPARISON OF RESULTS

The hourly emission factor methodology developed by Christian Gordon and Alan Fung was designed to track emission reductions from renewable technologies [4]. If CO_2e data was collected from Environment Canada, the methodology could also be employed in operational carbon quantification by profiling hourly CO_2e emission factors alongside hourly electricity consumption data. Scope two emissions can be determined with hourly precision. For the study year of 2009, hourly emission factors were developed using Gordon and Fung's methodology as well as the methodology being proposed through this study. Two separate 2009 hourly consumption datasets, one for a theatre and one for a Net System Load Shape (NSLS), were profiled alongside each set of 2009 hourly emission factors to calculate and compare CO_2e footprints on an annual and monthly basis. One sample month from each season has been chosen.

As illustrated in Tables 1 and 2, Gordon and Fung's methodology tends to overestimate CO_2e emissions when compared to the proposed methodology. Annual CO_2e footprints for both entities show deviation by nearly 5 %. Deviation varied for each of the sample months, but reached its peak in July at nearly 6 %. The variability stems mainly from the use of different facility emission factors. However, a portion of the variability is the result of Gordon and Fung dismissing non-carbon dioxide GHGs from coal-fired facility emission calculations. After running a test using the proposed methodology (where both CO_2 and CO_2e data was available) it has been determined that annual CO_2e emissions for the NSLS would be underestimated by approximately 7,000 metric tonnes; the equivalent of annual emissions from 1,373 passenger vehicles [8].

	Annual footprints (in tonnes of CO_2e)		
	Our Method	Gordon and Fung	Provincial Avg
THEATRE	64.424	67.611	55.933
% Accuracy to Our Method	-	95.29%	82.73%
NSLS	1,637,825	1,720,461	1,490,165
% Accuracy to Our Method	-	95.20%	90.98%

Table 1. Annual CO_2e footprint comparisons for both case studies.

		Monthly Footprints (in tonnes of CO_2e)		
		Our Method	Gordon and Fung	Provincial Avg
THEATRE	JAN	10.32	10.65	5.88
% Accuracy to Our Method		-	96.98%	56.95%
	APRIL	4.27	4.29	4.38
% Accuracy to Our Method		-	99.42%	97.51%
	JULY	1.95	2.07	2.83
% Accuracy to Our Method		-	94.19%	68.97%
	OCT	5.20	5.46	4.99
% Accuracy to Our Method		-	95.36%	95.94%
NSLS	JAN	252,959	260,675	145,177
% Accuracy to Our Method		-	97.04%	57.39%
	APRIL	108,925	109,574	114,807
% Accuracy to Our Method		-	99.41%	94.88%
	JULY	79,920	84,781	120,732
% Accuracy to Our Method		-	94.27%	66.20%
	OCT	117,979	123,624	117,785
% Accuracy to Our Method		-	95.43%	99.84%

Table 2. Monthly CO_2e footprint comparisons for both case studies.

5. CONCLUSIONS

It is recommended that Gordon and Fung's methodology for calculating hourly emission factors be modified. The accuracy of emission calculations can be increased by developing FSEFs to account for the efficiencies of each power generation facility that produces emissions during power generation. Furthermore, the use of emissions data provided by Environment Canada allows for calculations that use a consistent unit of measurement (i.e. CO_2e). Through both of these improvements, calculations using our methodology yield more accurate emission reduction values as well as more accurate carbon footprint calculations. The accuracy is a substantial improvement from using the provincial average emission factor and should be strongly considered for adoption in operational carbon quantification.

6. RECOMMENDATIONS

To date, standard GHG accounting protocols do not recommend the use of hourly emission factors in operational emission quantification. As proven in the case study results, the proposed methodology substantially improves the accuracy of calculations when compared to using the annual average grid intensity. It also helps one identify emission trends and opportunities for reductions based on shifted or reduced consumption. It is recommended that the proposed methodology be adopted for use in Ontario, and the development of hourly emission factors be pursued in other power markets. The hourly emission calculations are a step towards the development of real-time grid intensity values, and therefore real-time management of scope two emissions. The real time emission factors can be accurately estimated through use of the methodology provided above and the Independent Electricity System Operator's (IESO) projected grid mixes. It is recommended that the live grid intensities be published online and updated each hour for organizations looking for improved accuracy in carbon quantification. To further improve the accuracy of hourly emission factors, our research team recommends that imports and exports be incorporated into hourly emission factor calculations. By re-applying this methodology to power markets connected with Ontario and obtaining hourly intertie data, imports and exports can be accounted for in Ontario's hourly emission factors. Finally, any attempt to eliminate the use of averages within the methodology without compromising accuracy is encouraged. For example, actual hourly efficiencies of each fossil fuel facility could be collected and used in the development of hourly emission factors instead of our FSEFs that reflect a particular study year.

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