Location-Based ISONE Pollutant Intensity Analysis

Exexcutive Summary

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Inside this report...

Motivation

Many entities, such as Harvard University[1] and other academic institutions, have adopted ambitious greenhouse gas ("GHG") emission reduction goals. As part of meeting these goals, these entities engage in detailed GHG emission accounting calculations to estimate their GHG "footprint," often according to a prescriptive procedure developed by the Greenhouse Gas Protocol.[2] Frequently, the largest contribution to an entity's GHG emissions are CO_2 emissions that result from consumption of electric grid-supplied electricity, so-called "Scope 2" emissions.[3] The simplest approach to calculate such emissions is to multiply an entity's grid electricity consumption, in units of MWh,[4] by the local grid's average CO_2 emission rate, in units of lbs/MWh. This average rate is often simply the sum of the CO_2 emissions from generators on a local grid during a calendar year, divided by the total amount of electricity generated by that grid within that same calendar year.

However, finer resolution data is now available for the ISONE grid that allows one to calculate an entity's Scope 2 emissions on an hourly basis instead of an annual basis by multiplying the ISONE grid's hourly CO_2 emission rate by an entity's electricity consumption during that hour. Using this finer resolution data to calculate an entity's Scope 2 emissions may provide several advantages. First, the finer resolution data may be more accurate in that it takes into account emissions at the time of consumption. Second, if there are hours when the CO_2 emission rate is particularly low, electricity consumption for heating may be favored over natural gas combustion from a GHG emissions perspective. Lastly, if there is a significant difference in the CO_2 emission rate between different hours in the day, time shifting electricity consumption may offer an easy way to lower an entity's Scope 2 emissions without actually reducing total electricity consumption.

This white paper summarizes a research project that attempted to answer these questions by calculating ISONE's hourly CO_2, NOX and SO_2 emission rates, referred to here as hourly pollutant intensities, between Dec 4, 2014 and April 30, 2016.[5] This executive summary provides a brief overview of the research project's methods, conclusions and recommendations. The remainder of the white paper discusses in detail the analysis method and results.

Analysis Approach

ISONE provides a generation fuel mix at intervals ranging between 5 minutes and 1 hour through ISONE's webservices website. The generation fuel mix describes how much electrical energy was injected into the ISONE grid by ten different types of generators and over six different connections with neighboring grids. This data was used to calculate hourly pollutant intensities in three steps. First, the amount of pollution emitted by each generator and each importing grid was calculated by multiplying the energy provided by each generator and import grid by a pollutant "emission factor" or import "pollutant intensity," all in units of lbs/MWh. Emission factors and import grid pollutant intensities were assigned based on data for generators in ISONE, New York, Quebec, and New Brunswick from eGRID2012, EPA's CAMD database, NEPOOL-GIS, the Canadian Electricity Association's 2013 annual report, Hydro Quebec's annual report,

1 In 2008, Harvard set an ambitious goal to reduce its GHG emissions by 30% from 2006 levels by 2016. See Harvard University, Sustainability Report, available at **report.green.harvard.edu.**

2 See Greenhouse Gas Protocol, *Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard* (May 2013), available at **http://www.ghgprotocol.org/files/ghgp/public/ghg-protocol-revised.pdf**; and Greenhouse Gas Protocol, *GHG Protocol Scope 2 Guidance,* (March 2015) available at **http://ghgprotocol.org/files/ghgp/Scope%202%20Guidance_Final.pdf.**

3 Greenhouse Gas Protocol, *Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard, supra* note 2 at 27.

4 Greenhouse Gas Protocol, *GHG Protocol Scope 2 Guidance, supra* note 2 at 49.

5 The start date for the analysis was determined by the availability of detailed generator type mix data from ISONE.

and New Brunswick Power's annual report. Second, the total amount of pollution emitted in a given hour was calculated by summing the pollution from each generator and import grid. Lastly, the pollution sum was divided by the total amount of electrical energy generated within or imported into the ISONE grid. Note that exports from the ISONE grid were purposefully ignored as exports do not change the pollutant intensity of electricity consumed from the ISONE grid. Uncertainty limits on CO_2 emission factors and pollution intensities were estimated based on the characteristics of generators in the generator databases. These calculations were performed twice, once assuming that all biomass combustion is carbon neutral and once assuming that all biomass combustion is not carbon neutral.

Two types of electricity consumption investments were then modeled to determine if such investments could take advantage of the hourly CO_2 pollutant intensity to lower an entity's Scope 2 CO_2 emissions. These investments included (1) an electric boiler, either heated directly or with a heat pump; and (2) a cold thermal storage device that could be charged during low CO_2 pollutant intensity hours and discharged during high CO_2 pollutant intensity hours.

Because the analysis method was intended to focus on an entity's Scope 2 emissions, the method purposefully did not use marginal emission factors or a sophisticated generator dispatch model, such as the EPA's AVERT, to estimate GHG emissions that would be avoided by changing electricity consumption. These methods were not used because, *inter alia*, calculating avoided emissions is specifically discouraged by the Greenhouse Gas Protocol.[6] In addition, marginal emission factors or dispatch models may make assumptions about the electrical grid, such as whether biomass is carbon neutral, that a consuming entity may not choose to make. Further, marginal emission factors and dispatch models tend to ignore imports from Canada, which are a significant source of electricity for ISONE.

Note also that this analysis used the "location-based" Scope 2 approach instead of the "market-based" Scope 2 approach,[7] and thus, the results apply to any consuming entity within ISONE. In order to perform the same analysis using a market-based approach, an entity would need to know the emission factors, on an hourly basis, for the generators from which it purchases its electricity.

Results

Biomass combustion can make a significant contribution to ISONE's CO_2 pollutant intensity

The analysis revealed that the degree to which biomass combustion is treated as carbon neutral can make a significant difference in ISONE's CO2 pollutant intensity. For example, in the 2015 calendar year, the average CO_2 pollutant intensity on the transmission system and including imports was 621 ± 30 or 759 ± 46 lbs/MWh, depending on whether biomass combustion was considered carbon neutral or not carbon neutral, respectively, a difference of 22%.

Imports significantly lower ISONE's CO_2 pollutant intensity

About 18% of ISONE's electricity is imported from New York, Quebec and New Brunswick. Because a majority of this electricity is produced with hydro or nuclear power, including these imports lowers the CO_2 pollutant intensity by about 10%, regardless of

6 Greenhouse Gas Protocol, *GHG Protocol Scope 2 Guidance, supra* note 2 at 28.

7 Greenhouse Gas Protocol, *GHG Protocol Scope 2 Guidance, supra* note 2 at 25 – 27.

whether biomass is carbon neutral.

There are significant variations in ISONE's hourly CO_2 pollutant intensity

The hourly CO_2 pollutant intensity, as measured on the transmission system, varies from a low of about 280 lbs/MWh to a high of nearly 1,000 lbs/MWh, if biomass is carbon neutral, and varies from a low of about 450 to a high of about 1,100 lbs/MWh, if biomass is not considered carbon neutral. The variations are slightly correlated with ISONE system load, the wholesale price of electricity, and the ambient temperature – higher system load and higher electricity prices tend to correspond to higher CO_2 pollutant intensity hours. Likewise, temperature extremes, either high or low temperatures, tend to correspond to higher CO_2 pollutant intensity hours. However, these correlations are not sufficient for system load, electricity price, or ambient temperature to serve as a proxy for CO_2 pollutant intensity. Note that there is no consistent correlation with the time of year.

The CO_2 pollutant intensity does consistently vary with the hour of the day. The ISONE grid tends to be less carbon intense around 4 AM and more carbon intense between 12 and 8 PM. The average difference between these hours was $63.8^{+9.1}_{-7.3}$ and $28.8^{+12.6}_{-11.2}$ lbs/MWh on the transmission system if biomass is considered carbon neutral or not carbon neutral, respectively. These daily differences are equivalent to a daily variation of about 11% and 4%, respectively.

The hourly pollutant intensities, daily variations, and correlations between hourly pollutant intensity and system load, wholesale price, and ambient temperature are illustrated in 13 figures in the main text.

At the present time, an hourly basis is likely equivalent to an annual basis for calculating Scope 2 CO_2 emissions

In order to determine whether an hourly basis is different than an annual basis for the purposes of calculating an entity's Scope 2 CO_2 emissions, Harvard's Scope 2 CO_2 emissions were estimated using the two different methods. The results of these two methods for CO_2 are presented in Table ES1 and differ by about 0.7%, an insignificant difference given the uncertainties in the CO_2 pollutant intensities. Thus, at the present time, these two methods are essentially equivalent. However, as further discussed in the white paper, these two methods may differ in the future as more renewable energy, which has a stronger daily variation, is used by ISONE.

An electric boiler can modestly lower Scope 2 CO_2 emissions if biomass combustion is considered carbon neutral

The ISONE grid has a sufficiently low CO_2 pollutant intensity that, if biomass is considered carbon neutral, there are a few hours when providing heat

Table ES1: A comparison of Harvard's pollutant emissions due to electricity consumption for the 2015 calendar year as calculated on an annual or hourly basis.

	CO2 EMISSIONS (LBS)	
Calculation Method	Biomass is carbon neutral	Biomass is not carbon neutral
Hourly Basis	135,800,000	166,200,000
Annual Basis	136,800,000	167,200,000

through direct resistive heating results in less CO_2 emissions than burning natural gas. These hours also tend to be hours when the price of electricity is very low. For example, if a 1 MW electric boiler were energized whenever the CO_2 pollutant intensity is less than natural gas combustion, the wholesale price in Boston is less than $20 / MWh and the hour is off-peak to avoid increasing electricity demand charges, then the boiler would reduce CO_2 emissions compared to a 1 MW natural gas boiler by 5,000 ± 3,700 lbs. The boiler would operate 1.7% of the time at a wholesale cost of $0.65 / MWh.

Note that if biomass is considered not carbon neutral, direct electric resistive heating would emit more CO_2 than natural gas combustion for all hours within the analyzed date range.

A heat-pump electric heater that displaces natural gas combustion can dramatically lower Scope 2 CO_2 emissions

The ISONE grid's CO_2 pollutant intensity is sufficiently low that a heat-pump type electric heater would always produce less CO_2 emissions than natural gas combustion. For example, if a 1 MW heat-pump powered electric heater with a coefficient of performance of 3 were operated whenever the electricity price was less than $20/MWh and during off-peak hours, CO_2 emissions would be reduced by 1,910,000 ± 70,000 or 1,500,000 ± 100,000 lbs compared to a 3 MW natural gas boiler, depending on whether biomass is carbon neutral or not carbon neutral, respectively. The heater would operate 20% of the time at a wholesale cost of $9.5/MWh.

Using thermal storage to shift daily electricity consumption can modestly reduce Scope 2 CO_2 emissions

The daily variation in the ISONE's CO_2 pollutant intensity is sufficiently strong that a cold storage device that was able to shift electricity consumption from high CO_2 pollutant intensity hours to low pollutant intensity hours would save CO_2 emissions. For example, a 6 MWh cold storage device, operated on days when the maximum temperature exceeded 75˚F for three hours every morning between 2 AM and 5 AM and then discharged between 1 PM and 6 PM on the same day, would reduce CO_2 emissions by $41{,}000^{+4{,}600}_{-5{,}600}$ and $15{,}000^{+7{,}000}_{-7{,}800}$ lbs under the biomass-is-carbon-neutral and the biomass-is-not-carbon-neutral scenarios, respectively. The storage device would also save $20,908 in wholesale electricity purchases.

Recommendations

Entities within ISONE that adopt a voluntary GHG emission reduction goal should carefully consider which CO_2 pollutant intensity they use to calculate their Scope 2 CO_2 emissions

The Greenhouse Gas Protocol does not settle which pollutant intensity an entity should use for calculating its Scope 2 emissions. Although the Protocol recommends that entities use eGRID2012's CO_2 pollutant intensity[8] and separately allows entities to calculate their own pollutant intensities through "Advanced Grid Studies,"[9] such as those undertaken for this analysis, it also recommends that entities use "the most appropriate, accurate, precise, and highest quality emission factors available [...]. "[10] Thus, entities that follow the Protocol, and especially those entities that have the capacity to analyze and calculate ISONE's CO_2 pollutant intensity, have to carefully evaluate which CO_2 pollutant intensity meets the GHG Protocol's

8 Greenhouse Gas Protocol, *GHG Protocol Scope 2 Guidance, supra* note 2 at 47.

9 *Id*. at 53.

10 *Id*. at 45. Note that the GHG Protocol refers to a grid's pollutant intensity as its "emission factor." This analysis uses the term "emission factor" only for the pollutant emissions from individual generator types.

standard. As this project has uncovered, the need for a careful evaluation is especially true in New England, where choices regarding biomass and imports can make a difference in the CO_2 pollutant intensity of up to 33%, and a number of different estimates of ISONE's CO_2 pollutant intensity are available.

To illustrate the range of CO_2 pollutant intensities available for ISONE, Table ES2 lists five different values for the CO_2 pollutant intensity, including this analysis and three published values from eGRID, ISONE and NEPOOL-GIS. Note that these values all ignore imports from neighboring grids.[11] The highest of these values is 34% greater than the lowest so that two entities that consume the same amount of electricity but that use different CO_2 pollutant intensity values could have Scope 2 emissions that differ by up to 34%. If one of these entities also included imports, this difference could grow to 45%.

As this analysis has revealed, the differences among these values are mostly due to how biomass combustion is treated.[12] While eGRID2012 explicitly assumes that all biomass combustion is carbon neutral, ISONE takes a mixed approach, and NEPOOL GIS assumes that all biomass combustion is not carbon neutral. As a consequence, when choosing to use one CO_2 pollutant intensity over another, an entity is making an implicit policy choice regarding whether biomass combustion is carbon neutral.

Unfortunately, the GHG Protocol does not provide clear guidance on how to treat biomass combustion. On the one hand, the Protocol requires that biomass combustion be reported – it explicitly states that biomass should not be considered carbon neutral.[13] On the other hand, the Protocol requires that biomass combustion not be included in Scope 2 emissions.[14] The extent to which reported biomass emissions count against an entity's GHG emission reduction goals is also not settled by the Protocol because entities are free under the Protocol to adopt GHG emission goals that cover any subset of emission sources.[15] In other words, an entity could adopt a voluntary GHG emission goal that explicitly does not cover biomass combustion. Such a goal would be equivalent to simply assuming that biomass combustion is carbon neutral.

11 As discussed above, imports lower ISONE's CO_2 pollutant intensity by about 10% under either biomass scenario. Imports were ignored for Table ES2 in order to make a comparison to the published values, which ignore imports.

12 NEPOOL-GIS may be slightly higher than a pure biomass-is-not-carbon neutral scenario because it may not correct emissions from combined-heat-and-power generators for emissions due to heating alone.

13 Greenhouse Gas Protocol, *GHG Protocol Scope 2 Guidance, supra* note 2 at 57.

14 *Id.* In essence, the Protocol requires entities to calculate their CO_2 emissions due to electricity consumption twice – once with biomass considered as carbon neutral and a second time with biomass considered as not carbon neutral. The carbon neutral calculation is then reported as Scope 2 emissions, and the extra emissions due to biomass combustion is reported separately.

15 Greenhouse Gas Protocol, *Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard, supra* note 2 at 77 – 78.

Table ES2: A comparison of the average pollutant intensities for ISONE generators only as calculated by five different methods including: this analysis under both biomass scenarios, eGRID2012, ISONE, and NEPOOL-GIS.

CALCULATION METHOD	CO_2 POLLUTANT INTENSITY (LBS/MWh)
This analysis 2015 (biomass is carbon neutral)	639 ± 33
This analysis 2015 (biomass is not carbon neutral)	788 ± 51
eGRID 2012	638
ISONE Report (2014)	726
NEPOOL-GIS (2015)	855

In sum, biomass combustion makes such a large contribution to CO_2 emissions in ISONE that when adopting a CO_2 pollutant intensity, an entity should carefully consider (1) whether it wants to treat biomass combustion as carbon neutral; and (2) the extent to which such combustion should count against its voluntary GHG emission reduction goal.

Entities within ISONE that have the capacity should consider calculating their Scope 2 CO_2 emissions on an hourly basis

As discussed above, at present, there is little reason for an entity to use either the annual or hourly basis for calculating Scope 2 CO_2 emissions because either method results in about the same number. However, for entities that have the staff resources, it makes sense to calculate their Scope 2 CO_2 emissions using both methods so that they keep apprised of changes in the ISONE CO_2 pollutant intensity that could reveal investment opportunities in the future.

As the grid becomes cleaner and includes more intermittent resources, opportunities for targeted investments that can take advantage of hourly or daily variations in the CO_2 pollutant intensity are likely to increase. As the grid becomes less CO_2 intense, the justification for using an electric boiler to displace natural gas combustion becomes stronger. In addition, as renewables become more integrated into the grid, the opportunities to take advantage of times when the grid is very clean through thermal storage are likely to increase. For example, if solar power becomes widespread, the grid may become close to carbon neutral in the middle of the day in the summer. These times may be ideal to charge cold storage devices for use later in the afternoon when solar power has declined. However, these opportunities can only be seized if the entity calculates its Scope 2 emissions on an hourly basis.

Entities within ISONE should consider targeted electricity consuming investments that save money and are carbon neutral when analyzed on an hourly basis

The analysis of electric boilers and cold water storage devices indicates that for devices other than heat-pumps, procurement of such devices is likely not justified from a CO_2 emissions perspective – the CO_2 savings are simply too low. However, these investments would lower an entity's energy expenditure. These financial savings could then be reinvested in other projects that have a greater CO_2 emission reduction impact, such as onsite energy efficiency projects. Although increasing electricity consumption would increase an entity's Scope 2 emissions if calculated on an annual basis, increasing electricity consumption during low CO_2 intensity hours that displaces natural gas consumption would not increase an entity's Scope 2 emissions, if calculated on an hourly basis. Thus, an entity should not be dissuaded from making electricity consuming or time shifting investments, as long as those investments do not increase emissions when analyzed on an hourly basis.

Entities within ISONE should consider heat-pump based heating technologies

As discussed above, the ISONE CO_2 pollutant intensity is sufficiently low that heat pumps that displace onsite natural gas combustion for heating can offer a substantial CO_2 emission reduction savings. As a consequence, entities within ISONE that seek to lower their CO_2 emissions should give serious consideration to electrifying their heating loads through the use of heat pumps.