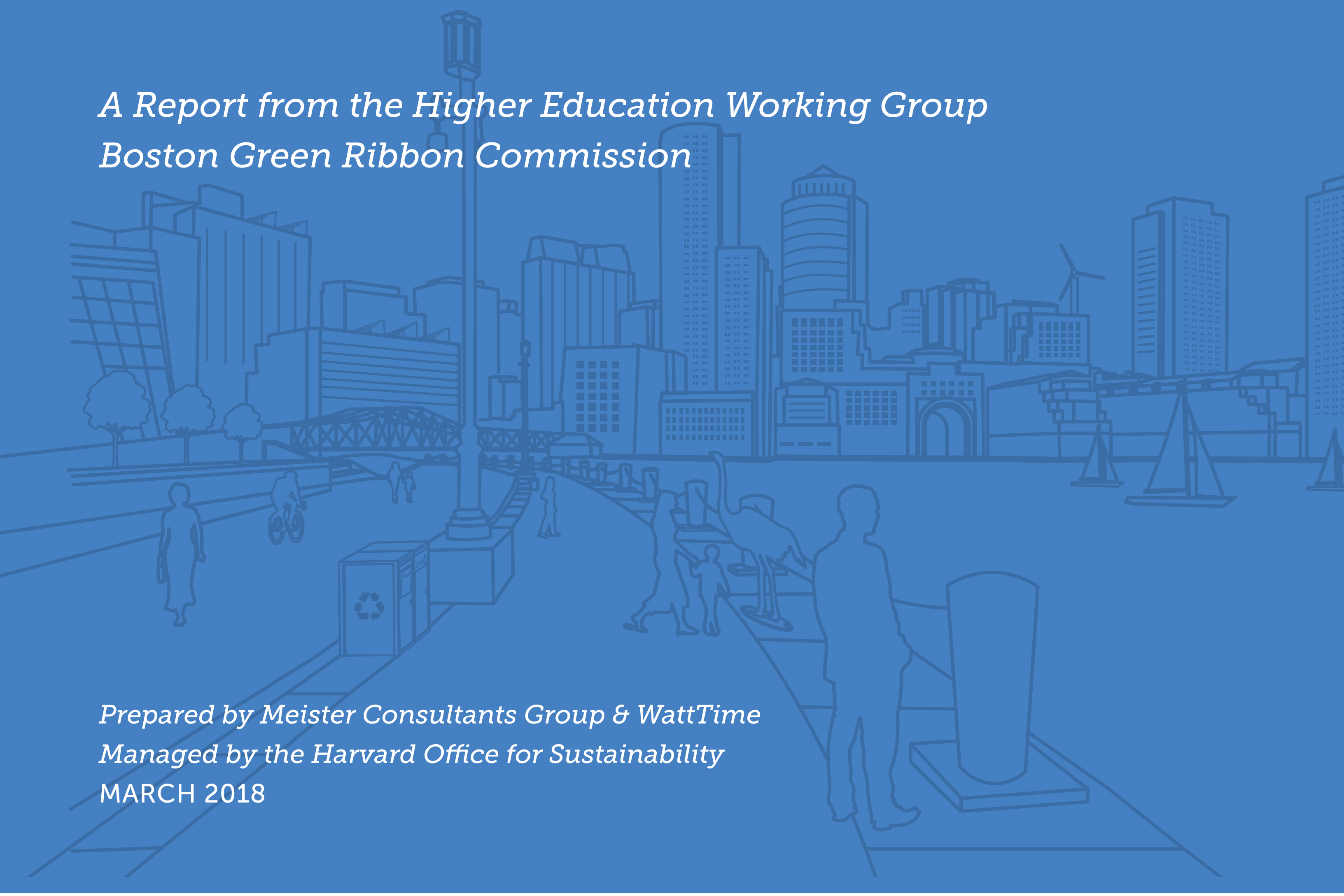
Institutional Renewable Energy Procurement:

Quantitative Impacts Addendum



A Report from the Higher Education Working Group
Boston Green Ribbon Commission

Prepared by Meister Consultants Group & WattTime
Managed by the Harvard Office for Sustainability
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INSTITUTIONAL RENEWABLE ENERGY PROCUREMENT QUANTITATIVE IMPACTS ADDENDUM

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Introduction

Given the background set out in the Guidance for Renewable Energy Purchasing and Associated Claims report ("the report"), the next step for institutions is to begin quantifying the emissions impacts of renewable energy purchases. Quantifying impacts will inform decision-making. **This addendum aims to provide more detailed guidance to institutions considering how to conduct emissions impact analyses associated with procurement decisions.** While also important to decision making, the other impacts and co-benefits of these procurement decisions (e.g. local air pollution, local job creation, etc.) are outside the scope of this report. **Section 1** outlines three different calculation methods, grounded in examples of existing efforts. These methods are: carbon footprint emissions accounting, avoided emissions supplemental calculation, and carbon offset accounting. While the methods are not technically mutually exclusive, in practice, institutions will typically select only one method to measure the impacts of a given renewable energy project. **Section 2** provides a framework for comparison between different potential courses of action, illustrated by theoretical but realistic examples.

Section 1- Impact calculation methods

The sections below provide an overview of three different widespread methodologies for calculating the emissions impacts of renewable energy purchasing.

Method A- Carbon footprint emissions accounting

Context

While multiple carbon footprinting standards exist, **the Greenhouse Gas Protocol (GHGP) is by far the most accepted standard.** Created by the World Resources Institute and World Business Council for Sustainable Development, the GHGP Corporate Accounting and Reporting Standard has guided standardization of carbon footprinting practices throughout industry since 2004. This report focuses only on the emissions calculations, not the full carbon footprinting process.

Methodology

The most recently updated Scope 2 Guidance of the GHGP lays out **two different forms** of carbon footprinting for organizations: a Location-Based and a Market-Based method. Institutions practicing carbon footprinting under the GHGP are **required to report both methods where possible, but in public materials institutions frequently make a single claim** for narrative simplicity. The Scope 2 Guidance amendment[1] should be consulted for details, as it both modified the process and provided more specific guidance to help standardize accounting for renewable electricity purchases.

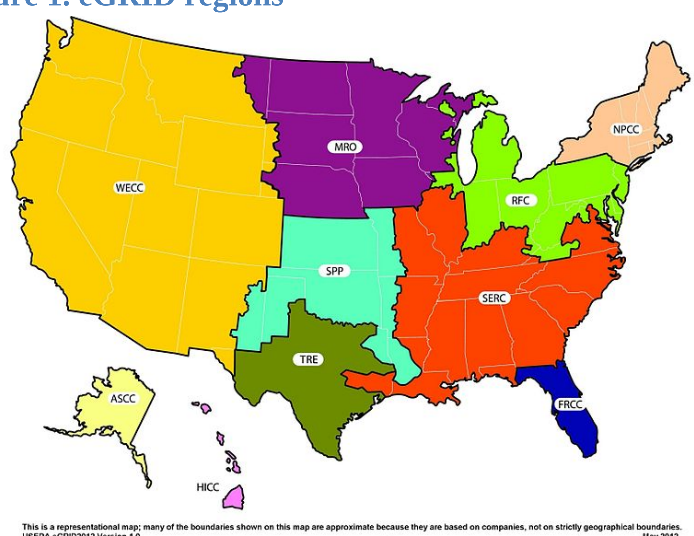
[1] Sotos, Mary. Greenhouse Gas Protocol Scope 2 Guidance. http://www.ghgprotocol.org/scope_2_guidance

The **Location-Based** method considers only institutions' total consumption of grid electricity, not their purchasing behavior. Therefore, institutions that use this method effectively **receive "credit" for renewable energy directly generated on-site by the institution itself, but not for any off-site renewable energy purchasing.**

The **Market-Based** method also begins with an institution's total consumption of grid electricity, but also **considers off-site purchasing**. (For each Renewable Energy Certificate (REC) purchased by the institution, the method subtracts a megawatt-hour of electricity consumed.) The Market-Based method is more commonly presented by institutions that purchase any renewable energy off-site. Therefore, it is the **"primary" carbon footprinting calculation** and the footprinting method that this addendum focuses on.

The essence of the calculation for carbon emissions is as follows: **Total electricity consumed, less megawatt-hours of renewable energy generation, multiplied by an average emissions factor** for electricity in the given location. This is because, quantitatively speaking, the methods assign equal weight to all megawatt-hours of generation regardless of quality or location, although it should be noted that suggestions for quality criteria are included in the GHGP. Institutions are not permitted to go carbon negative, (i.e. renewable energy megawatt-hours in excess of grid energy purchased are ignored).[2]

Figure 1. eGRID regions



The most common source for **appropriate emissions factors** for U.S. projects is the EPA's **eGRID database**, which breaks the grid into regions as shown in **Figure 1**. However, institutions are given flexibility in their choice of emissions factors. For example, some Boston-area institutions choose to use emissions factors from ISO-NE rather than eGRID's factors for NPCC.

Regardless of the data source, since the updated Scope 2 Guidance was issued in 2014, the GHGP now specifically mandates that all **institutions must use average, not marginal, emissions factors** to calculate their GHG footprint.

[2] Note that creates a challenge for institutions which own fossil fuel energy generating assets rather than purchase their electrical output from the grid. Known as Scope 1, rather than Scope 2 emissions, emissions from these sources cannot be counted as being displaced or offset by off-site renewable energy purchasing. This quirk of accounting does not apply to the other two methods in this addendum.

Further, since the Scope 2 Guidance update, **carbon footprint emissions accounting no longer claims to measure the amount of emissions reduced or avoided** by renewable energy purchasing. Rather, it simply **measures the amount of emissions a university or company are "responsible for"** based on the amount (number of megawatt-hours) of renewable energy an organization purchases. This means that the method essentially captures the **indirect effect of renewable energy purchasing on carbon footprinting**. In this way, it functions as a kind of de facto impact analysis technique. Carbon footprint emissions accounting is **extremely widespread** and is in fact more frequently used than the other more direct impact analysis techniques discussed in the following sections.

Overall, carbon footprinting has allowed different organizations to use a single standard. However, as discussed, nearly all projects are counted exactly equally on a per-megawatt-hour basis using the carbon footprinting method, regardless of differences in location or quality. This makes it **challenging for institutions to evaluate emissions reductions of renewable energy projects, or compare impacts across projects**.

Example calculation for carbon footprinting

The following stylized example illustrates the carbon footprinting approach.
Consider an institution with the following profile:

- Consumes 100 megawatt-hours (MWh) of electricity in Boston.
- Generates 10 MWh of physical electricity on-site.
- Purchases 10 MWh of physical electricity, and the RECs, from a local solar PPA in New England (ISO-NE) that is additional.
- Purchases 70 MWh of RECs from a solar project in the Mid-Atlantic (PJM) via a virtual PPA that is additional.
- Purchases 20 MWh of RECs from a wind project in the Midwest (MISO) that is not additional.

Under the location-based carbon footprinting method, no emissions reductions calculations are performed. The *implicit* math is equivalent to the key steps below:

Step	**Calculation**	**Notes**
1. Calculate megawatt-hours of applicable renewable energy generation	10 MWh	Excluded: *all* purchased renewable energy.
2. Apply an average emissions factor	577 lbs CO_2/MWh	All MWh renewable electricity apply the same emissions factor regardless of time or place, which is the average New England emissions factor. This calculation uses the latest (2014) eGRID factor.

Step	Calculation	Notes
3. Multiply to get total emissions reductions	The emissions reductions are 10 MWh x 577 lbs/MWh = **5,770 lbs**	

Again, under the location-based carbon footprinting method, *all* renewable energy purchasing is excluded. Institutions can only reduce their carbon footprint in this framework by directly generating their own renewable energy behind the meter. For this reason, the method is frequently not applicable to institutional renewable energy purchasing, and it is not considered further in this appendix.

Under the market-based method, there are also no explicit emissions reductions calculations. However, the *implicit* math is more involved:

Step	Calculation	Notes
1. Calculate megawatt-hours of applicable renewable energy generation	10 MWh (from solar generated) + 10MWh (from local solar purchased) + 70 MWh (from PJM solar) + 20 MWh (from MISO wind) – 10 MWh (from energy in excess of consumption) = 100 MWh	Excluded: renewable energy in excess of consumption.
2. Apply an average emissions factor	577 lbs CO_2/MWh	All MWh renewable electricity apply the same emissions factor regardless of time or place, which is the average New England emissions factor. This calculation uses the latest (2014) eGRID factor.
3. Multiply to get total emissions reductions	The emissions reductions are 100 MWh x 577 lbs/MWh = **57,700 lbs**	

Tracking and certification of carbon footprinting

Given that carbon footprinting does not measure emissions impacts of renewable energy projects, **no tracking or certification** exist for this sort of impact measurement. **Onsite projects do not need to be tracked directly**. This is because they reduce emissions indirectly by driving down the amount of electricity an institution purchases from the power grid in the first place. However, for **offsite projects, the method does require the use of RECs**. To that end, organizations must track and certify RECs under the normal rules for REC tracking and certification (e.g. Green-e, Generation Information Systems, etc.).

Method B- Avoided emissions supplemental calculation

Context

In contrast to carbon footprint emissions accounting, this section examines a method in which the GHGP does explicitly lay out a technique for quantifying the emissions impact of renewable energy purchasing. This is known as the avoided emissions supplemental calculation.

In the last section, we saw that carbon footprinting systems were not designed for impact measurement purposes, but rather for establishing broadly comparable emissions inventories. Carbon footprinting systems only measure the quantity of renewable energy and implicitly associate that quantity with an emissions reduction. **Avoided emissions calculations on the other hand, directly quantify the emissions reduction impacts of particular renewable energy projects.** Unlike carbon footprinting techniques, avoided emissions techniques reflect the fact that the **amount of emissions that renewable energy avoids per megawatt-hour of generation can vary greatly based on factors such as which power grid the project is located in**. For this reason, the results are systematically, and often substantially, different under the two systems.

Methodology

The GHGP contains general instructions for measuring the avoided emissions from a wide variety of emissions-reducing projects. For renewable energy purchasing, the most relevant section is the GHG Protocol Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects.[3] Key steps in the method are described below.

First, **define a project assessment boundary**. That is, define a specific project such as a renewable energy facility contracted via a power purchasing agreement, and consider whether any indirect or "secondary" effects are large enough to necessitate measurement. Secondary effects include any emissions which the project would cause or avoid that would not have otherwise occurred. For example, if constructing a wind project in a very remote area will require large amounts of materials to be transported to that area in order to make the project possible, transportation emissions should be considered as well.

Second, an entity should **determine the ratio of emissions that will be avoided based on constructing the power plant (known as the build margin or "BM") versus operating it (known as the operating margin or "OM")**. In some cases, an institution purchasing renewable energy plant will delay or cancel the construction of an equally sized power plant by another party such as the local utility. This occurs primarily in the case of a capacity-constrained grid, or a renewable energy project that provides continuous ("firm") power which

[3] Broekhoff, Derik et al. (2007) "Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects." World Resources Institute. World Business Council for Sustainable Development. http://www.wri.org/publication/guidelines-quantifying-ghg-reductions-grid-connected-electricity-projects

is unusual for renewables. Projects should select a value between 0 and 1 of the extent to which this situation applies to them.[4]

If this situation applies in part or in whole, the next step is to **identify a baseline of what power plant(s) would be built if the project did not occur**. There are a variety of acceptable methods to achieve this. Whatever the method, these power plants should be translated into an emissions intensity per megawatt-hour of generation from such a plant or plants. This emissions intensity per megawatt-hour is referred to as the build margin.

For projects with partial or no build margin effects, the next step is to **identify a baseline of which power plants will have their operations reduced or avoided if the project is constructed**, (i.e. the marginal power plants). This is referred to as the "operating margin." Again, there are a variety of acceptable method to achieve this, with a hierarchy of options in order of increasing rigor and complexity. The GHGP stated in a 2007 document that

"The ideal method to estimate operating margin (OM) emissions would be to identify precisely which power plants on a grid are backed down in response to the project activity's operation. In practice, this is difficult if not impossible to do."

Thus, it goes on to suggest a variety of options which it states are less rigorous but more feasible. However, recent research breakthroughs have challenged this statement, with new technologies becoming available in the last few years which do identify precisely which power plants on a grid lower production in response to a project activity's operation. WattTime used those new methods to generate the impact estimation table below.

Once the BM and OM are known, a project will need to estimate or determine the amount of electricity generated. Next, multiply the electricity generated by the emissions factors in order to generate an emissions avoided figure. The **calculation for emissions in a specific year or overall is**:

$$\boldsymbol{E = wgB + (1 - w)gO}$$

Where the below definitions hold:

- E = emissions avoided (in metric tons CO_2e);
- w = the weighting factor assigned to the build margin (the aforementioned value between 0 and 1, inclusive);
- g = the electricity generation from the project (in megawatt-hours);
- B = the build margin (in metric tons CO_2e per megawatt-hour); and
- O = the operating margin (also in metric tons CO_2e per megawatt-hour).

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[4] An examination by WattTime of publicly available avoided emissions analyses suggests that it is most common for organizations to select that this option does not apply to them.

This calculation generates a quantity of emissions. The GHGP also contains rules for whether emissions generated under this method "count" towards carbon footprinting. In order to count, **projects must not occur in a region with an emissions trading program**. Note that for universities and other organizations in the **Boston area, the implication is that all local projects disqualified** from the avoided emissions calculation because emissions reductions are already "counted" through the Regional Greenhouse Gas Initiative (RGGI). However, projects outside of the states and provinces covered by RGGI and related initiatives in California are eligible.[5]

Example calculation for avoided emissions

For the sake of comparison, we return to the stylized example first raised in Method A. Consider an institution with the following profile:

- Consumes 100 megawatt-hours (MWh) of electricity in Boston.
- Generates 10 MWh of physical electricity on-site.
- Purchases 10 MWh of physical electricity, and the RECs, from a local solar PPA in New England (ISO-NE) that is additional.
- Purchases 70 MWh of RECs from a solar project in the Mid-Atlantic (PJM) via a virtual PPA that is additional.
- Purchases 20 MWh of RECs from a wind project in the Midwest (MISO) that is not additional.

Under the avoided emissions method, explicit emissions reduction calculations are performed. The key math is equivalent to the key steps below:

Step	Calculation	Notes
1. Calculate megawatt-hours of applicable renewable energy generation	70 MWh (from PJM solar) + 20 MWh (from MISO wind)	Excluded: renewable energy generated in a region with cap-and-trade (e.g. New England).
2. Apply project-specific marginal emissions factors	2,187 lbs CO_2/MWh (for the PJM solar) and 1,707 lbs CO_2/MWh (for the MISO wind)	An individual emissions analysis is calculated for each project taking into account location-specific, time-specific, technology-specific operating margin and build margin effects. This calculation was performed by WattTime using

[5] In such regions, the GHGP includes an exception for projects which purchase carbon allowances from their local emissions trading program, effectively lowering the cap. The causal reasoning is thus that in such regions, building renewable energy projects does not reduce emissions at all, but lowering the cap does. However, it further states that this method may itself not reduce emissions, because many emissions trading program caps are not actually binding or fixed. This generates an apparent contradiction that such programs are simultaneously treated both as binding and as not binding, which is not addressed.

Step	Calculation	Notes
		2016-2017 hourly-level emissions factors and solar and wind output at those locations.
3. Multiply to get total emissions reductions	The emissions reductions are 70 MWh x 2,187 lbs/MWh **+** 20 MWh x 1,708 lbs/MWh = **187,250 lbs**	

Tracking and certification of avoided emissions

Avoided emissions can be tracked and certified, but the requirements are considerably less strict than requirements for carbon offsets. Institutions choosing to pursue avoided emissions certification may consider several options. The main options are listed in the table below.

Figure 2. Avoided emissions verification options: pros and cons

Verification Option	Description	Benefits	Drawbacks
Create Own Verification System	Outsource to 3rd party organization	• Higher potential credibility	• Likely to run afoul of RGGI with regards to EE/RE • Higher cost than entirely internal
	Create institution's own system and protocols – could involve publishing a white paper	• Maximum control and potentially low cost • Retaining knowledge in-house is beneficial for future year calculations • Potential to engage faculty and students**Error! Bookmark not defined.**	• Less credibility • Scale of project may be too low to support verification costs, increasing administrative overhead • Internal capacity may be limited
Partnerships	Partner with other university funds for verification (Duke/Yale)	• Lower cost than 3rd party review • More credible than internal calculations	• Other partners may have differing priorities • System would take time to establish

Method C- Carbon offset accounting

Context

Method C covers carbon offset accounting. While the calculation methodology itself for carbon offset accounting is relatively similar to that of the avoided emission supplemental calculation, it differs significantly on context, mechanics, and certification.

Unlike carbon footprinting and the supplemental avoided emissions calculations, both of which are in the GHGP, there is **no single dominant carbon offset protocol**. Rather, there are a number of different competing protocols, and within each protocol, there are multiple competing methodologies to calculate the impact of renewable energy projects.[6] Moreover, carbon offset registries continuously certify new calculation methodologies. This makes them substantially more adaptive to new technologies than the last two methods and creates a wide variety of specific details for calculation methodologies.

However, this wide variety in the specific implementation details masks a very strong similarity across the methodologies. Because the methodologies are competing with each other to interact with the same carbon registries, **they all use similar fundamental logic**.

Methodology

The fundamental logic of carbon offset methodologies is quite parallel to that of the avoided emissions calculation: **calculate a baseline, measure the total electricity generated by the project, and multiply by an operating and/or build margin as appropriate.** The result is a quantity of emissions avoided in metric tons.

There is however one significant difference between carbon offsets and avoided emissions calculations: they use different tests of additionality. (As defined in this report, additionality assures an action is additional to what would have occurred under a business-as-usual scenario.) The GHGP avoided emissions framework does not a have binding definition of additionality; it simply excludes projects in regions with cap-and-trade programs (on the basis that their emissions reductions are not additional to the effect of those programs). By contrast, **carbon offset frameworks have strict, binding tests for additionality.** To generate a carbon offset, a project must pass one of several tests demonstrating that it would not have existed without the carbon offset being purchased.

The most common test **requires demonstrating that the project would have faced a substantial financial or other barrier in absence of the offset purchase**. Thus, as renewable energy becomes increasingly cost-competitive with fossil fuel-based generation, there is a growing possibility that some projects which are considered additional under an avoided emissions framework may not be considered additional under the stricter definitions of carbon

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[6] Including for example, the Gold Standard, Verified Carbon Standard, Climate Action Reserve, and American Carbon Registry. For more details, see below Figure 3. *Certification* Programs and Eligible Project Types.

offset programs. Other tests of additionality are less likely to be relevant to a university purchasing context.

Example calculation for carbon offsets

Once again, for the sake of comparison, we return to the stylized example first raised in Method A, namely an institution with the following profile:

- Consumes 100 megawatt-hours (MWh) of electricity in Boston.
- Generates 10 MWh of physical electricity on-site.
- Purchases 10 MWh of physical electricity, and the RECs, from a local solar PPA in New England (ISO-NE) that is additional.
- Purchases 70 MWh of RECs from a solar project in the Mid-Atlantic (PJM) via a virtual PPA that is additional.
- Purchases 20 MWh of RECs from a wind project in the Midwest (MISO) that is not additional.

Under the carbon offset method, explicit emissions reduction calculations are performed. The key math is equivalent to the key steps below:

Step	Value	Notes
1. Calculate megawatt-hours of applicable renewable energy generation	70 MWh (from PJM solar with additionality)	Excluded: renewable energy that is either generated in a region with cap-and-trade (e.g. New England), or that is non-additional
2. Apply project-specific marginal emissions factors	2,187 lbs CO_2/MWh	An individual emissions analysis is calculated for each project taking into account location-specific, time-specific, technology-specific operating margin and build margin effects. This calculation was performed by WattTime using 2016-2017 hourly-level emissions factors and solar and wind output at those locations.
3. Multiply to get total emissions reductions	The emissions reductions are 70 MWh x 2,187 lbs/MWh = **153,090 lbs**	

Tracking and certification of carbon offsets

Several options exist to pursue carbon offset certification. The four that together comprise the clear majority of market share are the Verified Carbon Standard, the Climate Action Reserve (CAR), the Gold Standard (which expands upon the Clean Development Mechanism), and the

American Carbon Registry.[7] As discussed above, the methods are broadly similar from the perspective of the offset buyer and organizations can technically use more than one.

The types of projects eligible for certification under each program are listed in the table below. Again, renewable energy and energy efficiency projects in RGGI territory, including New England, are not eligible for certification. The methods are laid out in Error! Reference source not found..

Figure 3. Certification Programs and Eligible Project Types

Program	Eligible Project Types[8]
The Gold Standard (expands on Carbon Development Mechanism)	• Energy Efficiency • **Renewable Energy**
Verified Carbon Standard (VCS)	• Agriculture, Forestry and other Land Uses (AFOLU) • Energy Efficiency • Methane Capture • **Renewable Energy** • SF6 Destruction
Climate Action Reserve (CAR)	• Coal Mine Methane • Forest (v3.0 or newer) • Nitric Acid Production • Nitrogen Management (v1.1 or newer) • Organic Waste Composting (v1.1 or newer) • Organic Waste Digestion • Ozone Depleting Substances • Rice Cultivation (v1.1 or newer) • U.S. Landfill • U.S. Livestock • Urban Forest
American Carbon Registry (ACR)	• Agriculture, Forestry and Other Land Use (AFOLU) • Energy Efficiency • Industrial Process Emissions • **Renewable Energy** • Transportation

[7] Hamrick et al. "Raising Ambition: State of the Voluntary Carbon Markets". Ecosystem Marketplace, May 2016. http://www.forest-trends.org/documents/files/doc_5242.pdf

[8] Exceptions to the eligible project types can be found on the Green-E page for Endorsed Programs on Project Certification.

Section 2- Results of comparing methods

As the examples throughout Section 1 show, institutions can calculate significantly different emissions intensities for the same renewable energy project depending on which method they use. This section discusses the technical difference between the calculation methods, then turns to the implications of these differences in terms of GHG and health impacts, and concludes with high-level notes from the literature and a discussion on when schools may choose to utilize the various methods.

Differences in GHG calculations

The **carbon footprint method measures renewable energy projects in megawatt-hours, not in emissions reductions**. In doing so, carbon footprinting implicitly makes two critical assumptions that drive much of the difference between methods:

(1) That the project displaced energy from all power plants in the region equally (as opposed to leaving baseload power plants unaffected and displacing only specific marginal or peaker power plants), and

(2) That the project displaced power plants in the same grid where the institution consumed power (as opposed to where the project actually generated power).

The first assumption is never true, and the second is true only when projects are located in the same grid as the purchasing institution. Since the avoided emissions calculations and carbon offset calculations are not required to make these simplifying assumptions, the three different methods generate substantially different results, particularly when evaluating projects located in other grids.

Figure 4 considers how the various accounting methods treat the various example projects considered above based on its location and the buyer's level of additionality in the project. For simplicity, the less commonly used location-based carbon footprinting method (which completely ignores off-site renewable energy purchasing) is not included. The carbon footprinting approaches uses emissions factors from eGRID; the avoided emissions and carbon offset approach use an emissions analysis from WattTime.

Figure 4. Effect of different accounting frameworks, locations, and levels of additionality on reported CO_2 emissions reductions for a Boston-based institution

Project type and location	Carbon Footprinting (Market)	Avoided Emissions	Carbon Offset
	in lbs CO2 per MWh		
A local (ISO-NE / Massachusetts) solar project	577	0	0
A nonlocal (PJM / North Carolina) solar project that is additional	577	2,187	2,187
A nonlocal (MISO / Minnesota) wind farm that is not additional	577	1,707	0

These results illustrate patterns discussed above. First, the footprinting method ignores the question of where energy is actually injected into the grid, and instead measures what the emissions factor is at the location where the energy is accounted for. This is why all results in the first column are the same: the footprinting method yields the same answer for any purchase.

For an institution based in Texas, this chart would look very different. First, every wind project would be accounted for using the local Texas rate of emissions intensity. Second, the fact that Boston is located in the territory of RGGI means that the GHGP does not "credit" avoided emissions or carbon offsets based on local emissions reductions. Further, carbon offsets do not "credit" nonlocal emissions reductions that are not additional. Thus, carbon offsets represent the most stringent criteria for emissions to "count."

A second notable pattern in these results is that, **while avoided emissions and carbon offsets have stricter eligibility criteria, they also have higher impacts per megawatt hour**. This is because these methods use marginal emissions rates, not average emissions rates. That is, they are not assumed to displace an equal share of all power plants in a given region. Instead, these methods use only the emissions factors from the specific power plants likely to be displaced by the renewable energy generation. It is worth noting that nuclear and renewable energy are much less frequently displaced by new renewable energy construction due to their very low marginal cost of operation per MWh. Thus, marginal emissions rates typically include very few nuclear and renewable energy power plants, and are thus typically higher than average emissions rates.

In theory, the three different methods are not exclusive. In fact the GHGP states that except where prohibited locally, an organization is permitted to "double count" by both using a renewable energy project to reduce its carbon footprinting calculations, and to generate a carbon offset from the project. **However, in practice this is locally prohibited in the U.S. and other major markets.**

A renewable energy project in the U.S. typically generates either a Renewable Energy Certificate (REC) that allows it to function in the carbon footprinting context, or a carbon offset that allows it to function in the carbon offsetting context. Organizations to whom institutions report their carbon emissions, such as The Climate Registry, allow an institution to apply both methods to develop their carbon footprint. As such, **institutions can (and frequently do) report on a portfolio of projects, some of which are measured in RECs and some of which are measured in offsets.** In principle, a given project could even subdivide and report some megawatt-hours of consumption as RECs and others as offsets.

GHG impacts of different projects

Under carbon footprinting, the emissions factors associated with a renewable energy project depend on the location of the institution, which means that project location has no bearing on project impacts. However, for projects counted using avoided emissions or carbon offset frameworks, location can matter significantly. This is because renewable energy projects reduce or avoid emissions based on which fossil-fuel fired power plants are *prevented* from generating power by the construction of the renewable energy project. That factor can vary substantially based on where and when the renewable energy is generated. This section presents an evaluation of the CO_2 emissions impacts of different possible wind and solar projects, measured under different accounting frameworks, taking into account time and place where appropriate.

We first compare the effects of the siting power plants in different locations. We analyzed a generic wind and solar project in New England, and also one in each of six other regions from which it is relatively common to source renewable energy. **Figure 5** shows the physical reduction of emissions that would occur if a power plant were to be constructed at any of these locations in 2017. For ease of comparison, figures are color coded from light (least emissions reduced) to dark (most reduced).

Figure 5. CO_2 emissions reduced per megawatt-hour for different project locations and types

Region	Sample Solar Project - Avoided Emissions Method (CO_2) in lbs per MWh	Sample Wind Project - Avoided Emissions Method (CO_2) in lbs per MWh
ISO-NE (New England)	803	791
ERCOT (Texas)	1,265	1,278
MISO (Midwest)	1,707	1,718
SECI (Kansas)	1,866	1,881
NPPD (Nebraska)	1,914	1,916
MPCO (Montana)	2,054	2,050
PJM (Mid Atlantic)	2,176	2,187

Several clear trends are visible in these results. First, constructing a renewable energy facility essentially **anywhere outside of ISO-NE leads to substantially larger GHG emissions reductions than from a facility in New England.** For example, constructing a solar facility in North Carolina reduces emissions by 2,176 pounds of CO_2 per MWh, or 2.8 times more than a facility in New England. This is because the New England ISO replaced a number of coal-fired power plants with natural gas and is now one of the cleanest power grids.[9] In this way,

[9] Note that this is counting direct emissions only. None of the commonly accepted carbon accounting methods considers lifecycle emissions from fracked natural gas. The carbon footprinting method explicitly ignores lifecycle emissions, while possible that avoided emissions and carbon offsetting frameworks contain mechanisms by which these factors could later be included. If scientists ultimately conclude that the highest estimate of the amount of

additional clean energy generation in New England tends to displace emissions from relatively lower-emission natural gas-fired power plants, as opposed to other regions where it tends to displace higher-emission coal-fired plants.

A second pattern is that there is only a **modest emissions difference between a typical wind and solar farm sited in the same region**. This is noteworthy because solar is day-peaking whereas wind more commonly peaks at night. While this does mean that certain technologies have greater emissions benefits in certain regions, this technology-based variation is dwarfed by regional variation.

Third, the end points are important to note: Outside of New England, **Texas is the least impactful location** for wind generation compared to other common regions such as MISO, and **PJM (PJM is the most impactful location)**. While PJM has a large share of emissions-free power in the form of nuclear energy generation, because this nuclear power is rarely operated on the margin, constructing a wind or solar farm in PJM today nearly always reduces coal consumption rather than nuclear generation, with correspondingly greater emissions reductions. Of course these results can change over time and will need to be updated. Just as New England's grid has grown cleaner in recent years, so might other grids also change in their emissions intensities.

Health impacts (measuring non-CO2 pollutants)

We next consider the measurement of other pollutants from electricity (beyond CO2) that are important to consider from a health perspective. The specific pollutants include sulfur dioxide (SO_2) and nitric oxide and nitrogen dioxide (collectively, NO_X). In terms of measurement methods, the GHGP and carbon offsets do not apply to these other pollutants. The framework for measuring these impacts is described primarily in academic studies, and is largely aligned with the avoided emissions framework.

Although NO_X and SO_2 emissions come from the same fossil fuel sources as CO_2 emissions, and as a result are often correlated with CO2 emissions, there is an important difference between CO_2 and these non-CO_2 pollutants. This distinction centers on the existence of control technology. **While carbon capture and sequestration is still an extraordinarily rare technology at the power plant level, NO_X and SO_2 capture is relatively widespread among U.S. power plants.** For this reason, it is not unusual to find substantial differences between the relative contribution a power plant makes to CO_2, NO_X, and SO_2 emissions.

To exemplify these points, **Figure 6** below shows the results of **calculating avoided emissions per MWh of both SO_2 and NO_X for ISO-NE** and five other regions.

methane emissions from fracked natural gas are in fact the correct estimates, then life cycle emissions from natural gas are very significant. In that situation, some gas-fired power plants would be dramatically dirtier than others. No public dataset or framework yet exists to track which gas-fired plants use fracked gas.

Figure 6. Pounds of SO_2 and NO_X emissions per megawatt-hour reduced, by region

Region	Avoided Emissions (NO_X) in lbs per MWh	Avoided Emissions (SO_2) in lbs per MWh
ISO-NE (New England)	0.34	0.67
PJM (Mid Atlantic)	1.23	2.39
ERCOT (Texas)	0.61	1.44
MISO (Midwest)	1.26	2.20
SEC (Florida)	0.51	1.93
DUK (Carolinas)	1.03	0.76

These results indicate that at the grid scale, **SO_2 and NO_x impacts appear to be relatively strongly correlated with CO_2 emissions** despite the existence of control technologies. At a more detailed level, we can observe minor differences among the pollutants. For example, projects in DUK displace relatively little SO_2 while displacing a relatively more significant amount of NO_X.

Results are **broadly similar to the GHG impacts of different power plant choices**. ISO-NE is one of the cleanest grids in the country in terms of NO_X and SO_2 emissions as well as CO_2 emissions; therefore projects elsewhere typically have higher health benefits as well as higher climate change benefits. The highest-emitting region in terms of CO_2 pollution, PJM, is also highest among SO_2 and nearly so among NO_X. This makes sense, as PJM is a region in which coal-fired power plants are marginal with relative frequency. Thus, renewable energy projects in PJM have particularly strong CO_2 as well as local health impacts. While strongest in PJM, the pattern persists in regions with a higher percentage of coal-fired electricity. By contrast, regions such as ERCOT with a relatively high proportion of marginal natural gas have impacts that are higher than in ISO-NE's particularly clean grid, but lower than coal-intensive regions.

One important difference is that **while CO_2 emissions are a global pollutant, NO_X and SO_2 emissions are regional**.[10] While a project that reduces CO_2 emissions anywhere on the planet will theoretically have equal benefits to Boston-area residents, only the reductions of NOx and SO_2 from projects closer to Boston can accrue to local residents.[11]

[10] Air pollutants do drift across grid boundaries, thus emissions in one region can affect another. However, studies of air pollutant flow caution that it is a notoriously imprecise science and it is impossible to precisely quantify the exact portion of this drift across grid boundaries.
[11] Fowlie, Meredith. (2010.) Market-Based Emissions Regulation When Damages Vary Across Sources: What are the Gains from Differentiation? NBER Working paper No. w18801 https://papers.ssrn.com/sol3/cf_dev/AbsByAuth.cfm?per_id=1416673

Discussion of context in the literature

To contextualize this report within the broader literature, this section highlights some trends that are observed among relevant studies. A number of authors have considered the issue of quantifying the emissions benefits of the construction of renewable energy facilities. Key papers reviewed include Siler-Evans et al (2013) [12], Culler (2013)[13], Kaffine et al (2013)[14], Novan (2015)[15] and Callaway et al (2017)[16].

All the above papers use a **method that is largely equivalent to the avoided emissions method.** Differences between the papers' methods are largely minor variations of implementation which do not affect the framework in this report (e.g. specific details of how best to assess the grid boundary and the precise nature of the operating margin calculation). In general, the avoided emissions method is most similar to that used by academics and with the one exception of how to treat cap-and-trade programs; **the field demonstrates a remarkable degree of scientific consensus.** Even the paper by Brander et al (2017), which does not quantify the impacts of projects, argues that the standard carbon footprinting method is inaccurate and recommends that institutions adopt the avoided emissions calculation while also reporting the Location-Based carbon footprinting method.[17]

The parallel between the methods in the literature and the avoided emissions method is disrupted by only two caveats. First, these authors evaluate only operating margin and not build margin, regardless of local grid conditions. Second, all but one paper (Callaway et al) consider energy generated in regions covered by cap-and-trade programs to be emissions-reducing rather than assigning such projects a value of zero as the avoided emissions method does.

[12] Siler-Evans, K ., Azevedo, I.L., Morgan, M.G. & Apt, J. (2013.) Regional variations in the health, environmental, and climate benefits of wind and solar generation. Proc Natl Acad Sci USA 110(29):11768–11773.
[13] Cullen, Joseph. (2013.) Measuring the Environmental Benefits of Wind-Generated Electricity. American Economic Journal: Economic Policy, 5(4): 107-33. DOI: 10.1257/pol.5.4.107
[14] Kaffine, D.T., McBee, B.J. & Lieskovsky, J. (2013.) "Emissions Savings from Wind Power Generation in Texas," The Energy Journal, International Association for Energy Economics, vol. 0(Number 1).
[15] Novan, K. (2015.) Valuing the Wind: Renewable Energy Policies and Air Pollution Avoided. American Economic Journal: Economic Policy, 7(3): 291-326. DOI: 10.1257/pol.20130268
[16] Fowlie, M., Callaway, D., & McCormick, G. (2017.) Location, Location, Location: The Variable Value of Renewable Energy and Demand-side Efficiency Resources." Journal of the Association of Environmental and Resource Economists. https://doi.org/10.1086/694179
[17] Brander, M., Gillenwater, M., & Ascui, F. (2017.) A critical perspective on the market-based method for reporting purchased electricity.

As a final contextual note, in addition to quantifying emissions reduced through renewable energy production, this same method has also been used by researchers in evaluating many other questions, from electric vehicles[18] to energy storage.[19]

Discussion of when schools may choose to utilize various calculation methods

This subsection outlines key considerations that are likely to influence how an institution selects a calculation method. Relatedly, a brief discussion of standardization follows.

One criterion is **accuracy**. The avoided emissions and carbon offset methods are the most accurate measurements. This is because unlike the carbon footprinting method, the primary purpose of these methods is to accurately reflect the emissions impacts of renewable energy purchases. They are also the most consistent with the general consensus from the published academic literature, as described in the previous subsection. Note also that the inaccuracy of the carbon footprinting method is growing over time as the amount of renewable generation on the grid increases and affects the types of existing generation displaced.[20]

A second criterion is **administrative simplicity**. The carbon footprint method is the current de facto standard in large part because it is the administratively simplest method. Calculating avoided emissions and obtaining carbon offsets have historically been relatively involved endeavors. However, the recent emergence of new techniques such as those created by the aforementioned literature and WattTime's marginal emissions techniques, are rapidly simplifying the avoided emissions process. Relatedly, the recent emergence of new software techniques such as blockchain-based registries may soon make carbon offsets administratively simpler as well.

A third criterion is **compatibility with carbon targets established under the GHGP**. For institutions that choose to define emissions targets in terms of the GHGP, reductions measured in avoided emissions cannot be "credited" towards these targets. Reductions measured using carbon footprinting can count towards these targets, except in cases where institutions are seeking to reduce/offset emissions from on-site fossil fuel ("Scope 1")

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[18] Graff Zivin, J.S., Kotchen, M., & Mansur, E. Spatial and temporal heterogeneity of marginal emissions: implications for electric cars and other electricity-shifting policies. J. Econ. Behav. Organ. (2014), http://dx.doi.org/10.1016/j.jebo.2014.03.010

[19] Hittinger, E., & Azevedo, I. (2015). Bulk Energy Storage Increases United States Electricity System Emissions. *Environmental science & technology*, 2015, 49 (5), pp 3203–3210.

[20] The reason is that the gap between carbon footprinting and the most accurate measurements of emissions impacts stems primarily from the treatment of renewable energy. (While new renewable energy projects nearly never displace existing renewable energy projects, the carbon footprinting method implicitly treats them as if they always do.) Thus, as renewables continue to constitute a larger and larger share of the power grid, the inaccuracies in carbon footprinting method are growing.

generation. By contrast, projects using the carbon offset method are compatible for reducing/offsetting all types of emissions.[21]

Next, it is important to consider the **incentive to build the most impactful projects**. There are many reasons to select one renewable energy project over another.[22] The avoided emissions and carbon offset methods would make institutions aware of which projects have the greatest environmental impact. This awareness has the potential to increase impact by helping institutions select higher-emissions-impact projects more easily. The carbon offset method would also give institutions "credit" for selecting the most impactful projects, which might influence behavior further still.

Another criterion is **size of claimed reductions.** For projects outside of cap-and-trade regions, the avoided emissions and carbon offset methods lead to systematically larger impacts than those under the carbon footprinting method. The advantage is depicting that schools' renewable energy purchases are already having more impact than may be widely known. The disadvantage would come into play if institutions were to switch to the avoided emissions or carbon offset methods without adjusting their targets. If they were to do so, it may inadvertently lead to depressing the size of their investments in renewable energy, reducing total real-world environmental impact.

Given that New England is located in the RGGI cap-and-trade region, a separate criterion for Boston-area institutions is the **treatment of local projects.** The avoided emissions and carbon offsets methods do not "credit" projects which occur in regions covered by a cap-and-trade program, including all of New England. The theoretical basis for this is the idea that reducing emissions anywhere in the region simply allows emissions to increase somewhere else. As such, the system correctly reflects the fact that most renewable energy purchases in New England do have less impact on climate change. However, no exceptions appear to be made for cases wherein this theoretical idea does not actually apply, such as Massachusetts Class 1 RECs, or SRECs. Moreover, the system discourages local investment without sufficient attention to other (i.e., non-carbon) co-benefits of local projects including local job creation, local economic and health benefits, meeting local targets, and potentially improved public perception.

Public perception stands as another factor for consideration. Many individuals oppose carbon offsets as a substitute for direct emissions reductions. While this is a separate issue from the selection of a measurement technique, it is possible simply the words "carbon offset" could create a risk of poor public perception. On the other hand, the carbon footprinting method could also carry some risk of poor public perception, due to a small but vocal group of subject

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[21] While likely not relevant for the schools in the Higher Education Working Group, publicly held corporations considering the same questions may wish to note they often face different incentives. Many investors evaluating a company's carbon footprint look only at "gross", not "net", emissions under the GHGP. That is, they do not "credit" carbon offsets.

[22] See Table 3 in main report for description of the three listed types of impact.

matter experts who are opposed to this method.[23] The avoided emissions method may therefore carry the lowest risk of poor public perception. It is also the only method that would enable schools to quantify and make statements about non-CO_2 benefits, which may also improve perception.

The final criterion we consider is the treatment of **additionality**. The footprinting method explicitly excludes additionality, and the avoided emissions method considers it only on the matter of cap and trade. By contrast, projects are eligible to generate carbon offsets only if they meet stringent quality standards for additionality. Whether this is an advantage or a disadvantage of the method is subject to debate.

Figure 7 below summarizes the aforementioned criteria, focusing on which method or methods provide the most benefits for each criterion considered. For simplicity, each method is rated from low to high in terms of its strength against the given criteria where possible. In the cases of criteria where there is not a strength associated with its status, the eligibility level is described.

Figure 7. Strengths of different methods, by criterion

Criterion	Carbon Footprinting (Market-Based) Method	Avoided Emissions Method	Carbon Offset Method
Accuracy	Low	High	High
Administrative complexity	Low	Low	High
Counts towards GHGP targets	Yes (except for Scope 1 emissions)	No	Yes
Incentive for most impactful projects	Low (None)	Low	High
Size of estimates	Low (Smaller)	High (Larger)	High (Larger)
Treatment of New England projects	Eligible	Not eligible	Not eligible
Public perception	Low-Medium	Medium-High	Low-Medium
Treatment of non-additional projects	Eligible	Eligible	Not eligible

[23] E.g. the GHG Management Institute (http://ghginstitute.org), or the Brander et. al. paper mentioned above.

Benefits of Standardization

There are benefits and drawbacks to each of the three quantification methods considered here, and there is no rule requiring that all institutions adopt a given method (or even that institutions consistently use one method across their own portfolio). However, if the member institutions of the HEWG were able to agree on a single method, the positive effects internally and externally to the institutions would be significant.

To begin with, for any given institution, a single method would support transparency and reduce administrative complexity. Moreover, it would reduce administrative costs by allowing standard measurement tools to be created and shared across member institutions. It would also facilitate straightforward comparisons between institutions. This would reduce the risk of institutions "gaming" the system by selecting methods which make their particular mix of projects look best, rather than one that most effectively communicates status and progress on goals.

For all of the above reasons, it is recommended that HEWG schools align around a single method. Whether that single method is one of the three methods described here or possibly even some new consensus method, agreeing on a single approach would increase transparency, minimize accounting costs, decrease complexity, and prevent gaming the system. This type of action could further serve to guide other institutions outside the HEWG in adopting a standardized method.