Protocols, rates, factors, attribution, accounting, oh my! A survey of U.S. emission accounting resources and what stakeholders should know

Nathan Phillips, DNV
Ian Kelsey, DNV

ABSTRACT

We find ourselves at the beginning of a decarbonization epoch. And yet, in this period of tremendous ambition and hope, there lacks consensus on which data source provides the ground truth by which to translate our decisions around energy consumption into an emissions impact, the metric used to measure our decarbonization goals. Turning ambitious decarbonization goals into actionable plans will require that all stakeholders understand how they are measuring their progress, where the data is coming from, and why it is the best fit for their desired outcome.

In this session we will survey the current landscape of available open and closed source emissions data in the United States. Resources such as balancing authorities, E.I.A, Electricity Map, WattTime, and the Open Grid Emissions Initiative compete in this space, each vying to be the data source of ground truth for measuring progress toward our decarbonization goals. These resources provide data that is available across different geographies, may focus on specific decarbonization efforts such as energy storage, and may even have their own recommendations for how to perform emissions accounting. Readers and audience members will learn where to access these resources, and the varying outcomes of applying these different resources to real-world situations such as benchmarking, annual emissions accounting, and specific energy efficiency technology improvements across different grid regions. Participants will also understand where decarbonization policy (such as the proposed SEC rule on climate-related disclosure or the GHG Protocol) may not align with impact, also through the practical application of these resources.

Introduction

We find ourselves at the beginning of a decarbonization epoch. And yet, in this period of tremendous ambition and hope, there lacks consensus on which data source provides the ground truth by which to translate our decisions around energy consumption into an emissions impact, the metric used to measure our decarbonization goals, specifically those indirectly tied to consumers. Turning ambitious decarbonization goals into actionable plans will require that all stakeholders understand how they are measuring their progress, where the data is coming from, and why it is the best fit for their desired outcome.

Emissions inventory group Climate Trace offers guidance on what we mean when we refer to the ground truth in the context of GHG emissions: “ground truth data are direct measurements from the source that can be considered reliable and accurate” (Climate Trace 2023). Finding and leveraging reliable and accurate emissions data from electricity generation in the United States, however, is not as straight forward as setting our initial goals to decarbonize – as of 2021 there are nearly twelve thousand utility-scale electric power plants in the United States over 1 MW (EIA 2022). Where do we turn to for emissions data collated by grid region or sub-region, and once we have it, what are the different ways in which it can be leveraged to translate energy consumption into its emissions impact? This paper will survey the most common emissions metrics as well as the current landscape of available open and closed source emissions data in the United States to give stakeholders a better footing upon which to achieve their decarbonization goals. Through a review of popular data sources, readers will learn the varying outcomes of applying these different resources to real-world situations such as benchmarking, annual emissions accounting, and specific energy efficiency technology improvements across different grid regions. And, where decarbonization policy (such as the proposed SEC rule on climate-related disclosure or the GHG Protocol) may not align with impact, also through practical examples of the application of these resources.

A Primer on Emissions Rates, Attribution, and Accounting

Before selecting an emissions data source, it is critical to have a high-level understanding of the most-used terms around emissions data, attribution, and accounting.

Which Scope is in Scope?

Companies setting decarbonization goals will be contending with three emissions categories: Scope 1, Scope 2, and Scope 3. In brief, **Scope 1** emissions are those directly tied to the combustion of fossil fuels from sources within direct ownership and control. For most companies, assets such as fleet vehicles, gas boilers, gas-fired industrial equipment, or backup generators fall into this category (Deloitte 2023). Because Scope 1 emissions do not require a conversion of energy consumption to a GHG equivalent through an emissions factor, we will not be covering them here. **Scope 2** emissions, in contrast, are those that result from the use of energy generated elsewhere (typically purchased by a consumer from a utility). Scope 2 emissions are indirectly tied to consumers and require the methods and datasets discussed below to calculate. These emissions are the focus of this paper. Lastly are **Scope 3** emissions, those tied to the combustion of fossil fuels from sources not directly owned or controlled but part of an organization’s overall value chain – such as third-party data centers, product shipping, etc. Scope 3 emissions for one entity will be either the Scope 1 or 2 emissions of another and not the focus of this paper.

On Rates, Factors, and Intensity Values

It is commonplace to see the terms emissions rate, factor, and intensity used interchangeably. All three describe the weight of pollutant, in CO2, divided by the unit of energy associated to the release of that pollutant for a given period, i.e., 5-minute interval, 1-hour interval, annual interval. These values are typically reflected in grams or lbs of CO2 per kWh or MWh. While all three terms can be used interchangeably, we will do our best to mirror the terminology used by each respective data source throughout.

Marginal vs Averages Values

Emissions factors are typically available in two calculation methods, average and marginal. An average emissions factor represents the total emissions within a grid region divided by the total amount of energy generated. Within the grid region, the average is calculated between all power generating resources. Average is the most popular GHG calculation method, used in both location and market-based emissions accounting, which we will review shortly.

A marginal emissions factor describes the emissions tied to generation required if a new load were to be added to a grid region at a specific time. It is the measurement "of the change in emissions… caused by a change in electrical load" (WattTime 2022a). Marginal emissions rates are not as straight forward as calculating average values, and require modeling based on factors such as time of day, location, seasonality, and generation mix. It should be noted that marginal emissions can be further divided into short-run and long-run, where short-run is modeled based on grid assets as they currently exist, while long-run considers the "projected changes to the electric grid, as well as the potential for an incremental change in electrical demand" on a grid (NREL 2022). Both are considered potentially appropriate for consequential or impact emissions accounting, which we will review shortly, but due to how much more prolific short-run marginal values are compared to long-run, short-run values will be our focus (WattTime 2022b).

Accounting and Attribution Methods

All decarbonization goals aim for the same target – to reduce grid emissions to zero. Consumers are responsible for their share of those grid emissions generated through electricity consumption, but there are multiple ways to attribute what the actual share of emissions really is. Electricity Map, an emissions data provider, calls this process *attributional accounting,* and nicely frames up the challenge:

> There is unfortunately no scientifically proven way to determine the recipient of each unit of generated electricity, as there's unfortunately no way to "dye" a unit of generated electricity and observe where it ends up. Therefore, there is no scientifically "correct" way to allocate emissions from generators to consumers, meaning there are multiple attribution rules possible, each relying on certain assumptions, and each having their advantages and disadvantages (Electricity Map 2022).

Of all the attribution rules possible, there are three we will briefly cover here to set the stage when discussing data sources and their applications.

Location-based

Location-based attribution follows the principle that all consumers within a grid region use the same electricity, and the emissions tied to that energy are an average of the generation sources at any given moment. If the generation sources are 50% coal and 50% hydro, then all consumers are responsible for that mix. Once the electrons leave the generators, there is no way to determine in which proportions they travel to a given consumer. Location-based is one of the two currently accepted methods by the GHG Protocol.

Market-based

Market-based attribution follows the principle that consumers can fund the energy transition by purchasing Renewable Energy Credits (RECs) for energy they consume. In this paradigm, all emissions from all generators must still be accounted for, thus when a REC purchaser claims to be 100% emissions free, the other consumers on the grid must claim what is known as the "residual mix" of emissions from generation sources not under contract in RECs. A common knock against market-based attribution is the lack of guarantees a market can deliver renewable energy during the exact times a REC purchaser requires it (when the wind isn't blowing, or the sun isn't shining).[1] The emissions data sources discussed in this paper are less applicable for market-based accounting since both average and marginal rates do not represent the residual mix remaining after any contracted renewable energy generation. Market-based is currently the second accepted method by the GHG Protocol.

Consequential, or Impact

Consequential attribution utilizes marginal rather than average emissions rates to quantify the emissions avoided by a specific action. Rather than being used as a means of apportioning emissions to consumers in a way that totals up to the system-wide emissions value from all electricity generation on a grid, the consequential method multiplies the delta in energy consumption of an action by the marginal emissions rates to determine the increase or decrease in emissions resulting from that action, i.e. new EV charging infrastructure, or a solar + storage installation.

WattTime, the non-profit emissions data provider, wants to shift how marginal emissions rates are used, however, pushing the focus from current accounting methods' energy-as-proxy relationship to one that focuses on emissions specifically. In plain language, WattTime's impact accounting proposal uses marginal emissions "rates to determine induced emissions for load and avoided emissions for renewable generation to understand how overall system emission[s] change through actions" (WattTime 2022c). Suggested as an addition to the existing methods used in the GHG Protocol, in practice this method reconciles the direct emissions from electricity generation, Scope 1, with the induced and avoided emissions of both generating and consuming that electricity, Scope 2. The specifics are better explained in WattTime's own white paper, but this method allows for consumers to determine if the balance between their induced emissions and the decisions they make to avoid emissions are trending in a positive or negative direction. It also allows for the use of marginal rates while still balancing the leger between total generation and total consumption.

Rules and Regulations

The last bit of shared context required in this paper is a brief explanation of the SEC's new Climate Disclosure rules and the GHG Protocol. The SEC's proposed ruling requires public companies to disclose information on their GHG emissions, climate-related risks, and other environmental impacts in their annual reports. The rules apply to companies listed on the U.S. stock exchange and aim to provide investors with more consistent and comparable information on climate-related risks and opportunities. Companies are required to disclose their Scope 1, 2, and 3 emissions if material, as well as information on their climate-related governance and strategy. The rules also require companies to provide explanations of their exposure and risks associated with climate change. The rules go into effect in 2023, with certain disclosure requirements being phased in over time.

Once the SEC rules are in place, the GHG Protocol will likely be *the* standardized framework for companies to calculate and report their emissions responsibilities. The GHG

---

[1] 24/7 market-based attribution appears to be gaining traction to make market-based both a funding instrument as well as an accurate attribution method by enforcing the requirement that the demand and renewable energy available align within a grid region at an hourly granularity.

Protocol is an international standard and provides guidance on how to determine corporate responsibility of Scope 1, 2, and 3 emissions. Within it fit all of pieces discussed above, as the Protocol offers standardization and guidance but does not dictate certain areas such as accounting methodology (location or market-based are both permitted) or specific emissions data source. The flexibility of the GHG Protocol is what makes it such a powerful framework, but with this flexibility come a few items worth further discussion later in this paper.

The Data Landscape

With a shared foundation of terms and attribution methods, we can now dive into the numerous sources one can pull emissions data from. The following sources are not meant to be an exhaustive list, but those which, in our experience, are most utilized and discussed by organizations seeking to quantify emissions. Additionally, these data sources are those which we believe one could use directly to calculate the emissions impact of energy consumption rather than those which are typically used only to inform emissions models or require being joined to several other datasets.

Stepping through these data sources, we will move from nearest the source outward to those which collect, collate, or model emissions data. For comparisons, when possible, we will use California ISO (CAISO) as our example grid region due to the high saturation of renewables which leads to variable emissions factors suitable and interesting to compare. As shown in Figure 1, the emissions data landscape in the United States is heavily interconnected.

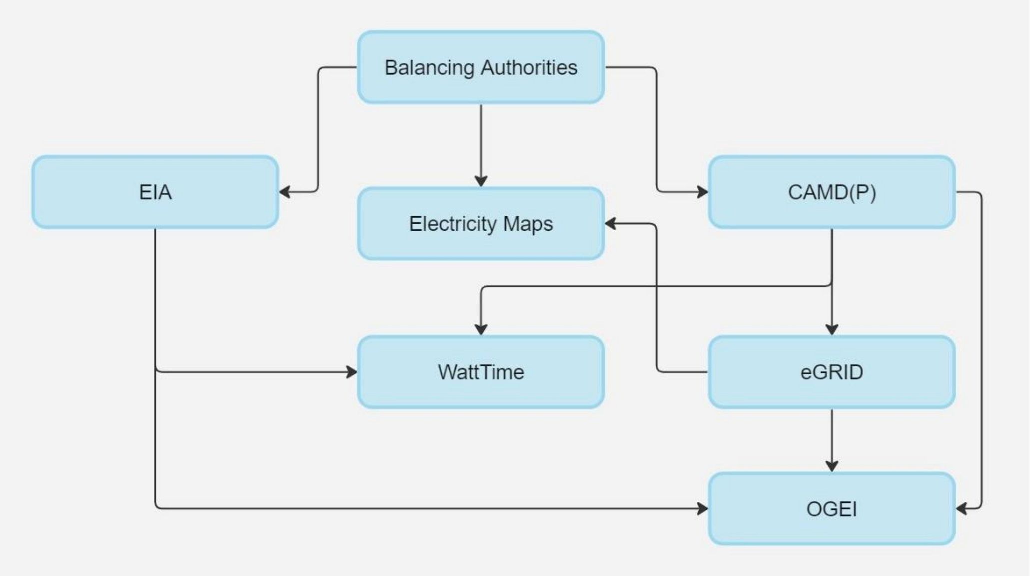

Figure 1. The complex relationship between emissions data resources in the United States.

Balancing Authorities

Balancing authorities are in most cases the primary means of separating out and attributing emissions tied to a given consumer based on their geographic location. Since balancing authorities are responsible for the operation of the electric grid and ensuring demand and supply are “balanced” in real time, they are also theoretically ideally positioned to report on the emissions tied to that electricity generation (NERC 2005). That said, balancing authorities typically do not provide emissions data for public use. CAISO, the largest balancing authority in the western interconnection, is one such balancing authority that *does* provide emissions data through their website.[2] This emissions data, however, is not formatted in a way that lends itself to emissions accounting. From CAISO's site, users can see:

- Total current CO2 emissions expressed in mTCO2/h
- Current average CO2 emissions rate expressed in mTCO2/MWh
- 5-minute total CO2 trends by day, expressed in mTCO2/h
- Monthly total current CO2 emissions expressed in mTCO2/h going back to 2014

What users cannot capture is an annual or hourly average or marginal emissions rate from a sole source. We believe it is possible, with a high potential for errors, to calculate your own rates by joining separately exported supply and emissions datasets. We have done exactly this in our comparisons below, but for the purposes of emissions accounting and attribution, this isn't our recommendation. Balancing authorities overall are likely not the best resource, but your mileage may vary based on what is available through individual balancing authority websites.

Energy Information Administration (EIA)

If balancing authorities are well positioned to report on direct emissions from electricity generation, but do not, or at least not typically, where can we go for those "reliable and accurate" ground truth measurements we seek? Fortunately, balancing authorities must report hourly *electric system* data to the U.S. Energy Information Administration (EIA) as required by the Federal Power Act.[3] This data is collected as part of the Form EIA-930 survey, in which balancing authorities must submit system demand, net generation, and interchange data at an hourly granularity, daily. Utilizing the hourly net generation data exactly as provided by the balancing authorities, the EIA *estimates* hourly CO2 emissions and calculates the average hourly emissions intensity in lbs CO2/kWh for both generated electricity and consumed electricity (generation plus imports, minus exports). The EIA calculates factors "for natural gas, coal, and petroleum using reported generation" with "CO2 emissions from fuels other than natural gas, coal, and petroleum [using] the same emissions factor for the entire United States" based on a Multiregional Input-Output (MRIO) model (EIA 2023). This model works off the assumption that imports and exports between various interconnected balancing authorities are in balance, and calculates emissions values based on this assumption.

The EIA supplies the following data elements[4] by balancing authority through an available API or as downloadable .csv or .xlsx files depending on the specific data and timeframe you seek:

- Estimated total hourly emissions in metric tons of CO2
- Estimated hourly emissions by fuel type in metric tons of CO2
- Estimated emissions for electricity imports or exports in metric tons of CO2
- Estimated average hourly emissions intensity in lbs CO2/kWh

---

[2] CAISO, "Today's Outlook," 2023, http://www.caiso.com/todaysoutlook/pages/emissions.html#section-current

[3] U.S. Energy Information Administration, "EIA-930 Database," https://www.eia.gov/survey/#eia-930

[4] Also available with emissions data is demand, demand by subregion (for select balancing authorities), demand forecast, net generation, net generation by energy source, total net interchange, and interchange data for directly interconnected balancing authorities.

The EIA also supplies pre-configured and partially customizable dashboards which can be saved and shared. Knowing this, the search for reliable and accurate data ends here, right? Well, not quite. Since these emissions values are estimated based upon supplied values from balancing authorities, they are limited to what the balancing authorities report on, namely only a subset of utility-scale generating units rather than all utility-scale generating units.[5] A consequence of this difference is that the aggregated emissions totals from the Form EIA-930 data "will be lower than the monthly and annual generation aggregations in other electricity publications" (EIA 2023). Based on availability of this data and its update frequency we believe EIA-930 is incredibly valuable despite EIA's warning to use caution when using the data due to the dependency on reported balancing authority values.

Emissions & Generation Resource Integrated Database (eGRID) & Clean Air Markets Division (CAMD)

Often viewed as *the* publicly available data source for emissions accounting in the United States, the Emissions & Generation Resource Integrated Database (eGRID) is developed by the Environmental Protection Agency's (EPA) Clean Air Markets Division (CAMD). Self-described as the "preeminent source of emissions data… for all U.S. electricity generating plants… [that] report data to the U.S. government" (eGRID 2023), eGRID's technical documentation lists a myriad of users and uses for their data including other Federal government entities, both state and local governments, and cites itself as the common data source for GHG Protocol calculations (eGRID 2023).

We have also decided to discuss eGRID's primary data source in this section, Power Sector Emissions Data (CAMD, or CAMPD), as both are administered by the EPA and are intertwined when trying to ascertain both hourly and annual emissions factors from the EPA. Whereas eGRID only provides *annual aggregated* generation and emissions data at the plant level, balancing authority, eGRID subregion,[6] and NERC region,[7] CAMD provides *hourly* emissions, generation, and fuel consumption data for fossil fuel generation units > 25 MW,[8] but only at the level of plant and state – not by balancing authority. Due to the differences in hourly vs annual granularity, as well the data segmentation discrepancies between the two, CAMD is potentially better served as a data source for groups collating and modeling emissions factors rather than energy consumers specifically looking to calculate their Scope 2 emissions directly.

---

[5] In our research, we could not find clear documentation on this distinction other than it impacts the EIA-930 data when aggregated.

[6] "eGRID subregions are identified and defined by EPA and were developed as a compromise between NERC regions (which EPA felt were too big) and balancing authorities (which EPA felt were generally too small). Using NERC regions and balancing authorities as a guide, the subregions were defined to limit the import and export of electricity in order to establish an aggregated area where the determined emission rates most accurately matched the generation and emissions from the plants within that subregion" (eGrid 2023).

[7] "NERC region refers to a region designated by the North American Electric Reliability Corporation (NERC). Each NERC region listed in eGRID represents one of nine regional portions of the North American electricity transmission grid: six in the contiguous United States, plus Alaska, Hawaii, and Puerto Rico (which are not part of the formal NERC regions but are considered so in eGRID)" (eGrid 2023).

[8] CAMD claims even with the > 25 MW consideration, Power Sector Emissions Data covers "approximately 96% of the fossil fuel generation in the U.S. based on 2018 data" (EPA 2023).

That said, CAMD data is available through both a web portal[9] and an API[10] for those interested in using it.

Returning to eGRID, the current dataset covers the 2021 calendar year and is available in a single .xlsx workbook from the eGRID web portal.[11] This file is split between sheets aggregating 2021 emissions data by plant, state, balancing authority, eGRID subregion, and NERC region. To supplement this workbook, eGRID supplies a 139-page technical document[12] with extensive explanation on the methodologies used – too deep to cover here. For our purposes, a partial summary of relevant available emissions data one could leverage for accounting purposes is as follows:

- Total annual 2021 emissions in tons of CO2
    - Values for NOx, SO2, CH4, and N2O also available
- Annual 2021 average emissions rates in lbs CO2/MWh
    - Values for NOx, SO2, CH4, and N2O also available
- Prior year's data back to 2004 (with a caveat that not all years can be linked to the current eGRID2021 data).

If annual emissions factors are all that is required for your emissions calculations, then eGRID is a well-suited, publicly available, and well-documented data source. If you require hourly granularity or more up-to-date or real-time emissions factors, then eGRID isn't ideal.

Open Grid Emissions Initiative (OGEI)

Moving from publicly available emissions data to true open-source emissions data, the Open Grid Emissions Initiative (OGEI) is a project led by Singularity Energy with the intent of filling a "critical need for high-quality, publicly-accessible, hourly grid emissions data for greenhouse gas (GHG) accounting", including "a public dataset of hourly, monthly, and annual U.S. electric grid generation, greenhouse gas, and air pollution data, all calculated using open-source, well-documented, and validated methodologies" (Singularity 2023). The notable distinction here between publicly available and open source is that open-source emissions methodologies can be modified by end users since they are freely provided through OGEI's GitHub repository.

Against the backdrop of the previously discussed publicly available data sources, which all face some limitation around data availability, segmentation, granularity, or update frequency, OGEI has published and documented the code used to provide hourly and annual emissions factors for each balancing authority in the United States. Additionally, OGEI can also supply power sector and power plant data, but both are less relevant to those looking to understand the emissions intensity and impact of the electricity they are consuming. OGEI is built upon several EIA datasets, including Form EIA-930, as well as the CAMD hourly dataset and eGRID to be as comprehensive as possible.

---

[9] EPA, "Clean Air Markets Custom Data Portal," https://campd.epa.gov/data/custom-data-download, Documentation: https://api.epa.gov/easey/content-mgmt/campd/documents/CustomDataDownload-QuickStartGuide1-1.pdf

[10] EPA, "Clean Air Markets API," https://www.epa.gov/airmarkets/cam-api-portal

[11] EPA, "eGRID Data Portal," https://www.epa.gov/egrid/download-data

[12] EPA, "Technical Guide," 2021, https://www.epa.gov/system/files/documents/2023-01/eGRID2021_technical_guide.pdf

OGEI emissions data is currently available for 2019-2021, with a note that due to the delay in input data available from the EIA, each year of data will be available in the Fall of the following year. Specific to emissions, one can fetch the following data from Singularity's web portal, or execute the entire OGEI data pipeline locally by following OGEI's README.md:[13]

- Hourly 2019-21 average emissions rates in either lbs CO2/MWh or kg CO2/MWh
    - Values for NOx, SO2, CH4, and N2O also available
- Monthly 2019-21 average emissions rates in either lbs CO2/MWh or kg CO2/MWh
    - Values for NOx, SO2, CH4, and N2O also available
- Annual 2019-21 average emissions rates in either lbs CO2/MWh or kg CO2/MWh
    - Values for NOx, SO2, CH4, and N2O also available

With hourly, monthly, and annual emissions factors segmented by balancing authority, plus the transparency provided through the OGEI documentation, [14] this initiative is a compelling resource. Like the other resources discussed above, however, it suffers from a significant lag in update frequency – data available through the end of 2021 as of March 2023.

Electricity Maps

From open source and publicly available, to partially open source and paywalled, Electricity Map occupies a unique space in the emissions data landscape. On the open-source side, Electricity Maps supplies the code behind their popular application, a map of real-time and historical GHG intensity values across the world, with full coverage of the United States. The raw data, however, requires a user to purchase Electricity Maps' API access, with several tiers/options depending on your requirements. Electricity Maps also makes available a limited free endpoint for data exploration, which we've utilized for this paper.

Through a well-documented API endpoint, users can fetch the following:

- Historical hourly average emissions rates in gCO2eq/kWh (back 3-5 years)
- Real time hourly average emissions rates in gCO2eq/kWh
- Forecasted hourly average emissions rates in gCO2eq/kWh (forward 24 hours)

Although not as explicitly documented as the previous data sources mentioned, by combing through Electricity Maps' documentation and GitHub repository we believe they build custom "parsers" which fetch electric system data directory from balancing authorities and the EIA which are then multiplied by the emissions factors provided by eGRID2020 to calculate emissions intensity. The paid access to the API endpoint buys one a more streamlined way to access both historical and real time data, whereas executing the open-source code yourself would

---

[13] After reading through both OGEI documentation, and the code repository's README.md, we were unable to execute the data pipeline on two separate PCs "out of the box," and needed to download the data directly from Singularity's website. This process was painless, but it should be noted this is a possibility when working with a living open-source project.

[14] Singularity Energy, "OGEI Documentation," https://docs.singularity.energy/docs/open-grid-emissions-docs/about_ogei-about-the-open-grid-emissions-initiative

limit the historical lookback and require some heavy lifting acquiring individual API keys from the data sources described above.

WattTime

The final emissions data source noted here is WattTime, a mission-driven non-profit owned by the Rocky Mountain Institute. WattTime provides marginal emissions data covering the United States with expanding coverage globally that is primarily paywalled and closed source.[15] Unique to WattTime is their use of Marginal Operating Emissions Rates (MOERs) rather than the average rates used by all other sources discussed above.[16] WattTime champions the use of sub-hourly (5-minute) emissions rates when calculating any type of emissions impact, rather than annual averages. Despite the exact mechanics of WattTime's methodology being closed-sourced, they do provide a white paper on their methods.[17] This document shores up the basis for WattTime's modeling, like many of the sources discussed here, is also EIA and CAMD data (WattTime 2022c).

Users access WattTime's MOERs entirely through a well-documented API, which supplies the following data points:

- Real-time emissions index (expressed as a percentile or lbs CO2/MWh) updated every 5 minutes
- 5- minute Historical MOERs in lbs CO2/MWh (at least 2-year lookback)
- 5-minute Forecasted MOERs in lbs CO2/MWh (forward 24 hours)

With WattTime's proposed impact accounting methodology, marginal emissions rates may now increase in popularity for their use in both an impact calculations and accounting frameworks simultaneously, bucking the common recommendation that these methods should never overlap if using both average and marginal rates together.[18]

The Data in Action

Any review of so many emissions data sources should follow with a direct comparison – how different can these intermingled and interconnected sources be? Limited by the free versions of two of the paywalled API endpoints, we have attempted as near an apples-to-apples comparison as possible by focusing on a single day in April in the CAISO balancing authority.

---

[15] Free users can pull down a real time emissions index for each balancing authority – a "statistical percentile value of the current MOER relative to the last one month of MOER values for the specified location (100=dirtiest, 0=cleanest)" (WattTime 2022c)

[16] WattTime is also the data provider for California's Self-Generation Incentive Program (SGIP). SGIP provides incentives for new storage installations in California based on certain compliance criteria around total emissions reductions calculated using the provided WattTime signals for each balancing authority within the program. While these are marginal signals, in our experience they differ from the "core" MOERs WattTime produces. Because this dataset is program specific, and because no data source exists for CAISO (only the sub-regions within), we decided to omit this data from comparison.

[17] WattTime, "MOER Modeling," 2022, https://www.watttime.org/app/uploads/2022/10/WattTime-MOER-modeling-20221004.pdf

[18] Electricity Maps, "Marginal Emissions: what they are, and when to use them," 2019, https://www.electricitymaps.com/blog/marginal-emissions-what-they-are-and-when-to-use-them

The simplicity of this 24-hour comparison reduces noise and nicely illustrates how various these values can be.

Using CAISO data from April 3rd of the most recently available year per source, all hourly emissions rates have been converted to lbs CO2/kWh. If hourly values were not available, such as with the eGRID2021 data, annual average emissions factors were substituted.

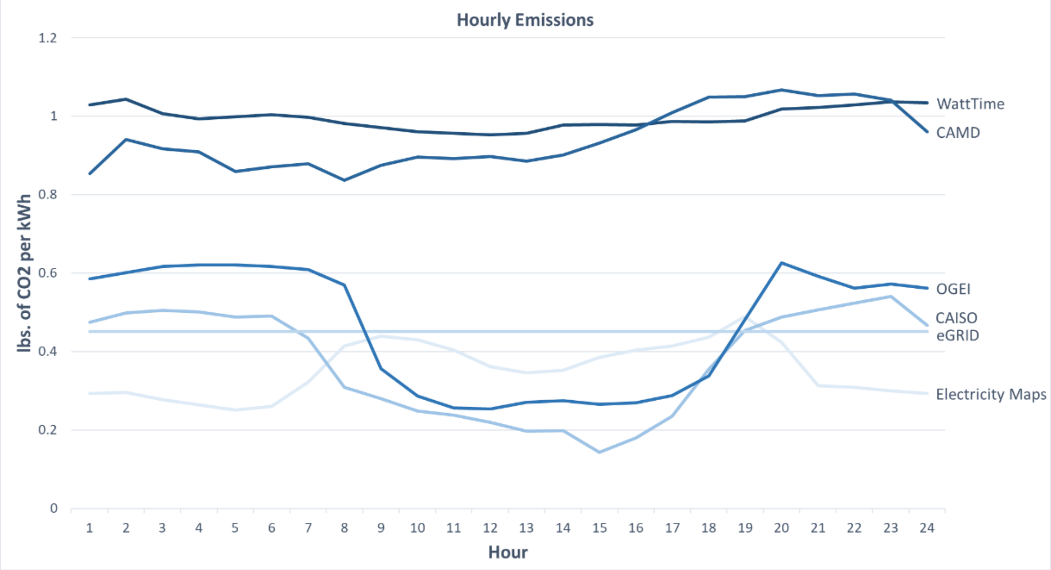

Figure 2. April 3rd 24-hour comparison of raw emissions data of most recently available year for all sources.

As shown in Figure 2, while the overall shapes for this 24-hour period look similar, the differences between the intensity of each emissions signal are non-trivial. How, then, do these differences manifest in certain “real-world” emissions calculations?

Benchmarking & Accounting

Using anonymized and normalized energy use data for three separate use cases – industrial, commercial retail, and commercial food service – we apply our day in April as an annual proxy to mock annual emissions totals. By following a location-based accounting method where hourly kWh consumption values are multiplied against their corresponding hourly emissions factors, and then summed to yield the total lbs CO2 attributed to the consumption for each use case, for each signal, it is apparent that depending on one’s desired outcome, there may be a real benefit to cherry-picking a data source.

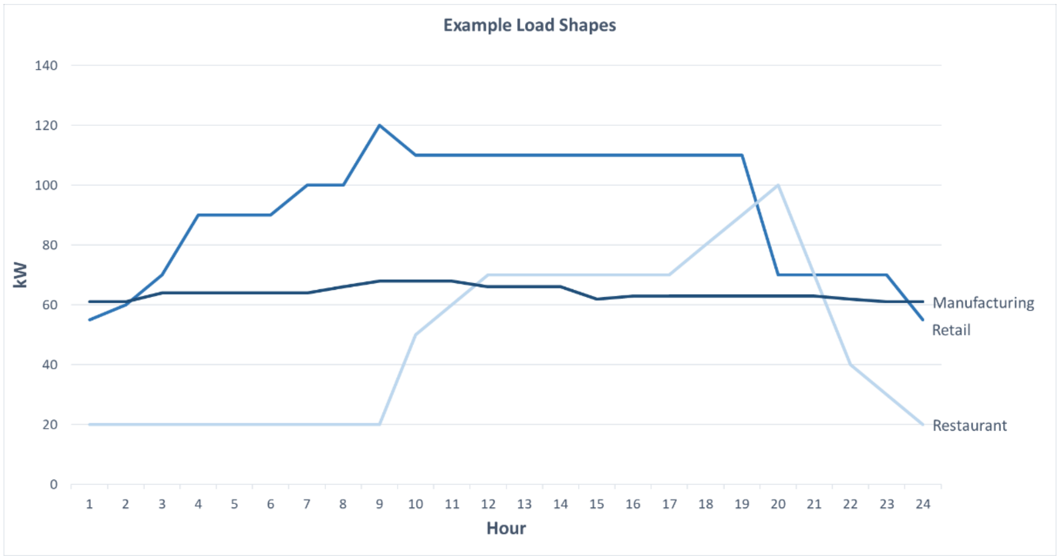

Figure 3. Anonymized example load shapes normalized between 0-140 kWh.

Figure 4 shows the significantly different emissions totals each of these companies could claim. Even with the removal of outlier data sources CAMD (which is for the entire State of California and not CAISO specifically and based only on fossil fuel generation) and WattTime (which uses higher marginal emissions rates) from the comparison, the average delta between the lowest total emissions value and the highest for all three cases is an average of 33%. Remaining optimistic that a data source won't be selected based only on the lowest apportioned emissions value, it is critical that once a source is chosen to benchmark first-year annual totals, that be the only source used in future calculations.

In this example, using values linked to CAISO yielded lower emissions values than multiplying against those for the entire state, but we certainly cannot claim this will always be the case. The takeaway message on location is that the "boundaries" around the geography tied to emissions data matters. On the use of marginal rates for accounting, WattTime has published a method to do this and where it fits into the GHG Protocol, noted in the "Primer" section above. Rather than unpack those specifics, our recommendation is the same as all other data sources: remain consistent in your calculations to avoid any skewed values based solely on data source variability.

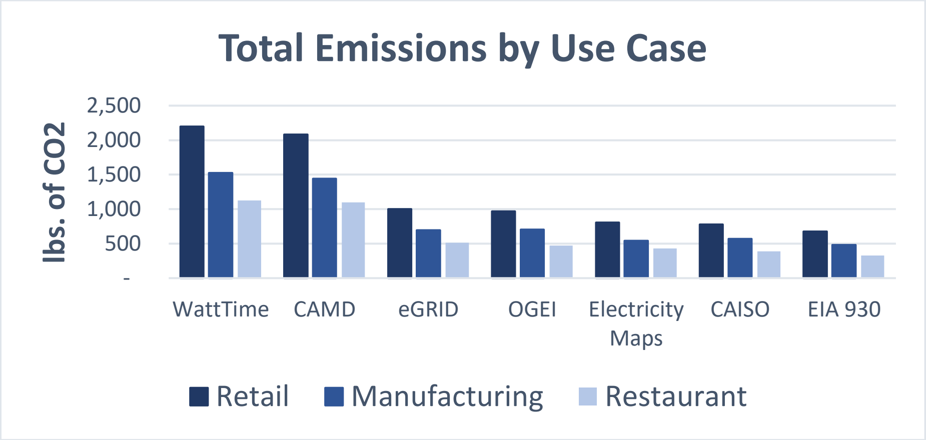

Figure 4. Varying total emissions in lbs CO2 per use case by data source.

Technology Switching – And Why Location Matters

Another common application of this emissions data is determining the impact of a certain energy efficiency decision. To illustrate how this type of calculation doesn't go unaffected by the variability of source data, we've picked an example energy efficiency technology improvement from California's Database for Energy Efficient Resources (DEER).[19] As our example, we've calculated the hourly kWh values saved from upgrading from a SEER 14 to a SEER 18 multizone heat pump in Southern California. Using the hourly energy savings tied to this change for our April 3rd example day, we performed the same multiplication as above and summed up the total lbs CO2 avoided by this technology switch. As shown in Figure 5, based on the source the avoided emissions tied to this change can range from .74 lbs CO2 to 2.15 lbs CO2 – attributed to a single day. Here, marginal emissions may give a better indication of the real grid impact of this change, and the difference between the average and marginal factors is worth noting. How you multiply and what you multiply meaningfully changes what you can claim from any decision pertaining to energy consumption.

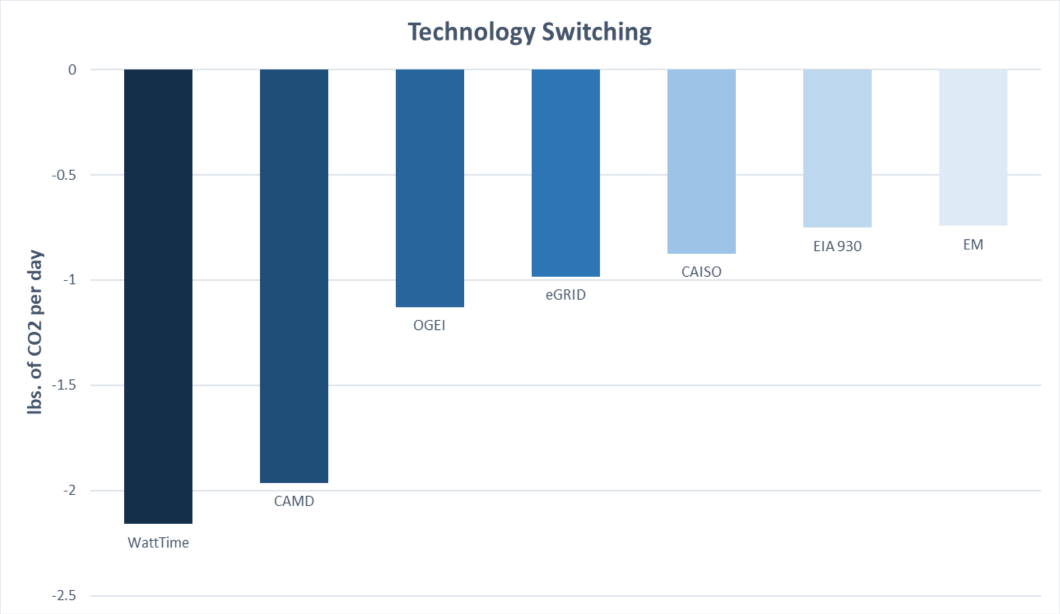

Figure 5. Daily avoided emissions from switching from SEER 14 to SEER 18 multizone heat pump in Southern California.

As mentioned in the accounting section above, the difference between the geographic boundaries tied to the emissions data used in any calculation makes a difference. Calculating the avoided emissions from decisions or actions tied to energy consumption shines an even brighter light on these differences. With the same 24-hour energy delta tied to upgrading our example multizone heat pump, we pulled WattTime's marginal emissions rates from April 3 of this year for Southwest Power Pool Kansas – selected because of its highly variable marginal data. We fully acknowledge the same technology would perform differently in Kansas than in Southern

---

[19] California Public Utilities Commission, "Energy Efficiency Resources," http://www.deeresources.com/

California, but for arguments sake, we made the comparison all the same. The difference in generation mixes and marginal variability between CAISO and SPP Kansas yielded a 6.8x increase in avoided emissions. This gap should give anyone considering using average emissions factors for the United States pause.

Decarbonization Policy and Protocol

If the SEC ruling on climate-related disclosure is approved as written, emissions accounting in the United States will become mainstream in a big way. While this legislation doesn't explicitly mandate the GHG Protocol, it does base its disclosure methodology upon it because of the Protocol's station as the most widely adopted disclosure framework. Beyond setting voluntary decarbonization targets, companies may soon be *required* to set them, and then answer to them year over year. With that in mind, the flexibility of the GHG Protocol allows for discretionary choices which could significantly alter any reported values, and the goals based upon them.

In the example calculations shown above, we utilized an hourly location-based method in which we chose to multiply hourly energy values by hourly emissions factors representing either CAISO or California. Our use of hourly values helped illustrate the tangible differences between all source data, and even more so on the effects this level of granularity has when translating various real-world load shapes into emissions equivalents. This granularity, however, is in no way assumed to be the way any of these calculations are performed currently – or will be performed in the future. In our experience, single annual average emissions factors are the far more adopted granularity for performing any emissions calculation. Returning to our single day in April, when we take the average of that 24-hour window for each source and multiply it by the sum kWh for each of our example consumers, and then compare those results to our values calculated on an hourly basis, naturally the totals no longer align. Based on our single-day example, the results can differ by as much as 10%, with no guaranteed pattern to indicate which method yields higher or lower total CO2 values. The more variable the emissions rates and how that variability aligns with the time of day a consumer uses energy dictates how great the delta between the calculation methods becomes. In a framework which doesn't prescribe hourly vs annual calculations, we simply want to flag that the calculated outcomes and claims based on those different methods will be just that, different.

When considering how any calculation aligns with a decarbonization goal, the more granular and more specific one can be in the evaluation of what the real value of a kWh consumed is at a given time, in a given place, is paramount. The goal shouldn't be to divide, assign, and apportion the "pie" of system-wide emissions to electricity consumers, it should be to reduce the size of the pie. There are plenty of resources cited in this paper to continue to pull on that thread, but hopefully our deliberately simple examples show the real potential impact and pitfalls of treating all kWh equally.

Conclusion

For most, the grand reveal of this paper will be how differently these interconnected data sources quantify the emissions tied to energy use within the same region. Others may find the survey of those data sources the most helpful insight gleaned, guiding their next steps. The conclusions themselves, however, are likely more familiar than unexpected once completely unpacked, simple and tangible examples in hand. No matter which data source you decide is most “reliable and accurate” for your purposes, the lessons from this comparison apply equally. When considering the specificity of your emissions calculations, details matter. As demonstrated, the choice to use annual averages, hourly averages, hourly marginal values, or those tied to balancing authorities vs states, all impact the final number assigned to the emissions equivalent of our energy usage. How we multiply and what multiply changes the value we assign to our emissions responsibility, and in turn, how we measure its reduction.

References

Climate Trace. "The Bottom Line on Ground Truth Data." Accessed March 2023. https://climatetrace.org/news/the-bottom-line-on-ground-truth-data.

Deloitte. "Zero in on Scope 1, 2, and 3 Emissions." Accessed March 2023. https://www2.deloitte.com/uk/en/focus/climate-change/zero-in-on-scope-1-2-and-3-emissions.html.

Electricity Maps. "Accounting Guide." Accessed March 2023. https://www.electricitymaps.com/guides/accounting-guide.

Energy Information Administration. "Electricity Data Browser." Accessed March 2023. https://www.eia.gov/electricity/gridmonitor/about.

Energy Information Administration. "Frequently Asked Questions (FAQs): What is the efficiency of different types of power plants?" Accessed March 2023. https://www.eia.gov/tools/faqs/faq.php?id=65&t=2.

Energy Information Administration. "Survey Forms & Instructions." Accessed March 2023. https://www.eia.gov/survey/#eia-930.

Environmental Protection Agency. "Air Emissions Factors and Quantification: Basic Information." Accessed March 2023. https://www.epa.gov/air-emissions-factors-and-quantification/basic-information-air-emissions-factors-and-quantification.

Environmental Protection Agency. "eGRID: Download Data." Accessed March 2023. https://www.epa.gov/egrid/download-data.

Environmental Protection Agency. "eGRID: Data Explorer." Accessed March 2023. https://www.epa.gov/egrid/data-explorer.

Environmental Protection Agency. "eGRID Technical Guide." Accessed March 2023. https://www.epa.gov/system/files/documents/2023-01/eGRID2021_technical_guide.pdf.

Environmental Protection Agency. "CAMD's Power Sector Emissions Data Guide." Accessed March 2023. https://www.epa.gov/system/files/documents/2022-07/CAMD%27s%20Power%20Sector%20Emissions%20Data%20Guide%20-%2007182022.pdf.

GHG Protocol. "Corporate Accounting and Reporting Standard." Accessed March 2023. https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf.

National Renewable Energy Laboratory. "Long-term Hourly Solar Radiation Data (LRMER)." Accessed March 2023. https://data.nrel.gov/submissions/183#:~:text=The%20LRMER%20is%20an%20estimate,years)%20change%20in%20electrical%20demand.

North American Electric Reliability Corporation. "Glossary." Accessed March 2023. https://www.nerc.com/pa/Stand/MOD%20V0%20Revision%20RF%20DL/Glossary.pdf.

Singularity Energy. "About the Open Grid Emissions Initiative." Accessed March 2023. https://docs.singularity.energy/docs/open-grid-emissions-docs/about_ogei-about-the-open-grid-emissions-initiative.

WattTime. "Accounting for Impact." Accessed March 2023. https://www.watttime.org/app/uploads/2022/09/WattTime-AccountingForImpact-202209-vFinal2.pdf.

WattTime. "API Documentation: List of Grid Regions." Accessed March 2023. https://www.watttime.org/api-documentation/#list-of-grid-regions.

WattTime. "MOER Modeling Methodology." Accessed March 2023. https://www.watttime.org/app/uploads/2022.