Tomorrow

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Whitepaper

A vision for how ambitious organizations can accurately measure electricity emissions to take genuine action

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Introduction

The climate crisis is here. The stakes have never been higher for corporate and institutional sustainability to be firmly rooted in science and drive as much real-world impact as possible. Fortunately, a wave of companies and other institutions are stepping up to consider how to take their sustainability programs to the next level. We at Tomorrow and WattTime are receiving more questions than ever about how measuring greenhouse gas emissions from electricity could be done right, done better, and done in a way that drives more impact. Because it is so critical that organizations succeed in this important goal, we are writing this joint briefing together.

To fully understand and report their greenhouse gas emissions from electricity, organizations broadly have two different questions they must answer:

1. What is the carbon footprint associated with their electricity used?
2. What is the carbon impact of different sustainability actions/interventions that they have been or could be undertaking?

At first glance, these might appear to be variations on the same question. But somewhat surprisingly, answering them accurately requires using two different *frameworks*: the **attributional framework** (answering the first question) and the **consequential framework** (answering the second).

Even though the **WRI** and **WBCSD** recognise these two frameworks and provide alternative standards for each through different parts of the **GHG Protocol**, organisations are not always fully aware of the difference. As a result, sustainability teams at many organizations worldwide still face ongoing questions about how best to measure electricity emissions for accuracy and impact.

In this document, we will first outline the principles of each framework and their relevance in decarbonizing our energy system. Then we will also lay out our vision of how we think ambitious companies could best answer the above questions using the most accurate science while driving the maximum impact possible.

Two complementary frameworks

1. The attributional framework accounts for an entity's inventory.

Every organization has an inventory of assets and some of these assets consume electricity (offices, factories, data centers, etc). These assets define an inventory boundary.

The *attributional* framework counts emissions related to the electricity consumption of these assets. It is called attributional as it consists of an allocation process in which emissions caused by the generation of electricity are divided up and attributed to different electricity consumers based on how much electricity they use.

The attributional framework therefore answers how one can measure the emissions of assets under the organization's responsibility. The following similar questions can also be answered by the attributional framework:

- What were the greenhouse gas emissions of our electricity usage last year?
- What is our electricity carbon footprint?
- To what extent were we powered by renewable energy?

The attributional emissions of an organization are calculated by summing up the emissions of all electricity-consuming assets in its inventory, where the emissions of each asset are the result of multiplying its electricity consumption with its associated grid **average emission factor.** This emission factor represents the emissions associated with consuming a unit of electricity, and is calculated in such a way that total electricity emissions are allocated amongst all electricity consumers on a grid.

There are different methods to decide how the emissions of an entire power grid should be allocated amongst its users. These include the location-based method (where all megawatt-hours are assigned the average emission factor of the grid to which the consuming asset is connected) and the market-based method (where each megawatt-hour is assigned an emissions factor based on which contractual rights have been purchased). Standards that specify how to perform attributional accounting include, for example, the GHG Protocol Scope 2 Guidance and ISO 14064-1.

As this framework doesn't consider effects and consequences outside of a company's inventory boundary, it does not measure the global consequences of an action undertaken by the organization. For example, if a company shifts the times at which it uses electricity, that intervention may affect the production (and thus emissions) of power plants on the local grid, which in turn may affect the emissions of everyone consuming from that grid. Situations like this are where the consequential framework comes in.

2. The consequential framework accounts for the *consequences* of an intervention.

Sometimes an intervention made by any one organization can affect the emissions of all grid users, and thus potentially have an impact beyond the inventory of the organization captured by the attributional framework. Such interventions may include shifting the timing of its energy consumption; installing or investing in a major new renewable energy facility; siting a major new electricity-consuming facility such as a data center; or even an energy efficiency retrofit. All of these interventions potentially affect generation at different power plants on the grid, or even nearby grids if power is imported or exported, and in so doing affect emissions of other company's inventories in addition to the company's own emissions inventory.

The consequential framework counts the change in emissions associated with an intervention, and therefore answers questions like:

- When is the best time to consume electricity to lower CO2 emissions?
- What is the effect of my newly installed energy storage system on the grid's CO2 emissions?
- What is the emissions impact of my investments in energy infrastructure?
- Where can I build a new wind farm for maximum impact?
- Where would building a new data center cause the least amount of CO2 emissions?

The consequential framework measures the total decrease (or increase) in global emissions that occur as a consequence of an organization performing a particular intervention. For a given intervention, its consequential emissions are calculated by adding up how much electricity will be affected by an intervention (whether added, removed, or shifted in location or time) and then multiplying these by a **marginal emission factor.** This marginal emission factor represents the additional emissions caused by consuming one additional unit of electricity from the grid (and equivalently the emissions avoided by consuming one less unit of electricity).

These marginal emission factors are computed in a way to represent the difference in total global emissions between a world where an organization made a certain intervention and a counterfactual world where it did not. The challenge is that this counterfactual world is not observable as it did not happen, and one must resort to a modelling exercise in order to estimate it. Different time scales can be considered: the short-term impact of an intervention (such as that intervention changing power plant production levels from one hour to the next) is described by the **operating margin**, whereas the long-term impact (such as that intervention changing the building or retirement of plants from one year to the next) is described by the **build margin**.

Marginal emission factors are typically different from average emissions factors used in the attributional framework. For example, short-term marginal factors that consider the operating margin typically exclude wind and solar generation, as the electricity they generate normally can't be affected by any short-term intervention (with the exception of curtailment events). However, average emission factors include all wind and solar production at times where the wind blows and the sun shines.

Note that marginal emission factors typically assume that the intervention causes a change in the real world. This is not always the case. Typically one would assume that if an organization's actions are the major driver behind a project (for example if it finances the construction of a wind farm) then their intervention did cause the project (i.e. constructing that wind farm) to happen. And if the intervention caused the project, then it reduced real-world emissions. But not all interventions do have such a clear effect. For example, if the same organization instead purchased low-cost unbundled renewable energy certificates (RECs) that only accounted for a very small fraction of the wind farm's financing, it may be the case that the wind farm would have been constructed regardless of whether those RECs were purchased.

Therefore, in the consequential framework, all interventions should be assessed for the degree to which they caused a real-world change (their so-called **additionality**). Marginal emission factors should only be applied if the intervention is deemed additional.

Example standards that specify how to perform consequential accounting are the **GHG Protocol Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects**, and the Clean Development Mechanism's **Tool to calculate the emission factor for an electricity system**.

A vision for ambitious organizations

The democratisation of energy and emissions data creates a new realm of possibilities where emissions can now be mapped at an unprecedented level of accuracy. In this section, we lay out foundational principles depicting a vision of how to ideally implement both the attributional and consequential frameworks in order to drive real climate action. While we acknowledge the usefulness of current implementations, we're hoping that this can act as a vision for ambitious organizations who want to report both the attributional and consequential emissions of their electricity emissions in the most methodologically sound way possible.

1. Measuring emissions accurately

The more institutions begin to actually use data to drive decision making, the more it matters that the data they use are correct and the right kind of data for the job in question. To drive accurate measurement and ensure genuine impact, the following data quality and relevance characteristics should be addressed under either framework:

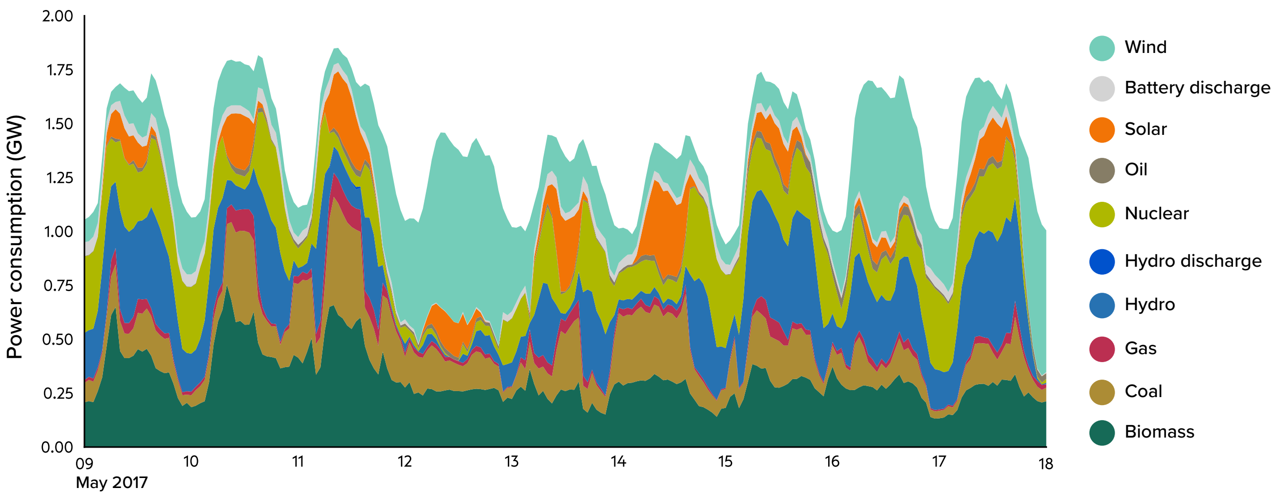
Accuracy

In many cases, complete and verified emissions data sources are not available. In the attributional framework, this occurs primarily due to missing data. In the consequential framework, it can occur particularly often due to the need to measure counterfactuals. When complete verified data are not available, one sometimes must use some estimates or assumptions. But every assumption is a quality risk. And emissions factors rooted as much as possible in real-world measurements rather than assumptions are much less prone to errors. **Results will therefore be more accurate if they minimize the amount of assumptions, and thus rely on measured, real-world data as much as possible**.

Timing

As a result of installing more and more intermittent renewables such as wind and solar, the available mix of power plants generating electricity will increasingly vary from hour to hour: during a windy day, wind turbines might dominate the mix, but when the wind doesn't blow, coal power plants or imports from a neighbouring grid might be used instead. Electricity therefore has an increasingly different footprint depending on when it was generated (see figure below). **Results will better reflect grid conditions if they use emission factors with a high temporal resolution (at least hourly) to account for this variability**.

Physical origin of electricity in East Denmark (including imports)



source: electricitymap.org

Interconnectors

Furthermore, as the electricity grid becomes increasingly interconnected and regional, it is not uncommon to see certain areas significantly depend on generation from neighboring grid regions at certain times. Emissions caused by the supply coming from neighboring areas should therefore be taken into account. **Results will therefore be more accurate if they use emission factors that incorporate the import and export of electricity to account for this interdependence.**

Physicality

Having more temporally and geographically granular emissions data doesn't help if they do not refer to the time or place where the intervention actually physically occurred. For example, if a company in California purchases electricity from a solar or wind farm in New York, we recommend measuring the consequences using emissions factors for New York. **Results will therefore represent the underlying physical emissions more accurately if they use emissions factors from the time and place of the physical electricity in question.**

Relevance

Furthermore, there is one additional data quality criterion that only applies to the consequential framework. Just as one should apply emissions factors from the time and place where the load occurs, one should also apply emissions factors from the type of change in load that actually occurs. Results will be more accurate if they use operating margin emissions factors for small, short-term changes in load, and use build margin emissions factors for interventions that have a longer-term impact on the electricity system, such as the construction of new generation assets. As a practical matter it is our understanding that there are not yet any standardized, universal sources of reliable build margin data available. Thus, this quality criterion is difficult to apply in practice in 2021, though we hope that will change over time.

2. Using emissions data to shift real-world load

For organizations who have the ability to shift their electricity usage or their electricity generation to certain times or places in order to reduce emissions, the question of which type of emissions factors to use arises. Should one optimize with the aim to maximize the reduction in attributional or consequential emissions?

Note that both metrics do not always yield the same decisions. For example, let us consider an electricity grid dominated by solar energy. In many electricity grids, the dirtiest peaker gas or oil plants only operate during times of peak demand, which typically is during the day. However, these hours of peak demand will coincide with times when solar energy is produced. During the day, attributional emissions can be very low (because solar might make up a large fraction of all electricity) but consequential emissions can be very high, as the consequence of consuming more electricity at this time will be to increase usage of gas peaking plants (one can't ask the sun to shine harder!).

Optimizing attributional emissions will aim to reduce a company's asset's emissions whereas optimizing based on consequential emissions will aim to reduce total system-wide emissions. If one wants to maximize global impact, then optimizing on consequential emissions is the recommended optimization target.

Note that irrespectively of which optimization target was selected, two distinct benefits of an intervention both occur and can be communicated:

1. Reduction in attributional emissions representing a reduction in the organization's emissions. Using that quantity, an organization can communicate that "by shifting the time at which we consume electricity, we were able to reduce our own emissions by X".
2. Avoided consequential emissions representing changes of emissions induced on the whole grid. Using that quantity, an organization can communicate that "by shifting the time at which we consume electricity, we were able to avoid X tons of CO_2 being emitted by the power grid".

3. Using emissions data to inform purchasing of electricity and contractual claims

Purchasing electricity and/or contractual claims using Power Purchasing Agreements (PPA), Guarantees of Origin (GO) or RECs schemes is a standard practice. The benefits of financing electricity generators through the purchase of their electricity can be significant and should not be ignored. But how should one account for them?

The market-based attributional method has historically used these contractual rights to enable contract holders to claim a zero footprint of their electricity consumption under the attributional framework. In contrast to the location-based method, the market-based method does not currently take into account the underlying physical constraints of electricity delivery (by e.g. allowing trades between disconnected regions). As these contracts do not strictly follow the underlying physical constraints of the grid, we see this method as currently suboptimal in the attribution of emissions.

However, a contract (REC, GO or PPA) may contribute materially to the project being built. If so, then it is additional and genuinely reduces total global emissions. Measuring the consequence of an intervention using the consequential framework would therefore quantify the total global emissions reductions caused by the intervention. Organizations that use the consequential framework to measure, and potentially maximize, the emissions benefits of their contractual purchase would be confident that their purchasing is driving real-world physical emissions reductions.

We therefore recommend excluding market-based contractual instruments from attributional accounting by using the location-based method, and instead suggest that the impact of market-based contractual instruments be assessed using the consequential framework.

Conclusion

When measuring electricity emissions, the GHG Protocol stipulates that companies must report their inventory using the attributional framework, and may also separately report their avoided emissions using the consequential framework. At Tomorrow and WattTime, we recommend measuring and reporting both while seeking to utilize the most scientifically sound methods available to do so. To do the best job of each, we recommend using the data quality and optimization suggestions above.

We recognize that following our recommendations may not be possible for every organization right now, but we hope that these suggestions can help chart a path towards a future where electricity carbon accounting practices become more accurate and grounded in the physical operations of the grid in order to drive tangible reductions in carbon emissions.

If you're interested in learning more about how these frameworks could be applied, we invite you to reach out to either of our organizations.

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