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Commentary

Reforming Carbon Accounting for Modern Power Systems

Florian Berg[1]*, Christopher R. Knittel[1], and Jack Morris[1]

The two standards that govern the climate claims of virtually all major companies are currently being rewritten. The Greenhouse Gas (GHG) Protocol, which has served as the foundation of corporate carbon accounting for over 25 years, and the Science Based Targets initiative (SBTi), which builds on the Protocol to validate net-zero plans, are both finalizing revisions to the rules for emissions from purchased electricity. Their reach is extraordinary: they guide voluntary disclosures, inform ESG ratings, and shape multi-trillion-dollar investment decisions[1]. The three leading environmental, social, and governance (ESG) standards setters, namely the International Sustainability Standards Board (ISSB), the European Sustainability Reporting Standards (ESRS), and the Global Reporting Initiative (GRI), explicitly endorse the GHG Protocol. In 2024, at least 23,000 firms disclosed carbon emissions according to the GHG Protocol while more than 10,000 firms relied on SBTi for defining net-zero targets[2,3].

Yet the Protocol's authority obscures a deeper problem: Scope 2, the framework governing indirect emissions from purchased electricity, steam, heat, and cooling, was designed for a simpler power system[4]. As grids have become more dynamic, congested, and interconnected, the gap between reported emissions and real-world impacts has widened. Scope 2, including the suggested revisions, cannot reliably tell whether a corporate action actually reduced grid emissions. It cannot distinguish a new wind farm that displaces a coal plant from one that merely displaces other renewables behind a transmission constraint; it offers no way to credit investments in storage or transmission; and it gives no signal about where on a congested grid new load should be sited. With both standards open for revision simultaneously, there is a narrow window to fix this.

Current Scope 2 reporting employs two approaches: location-based and market-based. The location-based method relies on annual grid-average emission factors. To report their emissions, firms multiply their electricity consumption by an average emission factor supplied by the grid operator.

The market-based approach allows firms to use energy attribute certificates (EAC) such as Renewable Energy Certificates (RECs) or Guarantees of Origin (GoOs) in Europe, to reduce reported emissions. Here, firms derive emission factors from their contractual agreements with energy producers. As a result, reported emissions may be lower than those of the grid supplying the electricity. Emissions from purchases not covered by such contracts are generally calculated using residual emission factors.

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The GHG Protocol is currently revising its standard with the stated goal to "better reflect the physical realities of the power grid[5]." According to the initial public consultation for Scope 2, the primary focus of the revision is on increasing temporal granularity to hourly matching and adding deliverability requirements, i.e., emission factors need to be derived from grids from which the actual electricity is delivered rather than broad geographic regions[6]. At the same time, SBTi is also going through a major overhaul. In addition to hourly matching and physical deliverability, SBTi is adding commissioning and re-powering (significant upgrade) date limits to eventually 5 years prior to EAC issuance[7].

One of the main problems is that modern grids are far more congested than they used to be. Transmission constraints have been steadily rising in recent years as energy demand has outpaced infrastructure spending. The rise in energy demand due to data centers and electrification will only worsen the problem. In particular, renewable energy generation tends to cluster geographically and around similar times (solar produces energy when there is sunlight) sometimes far from load centers. The resulting curtailment of renewable energy leads to longer run times for fossil fuel-based energy generation. It has been estimated that these transmission constraints increase emissions by roughly 10 million tons of CO2e in the Texas-based ERCOT grid in 2022 alone[8].

Hence, hourly matching and deliverability requirements might improve the accuracy of inventory accounting, commissioning and re-powering date limits might avoid EAC issuance for older renewable assets, but because of transmission constraints, they do not capture the causal effects of additional consumption or investment on the grid. As a result, these changes cannot ensure that new renewable supply displaces fossil generation rather than other renewables. Nor do they inform decisions about where to locate additional consumption within a grid because they overlook transmission constraints that may raise emissions intensity at the point of delivery. In addition, Scope 2 provides no way to capture the emissions effects of investments in storage and transmission, both of which have become increasingly important to the efficient functioning of modern grids. Consequently, these revisions fall short of turning carbon accounting into a meaningful decision-making tool for guiding carbon-free grid build out or credibly fulfilling corporate net-zero commitments.

Policy solution: Require dual reporting for inventories and impacts

To improve Scope 2 accounting, the GHG Protocol and SBTi need to open themselves to evaluating the real-world emissions impact of corporate decisions (consequential accounting) alongside pure emissions inventories (attributional accounting). Attributional accounting remains useful for standardized and comparable inventories. Consequential accounting, however, should be the foundation upon which progress on climate commitments is measured. Put differently, it should govern causal claims implied by net-zero targets. Ultimately, to create the right incentives, firms must be rewarded when they achieve real emissions reductions.

The most practical reform is to complement Scope 2 and SBTi with an additionality requirement based on a consequential accounting method for renewable electricity consumption claims. Investment decisions should likewise be subject to an additionality requirement; in particular, EACs need such a requirement. Comparable certificates should also be issued for storage and transmission investments, subject to an additionality requirement, and recognized under Scope 2 accounting to support the critical infrastructure needed to decarbonize the grid.

Besides the Scope 2 revision, the GHG Protocol established a separate subgroup to produce an appropriate methodology for electricity-sector emissions impacts on which such an additionality requirement could be based[9]. Moreover, a separate Actions and Market Instruments (AMI) Technical Working Group is developing a multi-statement reporting structure that would report consequential statements alongside attributional ones[10]. The decision on whether the consequential statement is required or optional has not yet been taken. We argue it should be required for any claim of progress toward net-zero targets. SBTi's draft Corporate Net-Zero Standard V2 does not yet engage with this work. We argue that SBTi should adopt the multi-statement structure and require an additionality assessment for net-zero target validation.

Such an additionality assessment would answer a simple question: *Did this specific action cause a net reduction in grid emissions relative to what would have happened otherwise?* In our Virginia-based empirical example below, we show how moving from average-based factors to consequential accounting changes the measured impact of consumption and investment decisions. In addition, we show that consequential accounting can be used to measure the impact of investment in storage and transmission.

Locational marginal emissions (LMEs) provide a natural foundation for such an approach. LMEs estimate how emissions change when electricity demand increases or decreases at a specific place and time. Because they reflect marginal generation and transmission constraints, they can capture effects that annual averages and hourly matching miss. This mirrors how electricity prices are determined at the nodal level with locational marginal prices (LMPs). LMEs can be estimated at any temporal granularity; we believe hourly LMEs are sufficiently granular to capture meaningful differences. In our Virginia illustration, these differences are economically meaningful: hourly matching affects consumption and investment decisions only slightly relative to current practice, whereas consequential accounting materially alters the ranking of both consumption and investment choices.

Evidence from the Virginia grid: Why impact-based accounting matters

To show how average-based emission factors can potentially misrepresent the actual impact of corporate decisions, we apply three accounting approaches, annual average grid factors (current Scope 2), hourly matching (proposed Scope 2), and LME-based consequential accounting, to 2023 data from PJM nodes around the Loudoun County, Virginia data-center cluster. We simulate the annual emissions impact of a 10-MW addition across four activity types: electricity consumption, solar generation, battery storage, and transmission capacity. The intention is a proof of concept, not an exhaustive grid-wide accounting. The results are summarized in Fig. 1.

Possible Sites for +10MW of Energy Technology				Emissions Impact under Protocol		
	Description	CF Average	LME Average	Current GHG Protocol	24/7 Hourly Matching	Locational Marginal Emissions
		%	kgCO2/MWh	tCO2/yr	tCO2/yr	tCO2/yr
Data Center A	*Flat load in data center cluster*	-	638	**28,971**	28,612	52,422
Data Center B	*Flat load outside data center cluster*	-	572	**28,971**	28,612	50,246
Data Center C	*VRE-following load in data center cluster*	-	638	**28,971**	**27,979**	52,493
Data Center D	*VRE-following load outside data center cluster*	-	572	**28,971**	**27,979**	**50,021**
Solar A	*Northern VA, in data center cluster*	24	638	-7,002	-6,903	**-13,371**
Solar B	*Northern VA, outside data center cluster*	24	574	-7,002	-6,903	-12,677
Solar C	*Southern VA, sunnier*	27	554	**-7,958**	**-7,857**	-13,283
Solar D	*Chicago IL, less sunny*	21	484	-6,163	-6,133	-9,841
Storage A	*Inside data center cluster*	-	638	**902**	599	**-1,276**
Storage B	*Outside data center cluster*	-	572	904	**596**	-1,126
Transmission A	*Border of data center cluster*	-	570, 638	**0**	**0**	**-1,256**
Transmission B	*Outside data center cluster*	-	572, 584	**0**	**0**	-687

Environmentally Preferred Site Under Protocol
Attributed Induced Emissions
Attributed Avoided Emissions

Figure 1. Attributed emissions impacts of 10 MW of new electricity consumption, solar, storage, and transmission projects by siting location under three carbon accounting alternatives, simulated with 2023 observed emissions rates, generation, and capacity factors[8,11,12]

Average-based factors mismeasure the impact of new load. In our example, induced emissions from a 10-MW data center are 73–81% higher when measured at the marginal generator than when computed against an annual grid average, meaning corporate net-zero claims built on attributional Scope 2 accounting may understate the climate impact of additional consumption on a constrained grid. The siting signal also sharpens. Annual averaging is silent on location by definition. Hourly matching cannot distinguish a data center placed inside the congested cluster (A and C) from one placed nearby outside it (B and D). LME-based accounting separates them by close to 5% and thus enables decision-making that results in lower emissions.

Consequential accounting reorders investment in renewable generation in a similar way. Under annual and hourly matching, solar in cloudier Chicago (Solar C) avoids roughly 13% more emissions than the same 10-MW array in Northern Virginia (Solar A). Under consequential accounting, the ranking changes, with avoided emissions being highest for Solar A.

Battery storage appears as a net emitter under both attributional methods because battery technologies have less than 100% round-trip efficiency, with some energy lost during charging and discharging. LMEs reveal storage as an abater by capturing the low-emissions hours when batteries charge and the high-emissions hours when they discharge. Although hourly matching provides a temporal signal, grid-wide averaging dilutes it and fails to demonstrate the emissions reduction capability of battery storage. Hence, consequential accounting could enable investment in storage through the issuance of storage-discharge certificates.

Finally, transmission upgrades expose a gap that average-based methods cannot bridge at all. Both annual averaging and hourly matching cannot attribute any emissions to either of our simulated lines. LMEs enable us to see that the line connecting the congested data-center cluster (Transmission A) avoids nearly twice the emissions of a similar but unconnected nearby line (Transmission B), because added capacity lets more low-cost, low-emission generation reach demand. Hence, consequential accounting could form the basis of congestion-relief certificates.

Toward a Consequential Carbon Accounting Framework

The GHG Protocol transformed corporate climate reporting by creating a universal language for emission inventories. SBTi became the gold standard for net-zero targets. These frameworks should preserve attributional reporting for comparability while requiring an additionality assessment for consequential claims. That method must measure the emissions effects of incremental consumption and investment at the relevant location and time so that firms are able to receive credit for grid-improving actions, such as siting choices, new renewable generation, storage, and transmission. Ultimately, firms should reflect these impacts in their emissions statements, and impact-based methods should be the foundation of reporting progress on climate targets.

If reform stops at hourly matching, grid-wide boundaries, commissioning as well as re-powering date limits, and optional consequential accounting, the GHG Protocol and SBTi will not fix the deeper problem of causal attribution. If, instead, both standard-setters adopt reporting that pairs attributional inventories with mandatory impact-based disclosure to guide decision making and reporting progress on net-zero targets, they can better distinguish symbolic claims from real decarbonization while directing capital toward the infrastructure needed for low-carbon grids. With their ongoing revisions, the GHG Protocol and SBTi have a rare window to reshape global carbon accounting for the coming decades. They should seize it.

Endnotes

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Data, code, and materials availability: Our public repository (https://github.com/jf-morris/lme_consequential_accounting) contains all code and all available data used to produce the results in our report "Carbon Accounting for a Congested Grid". We acquired historical 2021-2024 locational marginal emission rates (LMEs), locational marginal prices (LMPs), and project-level renewable capacity factor data from REsurety, Inc. Please contact REsurety (https://resurety.com/contact/) to get access to this data. Historical generation, load, emissions, imports, and exports were acquired from public PJM Data Miner 2 (https://dataminer2.pjm.com/list).

About the Authors



Florian Berg is a principal research scientist at the MIT Sloan School of Management where he cofounded and co-runs the Aggregate Confusion Project. His research interest covers sustainability related measurement with a focus on ESG ratings, disclosure, investor impact, carbon accounting, and voluntary carbon markets. He received his PhD in financial economics from Paris-Dauphine University. During his PhD, he held a visiting research position at ETH Zurich. Florian worked as a quantitative researcher at Amundi Asset Management and as a quantitative strategist/ trader at Alphadyne Asset Management. He taught at Paris-Dauphine University, Sciences-Po Paris, and MIT Sloan. Florian has written op-eds for the Financial Times as well as the Wall Street Journal among others. His research won numerous awards including the Pagano and Zechner price and the 2025 Financial Times award for most impactful responsible research in a business school. He is also a member of the Consultative Working Group of ESMA, the European securities regulator.



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