# Scope 2: Physical Power Usage Accounting Is Fictional, Pricing And Marginal Impact Accounting Are Real

William W. Hogan[i]

December 12, 2025

> "Importantly, 24x7 energy matching ignores the lessons learned from the development of Locational Marginal Prices (LMPs): in power systems, it is not possible to match individual production and consumption at different locations." (Andersen et al., 2025)

## Background

The World Resources Institute organized public comments on accounting for Greenhouse Gas (GHG) emissions associated with purchases of electricity.[1] The majority of the questions asked about properties of alternative emission accounting conventions. Question 152 allowed for comments on the foundations:

> "152. In your view, balancing scientific integrity, climate impact, and feasibility, what scope 2 revisions or combination of revisions are most appropriate? Please address each of the three core decision-making criteria: integrity, impact, and feasibility in your answer, and describe how the approach satisfies each criterion."

The present note addresses the failure of the current GHP Scope 2 revision proposal to meet its own Scientific Integrity criteria, as the accounting ignores the special problems that arise due to the physics underlying power flows.

## Comment

The Greenhouse Gas Protocol pursuit of a definition for indirect Scope 2 GHG emissions embedded in purchases of electricity is based on an implicit premise that is incompatible with the laws of physics. The implicit assumption is that there must be a meaningful way to connect individual consumption and production of electricity within a power grid. This assumption is not true.

The GHGP is currently at risk of repeating a regulatory failure addressed 30 years ago by the U.S. electricity sector: the 'Contract Path' fallacy. After passage of the Energy Policy Act of 1992, the Federal Energy Regulatory Commission (FERC) undertook an extensive period of comment and

[1] WRI public consultation

analysis regarding open access to the high voltage transmission grid in a move away from the monopoly model. A major milestone was FERC Order 888 issued on April 24, 1996:

> "Today the Commission issues three final, interrelated rules designed to remove impediments to competition in the wholesale bulk power marketplace and to bring more efficient, lower cost power to the Nation's electricity consumers. The legal and policy cornerstone of these rules is to remedy undue discrimination in access to the monopoly owned transmission wires that control whether and to whom electricity can be transported in interstate commerce." (FERC, 1996b, p. 1)

The extensive prior public comment period revealed that there was no method for organizing individual power transactions connecting individual load and generation as in the manner envisioned by Scope 2 emission accounting. The Commission repeatedly asked for a workable mechanism to assign transmission capacity to support a market solution based on individual scheduling. The industry repeatedly explained that the available transmission transfer capacity depended largely on how the system was used.

The Commission recognized the fundamental problem in its summary of the deep flaws in the "contract path" model for connecting individual generation and load:

> "We will not, at this time, require that flow-based pricing and contracting be used in the electric industry. In reaching this conclusion, we recognize that there may be difficulties in using a traditional contract path approach in a non-discriminatory open access transmission environment, as described by Hogan and others. At the same time, however, contract path pricing and contracting is the longstanding approach used in the electric industry and it is the approach familiar to all participants in the industry. To require now a dramatic overhaul of the traditional approach -- such as a shift to some form of flow-based pricing and contracting -- could severely slow, if not derail for some time, the move to open access and more competitive wholesale bulk power markets." (FERC, 1996b, p. 96)

The importance of this issue was illustrated by the FERC notice of proposed rulemaking (NOPR) issued by the Commission on April 24, 1996, under the notion of the Capacity Reservation Tarriff (CRT):

> "The Federal Energy Regulatory Commission (Commission) is proposing a rule that specifies filing requirements to be followed by public utilities in making transmission tariff filings based on capacity reservations for all transmission users. The proposed capacity reservation open access transmission tariff, if adopted, would replace the open access transmission tariff required by the Commission in Promoting Wholesale Competition Through Open Access Nondiscriminatory Transmission Services by Public Utilities; Recovery of Stranded Costs by Public Utilities and Transmitting Utilities, Order No. 888, FERC Stats. & Regs. ¶ 31,036 (1996)." (FERC, 1996a)

In other words, after deliberating for years and adopting a fundamentally flawed proposal to organize electricity markets under the contract path model in Order 888, on the ***same day*** the Commission launched a process to overturn the whole enterprise!

In the event, the CRT process was overtaken by various attempts to design workable electricity that would confront the realities of basic physics.

The central basics include:

1. In a meshed transmission network, power flows on every parallel path between the points of injection and withdrawal.
2. Individual load and individual generation need not balance, and imposing such a mandate would violate security constraints and cause grid collapse.
3. Total load and total generation must balance, essentially instantaneously.
4. Every power system needs a system operator to coordinate the actual real-time dispatch.

If you are not a power engineer, the collective implication of these basic facts is highly counterintuitive. The meshed network is not like a copper plate, where all load and generation could be treated as being at the same location. The meshed network is not like a pipeline or transportation system with a well-defined contract path through the system. The capacity of the meshed network depends on the pattern of injection and withdrawal, so power flows cannot be determined independently. Markets on a meshed power network cannot be like other markets (Hogan, 1992).

These basics lead to the real-time electricity market design of a bid-based-security-constrained-economic-dispatch-with-locational-marginal-prices (BBSCEDLMP). All the named elements matter. Bilateral contracts between individual generators and loads are included as financial hedging instruments, but these contracts do not need to be even known to the system operator, and they do not directly affect the economic dispatch.

There were many flawed attempts to avoid this reality (Hogan, 2002). However, today BBSCEDLMP is the essential real-time market design embraced in all the organized electricity markets in North America.

In essence, the promise of Scope 2 GHG accounting is that what we cannot do for physical power we can somehow manage for GHG emissions. Were this possible, there are many collateral issues that might arise (Leggett and Gillenwater, 2025). But what we cannot do for individual power production, we also cannot do for individual GHG emissions.

Facing the market design limitations imposed by existing high voltage grids leads back to first principles in considering the production of both green energy and GHGs.

Although we cannot connect individual generation and load, despite the underlying presumption of Scope 2 accounting, there is much that can be done. For example, within the framework of central economic dispatch, we can define and calculate the system marginal emission impact of small changes in generation and load (Rudkevich and Ruiz, 2012). This has been done for a number of years, for example, in the PJM Regional Transmission Organization (PJM-Interconnection, 2021). Marginal emissions for individual loads are not the same as average emissions, but marginal emissions are well defined whereas average emissions for individual transactions are not. Much as with locational real-time prices for power, the results for marginal emissions can be quite surprising: marginal emission rates can be very different across the system at the same point in time, and across time at the same location.

Importantly, the environmental implications of GHG emissions are different from the effect of local pollutants like small particulates. The timing and exact location of small particulate emissions are relevant in defining incidence through air transport models and the health impacts through population exposure. By contrast, the harm from GHGs is a global problem over long time horizons and with global mixing of the atmosphere. For GHG emissions, knowing the year is essentially as good as knowing the hour, and the location of the emissions does not matter in determining the effects on the climate.

The economic perspective of charging for emissions is especially helpful here. Carbon pricing can be done in a straightforward way and implemented with essentially no changes in the electricity market design with economic dispatch. The emissions would be measured at the source and priced accordingly. The carbon price would be part of the input to the economic dispatch to account for the social cost of carbon (Barrage and Nordhaus, 2024). The locational-marginal-price (LMP) for power would incorporate the effect of the carbon price. Efficient choices would follow marginal signals, and the total payments would cover the total, not just the marginal, emissions. In part, such carbon pricing is already included in electricity markets with explicit carbon prices or through existing cap-and-trade systems.

In short, the lesson from the experience with electricity markets is: don't fight the underlying physics. To maintain its avowed scientific integrity, the GHGP should abandon the fiction of physical matching of contracted load and generation. It should instead pursue a design that recognizes the physical reality, such as ex post accounting for marginal emissions or directly pricing total carbon emissions.

## References

Andersen, L., Baldick, R., Bohn, R., Caramanis, M., Cardell, J., Carlberg, D., Dvorkin, Y., Farid, A. M., Freed, P., Gillenwater, M., Hobbs, B., Hollenbeck, B., Howard, D., Kelly, A., Lahd, H., Leggett, M., McCormick, G., Miller, D., Minor, P., O'Sullivan, F., Putnam, M., Richardson, H., Roald, L., Rudkevich, A., Smith, T., Silverman, A., Sioshansi, R., Sofia, S., Tabors, R., Taylor, L. & Thomas, A. 2025. Open Letter: Expert Consensus on carbon impact. https://expertconsensusoncarbonimpact.com/.

Barrage, L. & Nordhaus, W. 2024. Policies, Projections, and the Social Cost of Carbon: Results from the DICE-2023 Model. *Proceedings of the National Academy of Sciences USA,* 121**,** e2312030121, https://doi.org/10.1073/pnas.2312030121.

FERC 1996a. Capacity Reservation Tariff: Notice of Proposed Rulemaking. Federal Energy Regulatory Commission, https://www.govinfo.gov/content/pkg/FR-1996-05-10/pdf/9610692.pdf.

FERC 1996b. Order 888: Promoting Wholesale Competition Through Open Access Nondiscriminatory Transmission Services by Public Utilities, Recovery of Stranded Costs by Public Utilities and Transmitting Utilities; Dockets No. RM95-8-000, No. RM94-7-001. Federal Energy Regulatory Commission, https://www.ferc.gov/sites/default/files/202005/rm95-8-00w.txt.

Hogan, W. W. 1992. Contract networks for electric power transmission. *Journal of Regulatory Economics,* 4**,** 211–242, https://doi.org/10.1007/BF00133621.

Hogan, W. W. 2002. Electricity market restructuring: reforms of reforms. *Journal of Regulatory Economics,* 21**,** 103–132, http://ezp-prod1.hul.harvard.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=17768581&site=ehost-live&scope=site.

Leggett, M. & Gillenwater, M. 2025. Limitations of Hourly Matching Claims for Scope 2 Reporting. Ever.green and Greenhouse Gas Management Institute, https://ever.green/papers/hourly-matching.

PJM-Interconnection 2021. Marginal Emissions Rate – A PRIMER. https://pjm.com//media/etools/data-miner-2/marginal-emissions-primer.ashx.

Rudkevich, A. M. & Ruiz, P. A. (2012). Locational Carbon Footprint of the Power Industry: Implications for Operations, Planning and Policy Making. In Zheng, Q. P., Rebennack, S., Pardalos, P. M., Pereira, M. V. F. & Iliadis, N. A. (Eds.), *Handbook of $CO_2$ in Power Systems* (pp. 131–165-131–165). http://link.springer.com/chapter/10.1007/978-3-64227431-2_8.

[i] William W. Hogan is the Raymond Plank Research Professor of Global Energy Policy (Emeritus), John F. Kennedy School of Government, Harvard University. This paper draws on research for the Harvard Electricity Policy Group and for the Harvard-Japan Project on Energy and the Environment. The author is or has been a consultant on electric market reform and transmission issues for Allegheny Electric Global Market, American Electric Power, American National Power, Aquila, AQUIND Limited, Atlantic Wind Connection, Australian Gas Light Company, Avista Corporation, Avista Utilities, Avista Energy, Barclays Bank PLC, Brazil Power Exchange Administrator (ASMAE), British National Grid Company, California Independent Energy Producers Association, California Independent System Operator, California Suppliers Group, Calpine Corporation, CAM Energy, Canadian Imperial Bank of Commerce, Centerpoint Energy, Central Maine Power Company, Chubu Electric Power Company, Citigroup, City Power Marketing LLC, Cobalt Capital Management LLC, Comision Reguladora De Energia (CRE, Mexico), Commonwealth Edison Company, COMPETE Coalition, Conectiv, Constellation Energy, Constellation Energy Commodities Group, Constellation Power Source, Coral Power, Credit First Suisse Boston, DC Energy, Detroit Edison Company, Deutsche Bank, Deutsche Bank Energy Trading LLC, Duquesne Light Company, Dyon LLC, Dynegy, Edison Electric Institute, Edison Mission Energy, Electricity Authority New Zealand, Electricity Corporation of New Zealand, Electric Power Supply Association, El Paso Electric, Energy Endeavors LP, Energy Security Board Australia, Exelon, Financial Marketers Coalition, FirstEnergy Corporation, FTI Consulting, GenOn Energy, GPU Inc. (and the Supporting Companies of PJM), GPU PowerNet Pty Ltd., GDF SUEZ Energy Resources NA, Great Bay Energy LLC,

GWF Energy, Independent Energy Producers Assn, ISO New England, Israel Public Utility Authority-Electricity, Koch Energy Trading, Inc., JP Morgan, LECG LLC, Luz del Sur, Maine Public Advocate, Maine Public Utilities Commission, Merrill Lynch, Midwest ISO, Mirant Corporation, MIT Grid Study, Monterey Enterprises LLC, MPS Merchant Services, Inc. (f/k/a Aquila Power Corporation), JP Morgan Ventures Energy Corp., Morgan Stanley Capital Group, Morrison & Foerster LLP, National Independent Energy Producers, New England Power Company, New York Independent System Operator, New York Power Pool, New York Utilities Collaborative, Niagara Mohawk Corporation, North Dakota Public Service Commission, NRG Energy, Inc., Ontario Attorney General, Ontario IMO, Ontario Ministries of Energy and Infrastructure, Pepco, Pinpoint Power, PJM Office of Interconnection, PJM Power Provider (P3) Group, Powerex Corp., Powhatan Energy Fund LLC, PPL Corporation, PPL Montana LLC, PPL EnergyPlus LLC, Public Service Company of Colorado, Public Service Electric & Gas Company, Public Service New Mexico, PSEG Companies, Red Wolf Energy Trading, Reliant Energy, Rhode Island Public Utilities Commission, Round Rock Energy LP, San Diego Gas & Electric Company, Secretaría de Energía (SENER, Mexico), Sempra Energy, SESCO LLC, Shell Energy North America (U.S.) L.P., SPP, Texas Genco, Texas Utilities Co, Tokyo Electric Power Company, Toronto Dominion Bank, Total Gas & Power North America, Transalta, TransAlta Energy Marketing (California), TransAlta Energy Marketing (U.S.) Inc., Transcanada, TransCanada Energy LTD., TransÉnergie, Transpower of New Zealand, Tucson Electric Power, Twin Cities Power LLC, Vitol Inc., Westbrook Power, Western Power Trading Forum, Williams Energy Group, Wisconsin Electric Power Company, and XO Energy. Lee Taylor provided helpful comments. The views presented here are not necessarily attributable to any of those mentioned, and any remaining errors are solely the responsibility of the author. (Related papers can be found on the web at www.whogan.com )