Institute *for*
Policy Integrity
NEW YORK UNIVERSITY SCHOOL OF LAW

August 16, 2023

Hon. Michelle L. Phillips, Secretary
New York State Public Service Commission
Three Empire State Plaza
Albany, New York 12223-1350

**VIA ELECTRONIC SUBMISSION**

**Subject:** Case 15-E-0302 – Proceeding on Motion of the Commission to Implement a Large-Scale Renewable Program and a Clean Energy Standard

Dear Secretary Phillips:

In response to the Public Service Commission's (the Commission or PSC) Order Instituting Process Regarding Zero Emission Target issued and effective May 18, 2023 (the Order),[1] and the Notice Extending Comment Period issued June 28, 2023, the Institute for Policy Integrity at New York University School of Law[2] (Policy Integrity) respectfully submits the following comments. Policy Integrity is a non-partisan think tank dedicated to improving the quality of government decisionmaking through advocacy and scholarship in the fields of administrative law, economics, and public policy. Policy Integrity has extensive experience advising stakeholders and government decisionmakers on the rational, balanced use of economic analysis, both in federal practice and at the state level.

We are grateful for your consideration of these comments.

Sincerely,

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[1] Case 15-E-0302, *Proceeding on Motion of the Commission to Implement a Large-Scale Renewable Program and a Clean Energy Standard*, Order Initiating Process Regarding Zero Emissions Target (May 18, 2023) [hereinafter Order].
[2] This document does not purport to present the views, if any, of New York University School of Law.

**POLICY INTEGRITY COMMENTS IN RESPONSE TO ORDER INITIATING PROCESS REGARDING ZERO-EMISSIONS TARGET**

## I. Introduction

Since January 2016, this docket has provided a forum for the Commission to develop programs to ensure the achievement of New York's increasingly rigorous renewable energy targets in tandem with greenhouse gas (GHG) emissions reductions from the electric sector.[3] Now, the Climate Leadership and Community Protection Act (CLCPA or the Act) requires the Commission to revisit and reconsider the relationship between these twin efforts. Specifically, section 66-p(2) of the Public Service Law directs the Commission to establish a program (the 66-p(2) program) to require the achievement of renewable-generation and emissions-reduction goals for the electric sector that are even more rigorous than those previously established through the Clean Energy Standard.[4] The 66-p(2) program requires that, by 2030, 70% of statewide electric generation be secured by jurisdictional load-serving entities to meet the electrical energy requirements of end-use customers in the state be generated by renewable energy systems,[5] and that, by 2040, the "statewide electrical demand system" be zero-emissions.[6] The fact that renewable generation and zero emissions are related but distinct goals is further underlined by CLCPA's directive to the Commission to regularly review the 66-p(2) program and determine "progress in meeting the overall targets for deployment of *renewable energy systems* and *zero emission sources*, including factors that will or are likely to frustrate progress toward the targets."[7]

The Order formally commences the Commission's iterative exploration of the 2040 zero-emissions target, and thus the relationship between that target and the renewable-generation target. The Order notes that the Act does not define "zero emissions" and that, as such, it has been left to the Commission to define it.[8] The Act is also silent on the meaning of "electrical demand system."

The questions set forth in the Order cover a wide range of matters. Policy Integrity's comments respond to only a small subset of these questions. Overall, these comments recommend as follows:

- The Commission must harmonize its work towards the 2040 zero-emissions target with the CLCPA as a whole, in coordination with Department of Environmental Conservation (DEC) and other agencies.
    - This work should be based on the best available science and economics.

[3] Case 15-E-0302, *Proceeding on Motion of the Commission to Implement a Large-Scale Renewable Program and a Clean Energy Standard*, Order Expanding Scope of Proceeding and Seeking Comments (Jan. 21, 2016).
[4] N.Y. Pub. Serv. Law § 66-p(2).
[5] *Id.*
[6] *Id.*
[7] *Id.* at § 66-p(3) (emphases added).
[8] Order at 12.

  - The Commission's analysis of benefits should be consistent with the DEC's approach, including adopting the DEC's Social Cost of Carbon.
- To qualify as a zero-emission resource, hydrogen would need zero lifecycle emissions.
  - Zero-emissions hydrogen requires zero production emissions. Today, the only hydrogen that induces no production emissions is electrolytic hydrogen powered by zero-emissions electricity. Verification protocols would be necessary to determine whether grid-connected electrolyzers cause zero production emissions. A marginal-emissions approach with temporal and spatial granularity would accurately measure the production emissions of grid-connected electrolyzers.
  - The Commission should allow electrolyzers to characterize their production emissions as zero using power-purchase agreements and renewable energy certificates, but only after mandating necessary safeguards. Specifically, the zero-emissions generation would need to be additional, and the zero-emissions generation would need to be time-matched and deliverable. To the extent the CLCPA would be satisfied by hydrogen whose production does not result in *net* emissions, the Commission could establish a carbon-matching framework in lieu of requiring hourly matching or deliverability.
  - The Commission must consider the climate impacts of leaked hydrogen, because hydrogen is itself an indirect GHG.
- Benefits to disadvantaged communities should be quantified in coordination with other agencies and disadvantaged community stakeholders, and should be tracked using holistic mapping tools.

## II. The Commission Must Harmonize This Program With the CLCPA as a Whole in Coordination with DEC and Other Agencies

The CLCPA assigns a variety of emissions-reduction responsibilities to a variety of agencies, and these disparate responsibilities add up to a whole-of-government push to combat climate change and assure benefits, including emissions-reductions benefits, to disadvantaged communities. DEC must inventory New York's economy-wide emissions,[9] establishing actual GHG budgets based on percentages of 1990 emissions,[10] and promulgating regulations to achieve statewide GHG emissions reductions.[11] And the Commission is responsible for the aforementioned 66-p(2) program,[12] as well as specific programs to procure significant quantities of specific renewable resources and storage,[13] and programs to achieve energy conservation and energy efficiency goals.[14]

More generally, sections 7 and 8 of the CLCPA make it clear that various agencies including the PSC have a critical supporting role to play in helping DEC to achieve economy-wide emissions reductions. To that end, the PSC must consider how its decisions would affect the achievability of statewide GHG-reduction goals and provide justification as well as alternatives or mitigation

[9] N.Y. ECL § 75-0105.
[10] *Id.* § 75-0107.
[11] *Id.* § 75-0109.
[12] N.Y. Pub. Serv. Law § 66-p(2).
[13] *Id.* § 66-p(5).
[14] *Id.* § 66-p(6).

if they are at risk of undermining achievability.[15] The Commission must also "promulgate regulations to contribute to achieving the statewide greenhouse gas emissions limits," which "shall not limit [DEC's] authority to regulate and control greenhouse gas emissions."[16] Thus, the overall structure of the CLCPA, and particularly the express language of Sections 7 and 8, make it clear that the Commission's programs must support DEC's efforts around economy-wide greenhouse gas emissions reductions.

### A. The Commission should adhere to the best available science and economics

The Order recognizes that the Act has given DEC a key role in establishing statewide (that is, economy-wide) GHG emissions limits.[17] Importantly, the statutory provision directing DEC to establish those GHG emissions limits states that "[i]n order to ensure the most accurate determination feasible, the department shall utilize the best available scientific, technological, and economic information on greenhouse gas emissions."[18]

Although this language is specifically applicable to the DEC, the Commission should approach its own programs with equal rigor. As discussed in greater detail in the section of these comments focused on hydrogen,[19] the overall structure of the CLCPA strongly suggests an overall strategy of *eliminating* any electric sector contribution to overall GHG emissions statewide, and relying on this fully decarbonized sector as a powerful lever to enable deep GHG emissions reductions in other sectors. As such, DEC's obligation to reduce statewide GHG emissions depends substantially on the Commission's success at eliminating emissions from the electric sector. Accordingly, the Commission's efforts to ensure that its programs support the achievement of the statewide goals must likewise be based on the best available science, technology, and economics. The Commission's stated intention of consulting with the New York State Energy Research and Development Authority (NYSERDA) is a positive step in this direction,[20] as is its issuance of these questions to stakeholders, many of whom can offer significant subject matter expertise. Ongoing coordination with sister agencies such as DEC and NYSERDA, as well as stakeholders, will be important for keeping the Commission's knowledge of science, technology, and economics up-to-date.

### B. The Commission's analysis of benefits should be consistent with DEC's, including the social cost of carbon

Given that the complementarity between Commission's role in the CLCPA's overall emissions-reductions scheme and DEC's role, the Commission's emissions-reduction efforts should, to the maximum extent possible, be well coordinated with those of DEC. This coordination includes adopting DEC's analytic frameworks when they are available and applicable to the Commission's own obligations. As such, the Commission's tools for the accounting of emissions reductions and benefits arising from emissions-reduction programs should be harmonized with

[15] 2019 N.Y. Sess. Law 106, § 7.
[16] *Id.* § 8.
[17] Order at 13.
[18] N.Y. ECL § 75-0107(3).
[19] *See infra* Section III.
[20] *See* Order at 18.

those of other agencies. Thus, the Commission should, to the extent possible, follow DEC's guidance with respect to the social cost of carbon (SCC). This will be important for any circumstance where benefits or costs are to be monetized, such as benefit-cost analysis of various policy options for pathways to achieving the 2040 target.

The Commission showed tremendous leadership in its early reliance on the SCC as a regulatory tool in 2016, when it incorporated the federal government's estimated damage cost associated with GHG emissions into a benefit-cost analysis framework in the Reforming the Energy Vision proceeding.[21] The Commission adopted the federal SCC estimate based on what the federal Interagency Working Group then viewed as a central estimate of the discount rate: 3%.[22] The PSC's leadership continued with the establishment of the compensation mechanism for "zero emission resources" under the Clean Energy Standard[23] and incorporating the SCC into incentive structures for distributed energy resources the following year.[24]

More recently, however, the CLCPA directed DEC, in consultation with NYSERDA, to establish a SCC for use by state agencies.[25] Compared to the Commission's SCC figures, the new DEC guidance—which has been continually updated—reflects more recent developments in science and economics, including with respect to the discount rate, and addresses additional GHGs.[26] As such, both the need for coherent coordination among state agencies *and* the need for the Commission to rely on the best available science and economics point in a single direction: following DEC's lead on the SCC.

DEC's central value for the damage cost for a ton of carbon in 2023 is $126 (in 2020$), far higher than the $49.25 that is the most recent calculation that we have been able to locate in a Commission proceeding.[27] The primary reason for this divergence appears to be DEC's decision to rely on 2% as the central discount rate. Although the federal Interagency Working Group has not yet officially adopted lower discount rate values (it continues to use 2.5%, 3%, and 5%, with 3% as the central figure), it acknowledges that "new data and evidence strongly suggests that the discount rate regarded as appropriate for intergenerational analysis is lower."[28] DEC gives multiple reasons for using a central figure of no greater than 2%:

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[21] Case 14-M-0101, *Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision*, Order Establishing the Benefit Cost Analysis Framework (Jan. 21, 2016).
[22] *Id.* at 27.
[23] *See* Case 15-E-0302, *Proceeding on Motion of the Commission to Implement a Large-Scale Renewable Program and a Clean Energy Standard*, Order Adopting a Clean Energy Standard (Aug. 1, 2016).
[24] *See* Case 15-E-0751, *In the Matter of the Value of Distributed Energy Resources* & Case 15-E-0082, *Proceeding on Motion of the Commission as to the Policies, Requirements and Conditions For Implementing a Community Net Metering Program*, Order on Net Energy Metering Transition, Phase One of Value of Distributed Energy Resources, and Related Matters (Mar. 9, 2017).
[25] N.Y. ECL § 75-0113(1).
[26] *See* N.Y. DEP'T OF ENV'T CONSERVATION, ESTABLISHING A VALUE OF CARBON: GUIDELINES FOR USE BY STATE AGENCIES (2022), https://perma.cc/8D3Z-NHAX [hereinafter DEC SCC Guidance].
[27] *Compare id.* at 34, *with* 15-E-0751, *In the Matter of the Value of Distributed Energy Resources, Updated Environmental Value*, Letter from Department of Public Service to Con Ed (April 21, 2021), and spreadsheet attached thereto, https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={5ED3467D-6B9C-4A4F-8E2C-E52A12E83F47}.
[28] INTERAGENCY WORKING GROUP, TECHNICAL SUPPORT DOCUMENT: SOCIAL COST OF CARBON, METHANE, AND NITROUS OXIDE INTERIM ESTIMATES UNDER EXECUTIVE ORDER 13990 5 (2021), https://perma.cc/8G9U-P3X4.

> First, although higher discount rates may be appropriate for guiding the long-term investment of private funds, they are less appropriate for decisions regarding public safety and welfare, particularly when considering the scope and scale of the impacts to the public from global climate change. . . . Second, multiple lines of research have concluded that the discount rates used by the federal [Interagency Working Group] underestimate the value of avoided damages from greenhouse gas emissions. Experts now generally consider a range of 1-3 percent to be more acceptable. A lower discount rate may help address the underestimation of the potential damages from climate change.[29]

The DEC guidance also recommends considering a range of values, including 1%, in recognition of varying preferences and the fact that no one number is optimal.[30] That said, given the compelling reasons DEC has stated for applying a very low discount rate, and the CLCPA's express recognition that a discount rate of zero can be appropriate,[31] it would be advisable in the future for DEC to give serious consideration to a central value between 1% and 2%. At the same time, the federal government's own estimate for the SCC may rise significantly in the near future.[32]

While there may be practical impediments to incorporating a far higher SCC into compensation mechanisms, DEC's current methodology is simply more accurate—more aligned with the best available science and economics, as contemplated by the CLCPA—than the approach pioneered by the Commission beginning in 2016. For so long as the DEC continues to keep its guidance aligned with the best available science and economics, the Commission should align its own figures those promulgated by the DEC to the extent feasible. At a minimum, the Commission should follow the DEC's SCC guidance—including subsequent modifications to that guidance that improve the alignment with best available science and economics—both in its benefit-cost analysis, and for the purpose of tracking CLCPA benefits, as further discussed below.

## III. Hydrogen Would Need Zero Lifecycle Emissions to Qualify as a Zero-Emissions Resource

This section responds to Question 2 posed by the Commission in the Order: "Should the term 'zero emissions' be construed to include some or all of the following types of resources, such as advanced nuclear (Gen III+ or Gen IV), long-duration storage, green hydrogen, renewable natural gas, carbon capture and sequestration, virtual power plants, distributed energy resources, or demand response resources? What other resource types should be included?"[33]

As a preliminary matter, however, we pause to note that whether "green" or other hydrogen qualifies as zero-emissions under the CLCPA is a distinct issue from what pre-2040 policies are

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[29] DEC SCC Guidance, *supra* note 26, at 18–19.
[30] *Id.* at 19.
[31] N.Y. ECL § 75-0113(2).
[32] *See* EPA, EXTERNAL REVIEW DRAFT OF REPORT ON THE SOCIAL COST OF GREENHOUSE GASES (Sept. 2022) (Docket No. EPA-HQ-OAR-2021-0317.
[33] Order at 15–16.

optimal to achieve the 2040 target. The Commission has an overarching mandate of "encourag[ing] all persons and corporations subject to its jurisdiction to formulate and carry out long-range programs . . . for the performance of their public service responsibilities with economy, efficiency, and care for the public safety, the preservation of environmental values."[34] This responsibility to foster long-range programs for the preservation of environmental values ultimately obligates the Commission to consider not only what resources may be considered zero-emissions in 2040, but how to create the conditions for those resources to be built out in an economically efficient manner. It might be the case, for example, that the Commission would want to incentivize non-zero-emissions hydrogen before 2040 in order to economically ensure the presence of zero-emissions hydrogen in 2040. Nonetheless, these comments focus (as the question posed in Order does) on when hydrogen would qualify as a zero-emissions resource under the CLCPA for purposes of the 2040 target.

In short, hydrogen would qualify as a zero-emissions resource when it has zero lifecycle emissions. These lifecycle emissions are relevant when determining which resources are zero-emissions under the CLCPA, as explained in Section A below. The discussion of hydrogen's lifecycle emissions tends to divide its lifecycle emissions into two categories: production emissions and hydrogen leakage. Production emissions includes the emissions from the hydrogen-production process plus the emissions from with any electricity usage during production and the upstream leakage of chemical feedstocks (i.e., methane). In Section III.B.1, these comments explain that the only hydrogen-production method with zero production emissions is electrolytic hydrogen powered by zero-emissions resources (e.g., renewables or nuclear). Section III.B.2 further explains that, to ensure hydrogen was produced via a grid-connected electrolyzer has zero production emissions, the Commission would need to implement rigorous verification procedures. Otherwise, it would be easy for generators to burn high-GHG hydrogen while erroneously claiming zero production emissions. In Section III.C, we discuss the second category of hydrogen's lifecycle emissions: leakage of hydrogen throughout the supply chain. Because hydrogen is itself an indirect GHG, this leakage would disqualify hydrogen from being a zero-emissions resource under the CLCPA.

Our recommendations present a flexible framework for evaluating which hydrogen would be a zero-emissions resource, including hydrogen produced outside of New York and transported here. As relevant, we explain how the recommendations would apply to the special case of hydrogen produced in New York after the 2040 zero-emissions target has been achieved, at which point the regional grid would be expected to be zero-emissions.

### A. Lifecycle emissions are cognizable under the CLCPA

Although hydrogen produces no GHG emissions upon combustion (or use in a fuel cell),[35] the fuel's lifecycle emissions are highly sensitive to how it is produced and transported. Lifecycle emissions matter because the Commission must ensure that the "statewide electrical demand

[34] N.Y. Pub. Serv. Law § 5(2).

[35] Burning hydrogen, however it is produced, results in $NO_X$ emissions that cause asthma and asthma attacks, and possibly other health impacts. U.S. EPA, INTEGRATED SCIENCE ASSESSMENT (ISA) FOR OXIDES OF NITROGEN—HEALTH CRITERIA lxxxvii (2016). People of color and those with low socioeconomic status already face increased exposure to $NO_X$, *id.*, so burning hydrogen at power plants implicates environmental justice concerns.

system will be zero emissions."[36] The plain meaning of the word "system" is "a regularly interacting or interdependent group of items forming a unified whole."[37] As such, the CLCPA requires zero emissions from the unified whole of all interacting items that serve New York's demand for electricity. If generators were to serve some of this demand by burning hydrogen, then some of the interacting items would be the processes of producing and delivering the hydrogen. Because the entire electrical demand system must be zero-emissions, hydrogen is a zero-emissions only when these processes cause zero emissions.[38]

Further, the CLCPA requires that New York's "statewide greenhouse gas emissions" include "greenhouse gases produced outside of the state that are associated with the generation of electricity imported into the state and the extraction and transmission of fossil fuels imported into the state."[39] Although this language does not specifically mention hydrogen that is imported into the state, it is reasonable to assume that the legislature would expect upstream emissions associated with imported hydrogen to be treated similarly to upstream emissions associated with other imported energy sources. It would be anomalous for the introduction of novel fuels that did not fit into one of the named categories to be permitted to undermine the integrity of the CLCPA's treatment of upstream emissions associated with legacy forms of imported energy, including both electricity and conventional fuels. Moreover, the imperative to avoid upstream emissions associated with hydrogen production is further underlined by the CLCPA's requirement that the DEC's regulations to achieve statewide GHG emissions targets include "measures to minimize leakage."[40]

The overall structure of the CLCPA strongly suggests an overall strategy of *eliminating* any electric sector contribution to overall GHG emissions statewide, and relying on that fully decarbonized sector as a powerful lever to enable deep GHG emissions reductions in other sectors. This is evidenced by the juxtaposition of the new Environmental Conservation Law and Public Service Law provisions added by the CLCPA, combined with CLCPA provisions that require agencies other than DEC to shore up DEC's economy-wide efforts. Article 75 of the Environmental Conservation Law creates a process for the adoption of statewide GHG emissions limits, with DEC holding the rudder.[41] By contrast, Section 66-p of the Public Service Law tasks the Commission with requiring transformative change to one sector (electric generation),[42] and is notably lacking in specificity about other sectors overseen by the Commission—including the natural gas system, which is a significant contributor to statewide GHG emissions.[43] Finally, the catch-all provisions in Sections 7 and 8 of the CLCPA require all state agencies to remain

[36] N.Y. Pub. Serv. Law § 66-p(2).
[37] *System*, Merriam-Webster Dictionary Online, http://www.merriam-webster.com/dictionary/system (last visited Aug. 11, 2023) (first definition).
[38] Although earlier orders and the CLCPA itself have made it clear that the embodied emissions of generation equipment (notably renewable energy systems) do not prevent otherwise non-emitting generators from qualifying as "zero emissions," there is no justification for ignoring emissions associated with fuel or fuel production, which are consistently treated as relevant to New York's GHG emissions footprint.
[39] N.Y. ECL § 75-0101(13).
[40] *Id.* § 75-0109(3)(e). "Leakage" is defined as a reduction in emissions of greenhouse gases within the state that is offset by an increase in emissions of greenhouse gases outside of the state. *Id.* § 75-0101(12).
[41] *Id.* § 75-0109.
[42] N.Y. Pub. Serv. Law § 66-p(2).
[43] *See* N.Y. DEP'T OF ENV'T CONSERVATION, 2022 NYS GREENHOUSE GAS EMISSIONS REPORT: SECTORAL REPORT #1 at 5 (2022).

mindful of and take steps to support achievement of the statewide GHG emissions goals in a role that supports and does not undercut DEC's leadership in this area.[44]

Viewing the CLCPA as a single scheme, it is apparent that by 2040, if the Commission permits hydrogen to play some role in meeting statewide electrical demand, it cannot fail to consider the risk that it could do so in a way that increases statewide (economy-wide) GHG emissions as understood in the new Article 75 of the Environmental Conservation Law. Although the new Section 66-p of the Public Service Law makes no specific reference to this definition for statewide GHG emissions supplied in Article 75, and although "statewide electrical demand system" and "zero emissions" are terms that are left undefined, it would defy logic for the Commission's obligation to ensure that the "statewide electrical demand system will be zero emissions" to be entirely satisfied by resources whose operation in fact increases *statewide* GHG emissions.

Accordingly, for hydrogen to be a zero-emissions resource under the CLCPA, it must have zero lifecycle emissions. In Section III.B, we discuss lifecycle emissions from production. In Section III.C, we address lifecycle emissions from hydrogen leakage.

### B. Zero-emissions hydrogen requires zero production emissions

Green hydrogen (i.e., hydrogen produced from electrolysis powered by renewable resources) and hydrogen produced via electrolysis powered by other zero-emissions resources (such as nuclear) do not induce any production emissions.[45] In contrast, other methods of hydrogen production are currently associated with high GHGs and are thus ineligible to be considered zero-emissions. While it is relatively straightforward to verify whether an off-grid electrolyzer is powered by zero-emissions electricity, this inquiry becomes more challenging for grid-connected electrolyzers. Accordingly, rigorous verification protocols would be necessary before any hydrogen produced at a grid-connected electrolyzers could be considered zero-emissions. These protocols would always be satisfied by grid-connected electrolysis in a zero-emissions grid (e.g., New York after 2040).

#### 1. The only hydrogen that currently induces no production emissions is electrolytic hydrogen powered by zero-emissions electricity

Of the multiple ways to produce hydrogen today, only electrolysis powered by zero-emissions electricity produces no GHG emissions.[46] The next cleanest major method is steam methane reforming/auto-thermal reforming (SMR/ATR) with greater than 90% carbon capture and storage (CCS).[47] These processes involve extracting hydrogen from methane using chemical processes that release $CO_2$ as a byproduct.[48] They have production emissions of approximately

[44] 2019 N.Y. Sess. Law 106, §§ 7–8.
[45] U.S. DEP'T OF ENERGY, PATHWAYS TO COMMERCIAL LIFTOFF: CLEAN HYDROGEN 10 fig.2 (2023), https://perma.cc/7U99-J28P [hereinafter DOE HYDROGEN LIFTOFF REPORT].
[46] DOE HYDROGEN LIFTOFF REPORT, *supra* note 35, at 10 fig.2.
[47] *Id.*
[48] *Id.*

2.5–6 kg $CO_2e$/kg $H_2$.[49] This total represents a combination of $CO_2$ directly released during SMR/ATR and upstream emissions of the methane feedstock from which the hydrogen is produced (e.g., fugitive emissions of methane during extraction, transportation, and storage).[50] As such, even if 100% CCS were achieved for SMR/ATR, the resulting hydrogen would have production emissions from associated upstream methane leakage. Without CCS, SMR/ATR has a carbon intensity of at least 10 kg $CO_2e$/kg $H_2$.[51] Using fossil fuels to power electrolysis is even more emissions-intensive: 22–24 kg $CO_2e$/kg $H_2$ for natural gas (without even accounting for upstream methane emissions) and 51–56 kg $CO_2e$/kg $H_2$ for coal.[52]

Electrolytic hydrogen powered by zero-emissions electricity is becoming increasingly available. The Inflation Reduction Act established lucrative tax credits for hydrogen production based on the hydrogen's production emissions.[53] In light of this subsidy, the Department of Energy (DOE) projects that electrolytic hydrogen using renewables will become cheaper than SMR/ATR hydrogen,[54] comprising 70–95% of total U.S. hydrogen production by 2030.[55] Developers have already announced numerous projects to produce electrolytic hydrogen using renewables or nuclear energy.[56] The Environmental Protection Agency (EPA) recently proposed regulations for baseload natural gas turbines with an option to co-fire 4% natural gas and 96% low-GHG hydrogen by 2038.[57] EPA proposes to define "low-GHG hydrogen" as hydrogen with production emissions of less $<0.45$ kg $CO_2e$/kg $H_2$.[58] Given the emissions intensities described in the previous paragraph, only electrolytic hydrogen produced with zero-emissions electricity has an emissions intensity below this threshold.[59]

In sum, the Commission should insist that, to qualify as a zero-emissions resource under the CLCPA, hydrogen must have production emissions of 0 kg $CO_2e$/kg $H_2$. Given today's

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[49] *Id*.
[50] *Id.*
[51] *Id.*
[52] *See* THOMAS KOCH BLANK & PATRICK MOLLY, RMI, HYDROGEN'S DECARBONIZATION IMPACT FOR INDUSTRY 5 (2020), https://perma.cc/T3XH-9DSQ ("Producing one kilogram of hydrogen with electrolysis requires 50–55 kWh of electricity. This power consumption leads to indirect $CO_2$ emissions, the level of which varies according to the sources of electricity used."); *Frequently Asked Questions*, U.S. ENERGY INFO. ADMIN., https://perma.cc/6DJ6-2C77 (providing the $CO_2$ intensity per kWh for natural gas and coal plants).
[53] 26 U.S.C. § 45V.
[54] DOE HYDROGEN LIFTOFF REPORT, *supra* note 35, at 26 fig.10.
[55] *Id.* at 37 fig.15. DOE projects that, after the clean hydrogen production tax credit expires, SMR/ATR hydrogen with CCS will grow in the 2030s and 2040s, but that electrolytic hydrogen produced by renewables will retain a significant market share. *Id.*
[56] New Source Performance Standards for Greenhouse Gas Emissions from New, Modified, and Reconstructed Fossil Fuel-Fired Electric Generating Units; Emission Guidelines for Greenhouse Gas Emissions from Existing Fossil Fuel-Fired Electric Generating Units; and Repeal of the Affordable Clean Energy Rule, 88 Fed. Reg. 33,240, 33312–13 (proposed May 23, 2023) [hereinafter EPA Proposed Rule].
[57] *Id.* at 33284 tbl.1, 33363.
[58] *Id.* at 33304, 33328 n.499.
[59] For a $<0.45$ kg $CO_2e$/kg $H_2$ production-emissions standard, "hydrogen producers would need to consume between 90 to 97.5 percent zero-carbon power to qualify," depending on the emissions intensity of the fraction of electricity that comes from non-zero-emissions resources. TESSA WEISS ET AL., RMI, CALIBRATING US TAX CREDITS FOR GRID-CONNECTED HYDROGEN PRODUCTION: A RECOMMENDATION, A FLEXIBILITY, AND A RED LINE (2023), https://perma.cc/6477-ES22 [hereinafter RMI POLICY BRIEF].

technology, only hydrogen produced via electrolysis powered by zero-emissions resources would satisfy this standard.

### 2. Verification protocols are necessary to determine whether grid-connected electrolyzers cause zero production emissions

In principle, electrolytic hydrogen produced via zero-emissions electricity results in zero production emissions, but, in practice, it can be difficult to determine whether a grid-connected electrolyzer can fairly be described as running on zero-emissions electricity. (The same attribution problem does not exist for the simpler case of an off-grid electrolyzer powered by dedicated zero-emissions resources.) Accordingly, the Commission would need to promulgate verification protocols before any electrolytic hydrogen from a grid-connected electrolyzer could be considered zero-emissions under the CLCPA. Otherwise, generators might erroneously burn electrolytic hydrogen with high production emissions.

These verification protocols should follow a marginal-emissions approach, meaning the electrolyzer would be held responsible for the emissions that it actually causes through its power consumption from the local grid. Under a marginal-emissions approach, grid-connected electrolytic hydrogen production does not cause any production emissions when the “marginal” resource on the local grid is zero-emissions. The marginal emissions rate is zero when and where zero-emissions resources are being curtailed or when the entire grid is zero-emissions (e.g., New York grid after the 2040 target has been achieved).

Further, the Commission should accommodate electrolyzers that use power purchase agreements (PPAs) or contracts for renewable energy certificates (RECs) to avoid their emissions—but only in combination with necessary safeguards. PPAs and RECs would allow electrolyzers to effectively decouple their emissions from those of the marginal generator on the local grid by paying for zero-emissions generation. These mechanisms and their attendant safeguards are irrelevant for electrolyzers operating on zero-emissions grids, because there would be no emissions for electrolyzers to avoid using PPAs or RECs.

#### a. A marginal-emissions approach with temporal and spatial granularity would accurately measure the production emissions of grid-connected electrolyzers

Given the realities of grid operation, the best way to measure production emissions from using grid electricity is to look at the emissions intensity of the marginal generator serving the local grid at the moment of hydrogen production, as opposed to the average emissions intensity of the local generation mix. The emissions from the marginal resource, if greater than zero, would be avoidable if the electrolyzer were not to run; therefore, the electrolyzer should be deemed to induce the emissions of this marginal generator, notwithstanding the average emissions intensity of the grid mix being consumed by other customers.

Given the realities of grid operation, the marginal resource is typically more-emitting than the average electricity mix because grid operators generally dispatch generation resources according to their operating costs. The first resources that a grid operator will rely on to meet demand are those that generate cheap electricity after they have been built, like solar, wind, and hydropower. Only when the output of these resources is not enough to satisfy demand will the grid operator call on resources with higher operating costs like natural gas that also tend to release more emissions.

Accordingly, whenever an electrolyzer draws power that is available to the local grid and the low-operating-cost, zero-emissions resources are committed, the electrolyzer will be deemed to be powered by fossil fuels. As discussed above, producing hydrogen via fossil-fuel-powered electrolysis is currently the most-emitting production method, worse than SMR/ATR without CCS.[60] In contrast, if an electrolyzer operates when the marginal resource is zero-emissions, the resulting hydrogen induces zero production emissions. In fact, the electrolyzer would be using zero-emissions electricity that would otherwise have been curtailed.

Identifying the marginal resource requires temporal and spatial granularity. Temporal granularity is necessary because the marginal resource on a local grid changes throughout the day. For example, in a high-renewables future, solar could be the marginal resource in certain locations during the day, but, as the sun sets, the grid operator may need to activate natural gas plants, making them the marginal resource. (This narrative is not representative of current conditions in NYISO, but it could reflect the situation in a region where out-of-state hydrogen is produced for shipment to New York, or circumstances in New York closer to the 2040 target.) Figures 1 and 2 show how quickly and dramatically the marginal resource can change within a single regional grid.[61] They demonstrate that accurately measuring the grid emissions of an electrolyzer depends on identifying the marginal resource when the electrolyzer was actually operating.

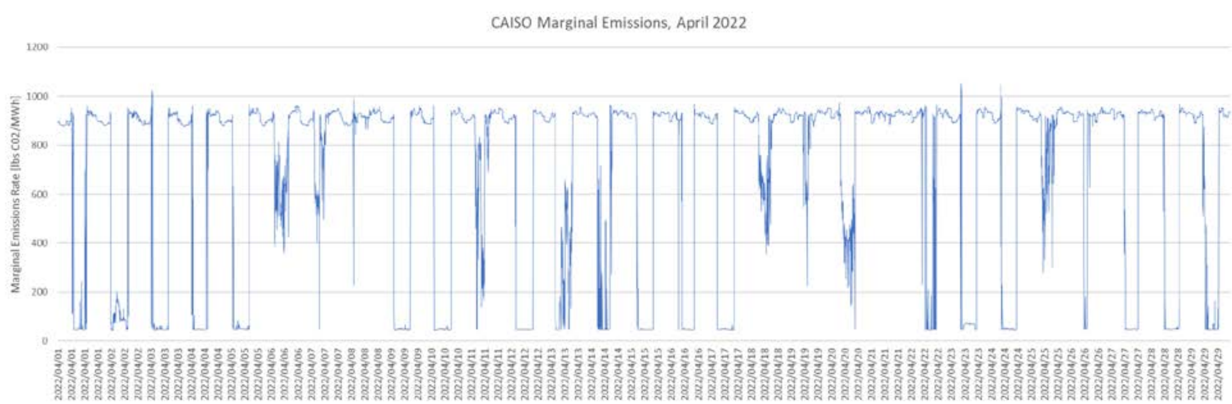


Figure 1: variability in CAISO marginal emissions rate

[60] Section III.B.1.
[61] Each figure reflects marginal emissions rates as modeled by WattTime. *See Methodology: How Does WattTime Calculate Marginal Emissions?*, WATTTIME, https://perma.cc/NTD8-F88L; WATTTIME, MARGINAL EMISSIONS MODELING: WATTTIME'S APPROACH TO MODELING AND VALIDATION (2022), https://perma.cc/6DMQ-NX7P.

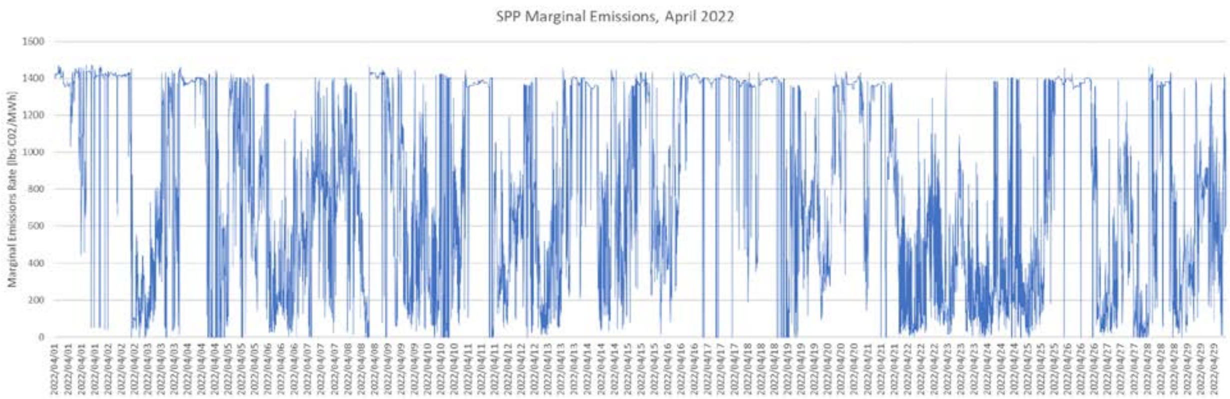

Figure 2: variability in SPP marginal emissions rate

Similarly, identifying the correct marginal generator is also a question of geography. Grid-balancing decisions happen on the balancing-authority level, or on a smaller spatial scale because of operational constraints—namely, transmission capacity. As a result, when an electrolyzer draws electricity from the grid to produce hydrogen, the production emissions will depend on where that electrolyzer is located. Figure 3 is a snapshot of the spatial variation in emissions rates of marginal resources at a moment in time.[62]

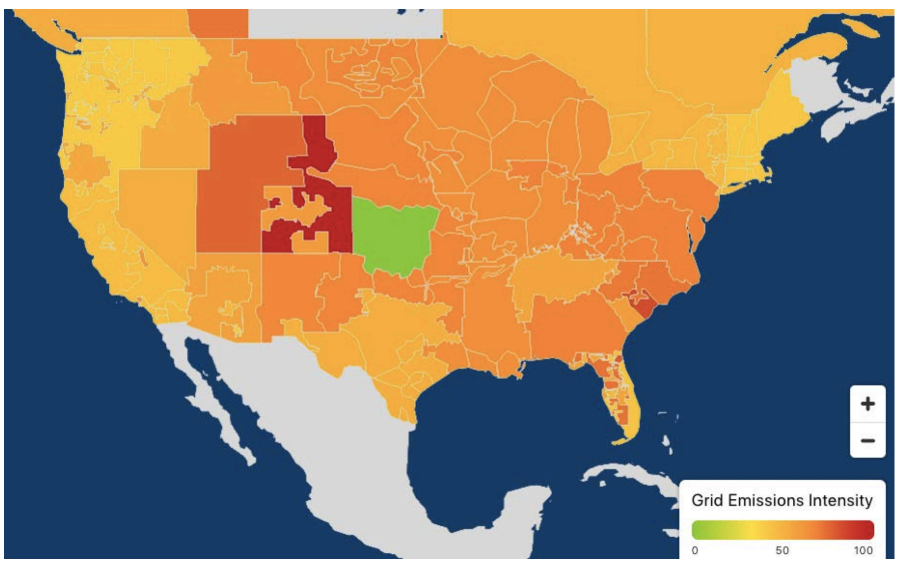

Figure 3: spatial variability in marginal emissions rates

Fortunately, a marginal-emissions approach would be feasible well before the Commission is required to meet its 2040 zero-emissions target. Marginal emissions rates are increasingly

[62] Figure 3 depicts the spatial variation in marginal emissions rates at a representative moment on the afternoon of July 25, 2023, as modeled by WattTime. *Grid Emissions Intensity by Electric Grid*, WATTTIME, https://www.watttime.org/explorer/#3.89/43.6/-111.64 (last visited Aug. 11, 2023).

available from grid operators[63] and private vendors,[64] and the Energy Information Administration is in the process of releasing real-time or near-real-time marginal emissions data for balancing authorities and pricing nodes.[65] NYISO is also exploring how best to provide this information.[66] If the Commission were to require these data, there would be more than enough lead time for market participants to stand up the necessary systems. Alternatively, perhaps as a stopgap until marginal emissions data are available everywhere, it may be desirable to use electricity prices that fall below a low threshold (e.g., $10/MWh) as a proxy for when the marginal generator is zero-emissions.[67]

Applying the marginal-emissions approach to New York, electrolytic hydrogen production would cause zero production emissions once the 2040 target has achieved because the marginal resource would always be zero-emissions. Hydrogen production would also induce zero production emissions in New York before 2040 if the electrolyzer operates when/where the marginal resource is zero-emitting on the local grid, which occurs whenever zero-emissions resources are being curtailed. This principle—that electrolytic hydrogen induces zero production emissions if it is produced at locations and times where the marginal resource is zero-emissions—also holds for hydrogen produced outside of New York and transported here.

#### b. The Commission should allow electrolyzers to characterize their production emissions as zero using PPAs and RECs—but only after mandating necessary safeguards

When a grid-connected electrolyzer produces hydrogen when/where the marginal generator is *not* zero-emissions (whether that is in New York before 2040 or outside of the state), the Commission should allow electrolyzers to enter into PPAs with specific zero-emissions generators to characterize their production emissions as zero.[68] The same goes for allowing electrolyzers to contract solely for the unbundled zero-emissions attribute of a generator's

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[63] *Five Minute Marginal Emission Rates*, PJM Interconnection, https://dataminer2.pjm.com/feed/fivemin_marginal_emissions/definition (last visited Nov. 30, 2022); *Dispatch Fuel Mix*, ISO New England, https://www.iso-ne.com/isoexpress/web/reports/operations/-/tree/gen-fuel-mix (last visited Aug. 11, 2023) (see "marginal flag string"); *see also California Self-Generation Incentive Program*, California Public Utility Commission & WattTime, https://sgipsignal.com/ (last visited Aug. 11, 2023); *see also Fuel on Margin*, SPP, https://marketplace.spp.org/pages/fuel-on-margin (last visited Aug. 11, 2023); *Real-Time Fuel on the Margin*, Midcontinent Independent System Operator, https://www.misoenergy.org/markets-and-operations/real-time--market-data/market-reports/#nt=%2FMarketReportType%3AReal-Time%2FMarketReportName%3AReal-Time%20Fuel%20on%20the%20Margin%20(xls)&t=10&p=0&s=MarketReportPublished&sd=desc (last visited Aug. 11, 2023).

[64] Karen Palmer et al., RESOURCES FOR THE FUTURE, OPTIONS FOR EIA TO PUBLISH $CO_2$ EMISSIONS RATES FOR ELECTRICITY 22–25 (2022), https://perma.cc/6VAA-JEQX.

[65] 42 U.S.C. § 18772(a)(2)(B) (instructing the Energy Information Administration to establish an online database that may include, where available, the estimated marginal greenhouse gas emissions per megawatt hour of electricity generated).

[66] LEILA NAYAR & VIJAY KAKI, NEW YORK ISO, EMISSIONS TRANSPARENCY: IMER INPUTS' WALKTHROUGH (2023), https://perma.cc/ND7P-6VDL; *See* John Norris, *NYISO Seeking to Increase Emissions Transparency*, RTO INSIDER (Apr. 18, 2023), https://www.rtoinsider.com/32021-nyiso-seeking-increase-emissions-transparency.

[67] *See* RMI POLICY BRIEF, *supra* note 52.

[68] *See Physical PPA*, EPA (Feb. 25, 2022), https://perma.cc/8YA3-F9GE; *Financial PPA*, EPA (Feb. 25, 2022), https://perma.cc/67XS-ZQBL.

electricity (e.g., a REC).[69] An electrolyzer could use either of these mechanisms to accurately describe the emissions intensity of its hydrogen production as zero, notwithstanding the emissions intensity of the marginal resource on the local grid.

But safeguards are essential. The zero-emissions generation associated with the PPA/RECs must be additional to the grid. Moreover, if the Commission understands the zero-emissions target, as applied to upstream production emissions, to be absolute (that is, not capable of being satisfied through netting) the PPA/RECs would need to be time-matched to the electrolyzer's consumption and deliverable to its location. However, to the extent the Commission determines that the emissions associated with hydrogen electrolysis should be evaluated based on their *net* effect, the Commission could instead implement a carbon-matching framework. Under such a framework, electrolyzers could use PPAs/RECs with new zero-emissions generation that displaces fossil-fuel-fired generation to exactly offset the GHG that they induce, regardless of whether those offsets occur exactly when and where the electrolyzers are inducing emissions.

This section on PPAs/RECs is irrelevant for any electrolyzer that is producing hydrogen when/where the marginal resource is zero-emissions, as we anticipate would be the case in New York after 2040. However, these mechanisms could enable electrolyzers to validly characterize the emissions intensity of their hydrogen production as zero when and where the marginal resource is not yet zero-emissions.

#### i. The zero-emissions generation would need to be additional

Before an electrolyzer can use a PPA/RECs to demonstrate that its production emissions are lower than what the marginal-emissions approach would indicate, the Commission must require that the zero-emissions electricity associated with the PPA/RECs be *additional*, as opposed to electricity that was always going to be generated and used by some other consumer. Without additionality, an electrolyzer would create new demand that might be met by a marginal fossil-fuel resource and claim credit for zero-emissions electricity that, until then, had been consumed by a different customer. In the end, the PPA/RECs would have reshuffled the allocation of electricity on paper while failing to genuinely prevent any emissions resulting from the electrolyzer's new load.[70]

Stated rigorously, demonstrating additionality means showing that that the associated clean generation would not have occurred but for the prospect that the clean generator could enter into a PPA with or sell the RECs to the electrolyzer.[71] This showing is epistemologically difficult, though, and we do not take a stance on which of the more administrable heuristics for assessing

[69] *See Renewable Energy Certificates*, EPA (Feb. 5, 2023), https://perma.cc/AHW5-8E3A.
[70] *See* Memorandum from Clean Air Task Force & Nat. Res. Def. Council to U.S. Dep't of the Treasury & Internal Revenue Serv. 7–8 (Apr. 10, 2023), https://perma.cc/87TB-GV3C; RMI POLICY BRIEF, *supra* note 52.
[71] *See* GOV'T ACCOUNTABILITY OFF., GAO-11-345, OPTIONS FOR ADDRESSING CHALLENGES TO CARBON OFFSET QUALITY 3 (2011), https://perma.cc/6FUU-ZEG6 ("An offset is additional if it would not have occurred without the incentives provided by the offset program."). Additionality is not necessarily satisfied by contracting with a clean generator that has yet to be built. In the context of RECs, if the associated generation would have happened irrespective of any REC sales, the RECs sold by that generator would not represent avoided emissions that could be claimed by an electrolyzer.

additionality would be most appropriate.[72] The Commission should note that the European Union's heuristic requires the generation facility to have come into operation not earlier than 36 months before the electrolyzer.[73] That rule, however, exists in tandem with other European policies that help that ensure new demand is met by clean generation.[74] Thus, a more stringent heuristic may be more appropriate here, where there is no such national policy.

#### ii. The zero-emissions generation would need to be time-matched and deliverable, unless the relevant target is net-zero

The earlier discussion of how marginal emissions rates vary with time and geography has serious implications for the use of PPAs/RECs to characterize an electrolyzer's production emissions.[75] In short, from an emissions-accounting perspective, it is often inappropriate to allow an electrolyzer to fully avoid its electricity emissions by matching its energy consumption to an equal quantity of energy generation from a zero-emissions generator, even when additionality has been satisfied.[76] The key issue is this: Without guardrails to match the actual quantity of emissions induced with the emissions avoided, the consumption of a given quantity of power by an electrolyzer will induce more emissions than what is avoided by the equivalent quantity of power generated by a zero-emissions generator at a different location/time if the electrolyzer draws power from the grid when/where the emissions rate of the marginal resource is higher than the emissions rate of the marginal resource when/where the zero-emissions generator injects power.

Consider this example of a purely temporal mismatch, which could be representative of hydrogen production outside New York, or production inside the state in the run-up to achieving the 2040 target. Imagine an electrolyzer operates during periods when the marginal generator on the local grid is natural gas and seeks to purchase RECs to characterize its emissions during these periods as zero. Whether the electrolyzer could validly avoid these natural gas emissions through RECs purchased from a zero-emissions generator on the same local grid would depend on the time when the RECs accrued to the contracted-with resource. If the contracted-with generator produced the zero-emissions power associated with the RECs at a time when the marginal generator (in the area of the grid where they are both located) was zero-emissions, then the REC would not be associated with any avoided emissions. That is because, if the contracted-with resource had not been operating, the missing electricity would have been supplied by a different zero-emissions resource. In contrast, if the relevant RECs (that is, the RECs on which the electrolyzer plans to rely to negate its production emissions) accrued to the zero-emissions generator at a time when natural gas was on the margin, then the RECs would represent true avoided emissions. In a world without the generator's zero-emissions electricity, the same quantity of power would have been supplied by more natural gas.

[72] *See id.* at 18–21 (comparing different approaches for testing additionality).
[73] Commission Delegated Regulation 2023/1184 of 10 February 2023 supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by establishing a Union methodology setting out detailed rules for the production of renewable liquid and gaseous transport fuels of non-biological origin, 2023 O.J. (L 157), https://perma.cc/5HFV-2F4Y.
[74] EPA Proposed Rule, *supra* note 56, at 33331.
[75] *See* Section III.B.2.a.
[76] *See generally* EPA & GREEN POWER P'SHIP, OFFSETS AND RECS: WHAT'S THE DIFFERENCE? (2018), https://www.epa.gov/sites/default/files/2018-03/documents/gpp_guide_recs_offsets.pdf.

This problem of temporal matching was recently considered by EPA in its proposal to allow natural gas plants to co-fire with low-GHG hydrogen.[77] EPA concluded that "[t]he EU and stakeholders examining costs and benefits of temporal [REC] alignment requirements generally find that hourly [REC] alignment is preferred before the 2032 proposed effective date of hydrogen co-firing requirements in this proposed rule, with most converging on or before 2030."[78] In other words, EPA found that, for hydrogen produced after approximately 2030, electrolyzers should need to avoid any production emissions using RECs that accrued within the same hour as the emissions.[79] Allowing matching over longer timescales (e.g., daily, monthly, or annual matching) would often result in a mismatch between the marginal resources during power consumption at the electrolyzer and power production at the zero-emissions generator.

Now consider the possibility of a geographic mismatch. When an electrolyzer pays for a generator to inject clean electricity into the grid, the injection needs to happen at a location where the electrolyzer could receive the power, given the organization of balancing authorities and transmission constraints. Otherwise, an electrolyzer might be consuming power in a region where the marginal resource is a fossil-fuel-fired plant while contracting with a zero-emissions resource located somewhere where renewables are on the margin. The result would be electrolysis powered by fossil fuels, because the clean generation could not reach the electrolyzer and merely displaced other zero-emissions generation.

For geographic matching, EPA expressed support for requiring alignment at the balancing-authority level.[80] This is a reasonable first approximation of deliverability; however, given the long lead time before the 2040 target, the Commission would have time to implement an even more accurate heuristic. Even within balancing authorities, transmission constraints prevent the free flow of electricity.[81] The Commission should therefore consider using regions that are smaller than balancing authorities and that better reflect transmission constraints, such as the geographic regions from DOE's National Transmission Needs Study.[82] Alternatively, in wholesale electricity markets, the lack of transmission capacity causes divergences among locational marginal prices, because purchasers must pay for more expensive sources of generation when cheaper electricity is not deliverable to their area.[83] The Commission should

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[77] EPA Proposed Rule, *supra* note 56, at 33328–31.
[78] *Id.* at 33331.
[79] *See also* RMI POLICY BRIEF, *supra* note 52 (recommending monthly matching until 2028 followed by hourly matching); Letter from Clean Air Task Force et al. to U.S. Dep't of the Treasury et al. 2–3 (Feb. 23, 2023), https://perma.cc/9DDG-G6PL (advocating for hourly matching).
[80] EPA Proposed Rule, *supra* note 56, at 33331.
[81] DEV MILLSTEIN ET AL., LAWRENCE BERKELEY NAT'L LAB'Y, THE LATEST MARKET DATA SHOW THAT THE POTENTIAL SAVINGS OF NEW ELECTRIC TRANSMISSION WAS HIGHER LAST YEAR THAN AT ANY POINT IN THE LAST DECADE 1–2 (2023), https://perma.cc/MMF2-FDV6; RESURETY, EMISSIONS IMPLICATIONS FOR CLEAN HYDROGEN ACCOUNTING METHODS 1–2 (2023), https://perma.cc/QL53-C5D6 ("[W]hile Local Hourly Energy Matching can help reduce net emissions in some locations, the impact of local transmission constraints often results in significant increases in net emissions even after energy is 'matched' by hour. . . . [T]ransmission constraints often cause wide variations in [locational marginal prices] and [locational marginal emissions] even within the same grid or sub-grid zone.").
[82] *See* RMI POLICY BRIEF, *supra* note 52.
[83] PJM INTERCONNECTION, TRANSMISSION CONGESTION CAN INCREASE COSTS 1–2 (2023), https://perma.cc/8TNZ-ENZ8.

consider whether a difference in locational marginal prices between the node where an electrolyzer consumes power and the node where a generator produces power could be used to evaluate deliverability in the context of a PPA or REC.[84]

In sum, hourly matching and deliverability are essential to ensuring that an electrolyzer with a PPA or RECs does not cause production emissions in real time. The Order does not take a stance on whether the 2040 zero-emissions electrical demand system target requires a complete elimination of emissions (for which real-time emissions would matter) or a net-zero target (which would potentially allow real-time emissions so long as they were offset in a timely fashion), or whether even finer distinctions might be appropriate (for example, whether a different standard might apply to emissions directly arising from electric generation versus upstream emissions). However, if the Commission determines that netting is a permissible approach to upstream emissions associated with hydrogen production, the Commission could establish a carbon-matching framework without hourly matching or deliverability (additionality would still be necessary). We describe this possibility next.

#### iii. To the extent the CLCPA will be satisfied by hydrogen whose production does not result in *net* emissions, the Commission could establish a carbon-matching framework in lieu of requiring hourly matching or deliverability

To ensure that electrolysis does not result in a net increase in overall emissions, it would suffice to ensure that PPA/RECs result in avoided emissions that fully offset the electrolyzer's production emissions. Under a "carbon-matching" framework, an electrolyzer could use the avoided emissions associated with the PPA or RECs to offset the electrolyzer's production emissions, regardless of when or where the zero-emissions generation happened.[85] For example, an electrolyzer in New Jersey could produce hydrogen while paying for new generation from a wind farm in Texas (either through a PPA or RECs), provided that the Texas wind farm produced power that was additional and that displaced fossil-fuel generation in Texas in a way that offset all of the electrolyzer's GHG emissions in New Jersey.

The production emissions of an electrolyzer is the product of the amount of power consumed and the emissions rate of the marginal generator when and where it was operating. And, assuming additionality has been satisfied, the avoided emissions attributable to a zero-emissions generator is the amount of power generated multiplied by the marginal emissions rate when and where the zero-emissions resource was generating electricity.[86]

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[84] Volts, *We're About to Give Billions of Dollars to Clean Hydrogen. How Should We Define It?*, at 29:03 (Mar. 29, 2023), https://perma.cc/87SE-ERN3 (statement of Rachel Fakhry) ("[T]he notion is that electrolyzers and the clean energy supply that is netting out their emissions need to be located within a region where the LMP differential is not bigger than X. . . . That is a very good proxy for . . . no congestion between the two . . . .").

[85] *See* Letter from Clean Incentive et al. to U.S. Dep't of the Treasury et al. (May 24, 2023), https://perma.cc/VUW2-8CE8; RESURETY, EMISSIONS IMPLICATIONS FOR CLEAN HYDROGEN ACCOUNTING METHODS (2023), https://perma.cc/QL53-C5D6.

[86] WATTTIME, ACCOUNTING FOR IMPACT: REFOCUSING GHG PROTOCOL SCOPE 2 METHODOLOGY ON 'IMPACT ACCOUNTING' 8 (2022), https://perma.cc/9B6W-BJFQ; Aleksandr Rudkevich & Pablo A. Ruiz, *Locational Carbon Footprint of the Power Industry: Implications for Operations, Planning and Policy Making, in* HANDBOOK OF $CO_2$ IN POWER SYSTEMS 131 (Qipeng P. Zheng et al., eds. 2012).

Compared to a system that requires hourly matching and deliverability, a carbon-matching framework could unlock efficiencies that would allow electrolyzers to more affordably characterize their grid emissions as zero, with at least equivalent accuracy. Electrolyzers could buy PPAs/RECs associated with GHG reductions from zero-emissions generators anywhere in the country, including regions with the best solar and wind resources. In contrast, under local hourly matching, a project would be limited to doing business with local generators. We emphasize, however, that nothing about a carbon-matching framework would obviate the need to demonstrate additionality.

### C. The Commission should consider the climate impacts of leaked hydrogen

Even if the proper verification protocols for grid emissions were in place, electrolytic hydrogen produced via zero-emissions electricity may still not qualify as a zero-emissions resource because of hydrogen leakage. Although hydrogen is not scientifically classified as a GHG, leaked hydrogen indirectly contributes to climate change by increasing the atmospheric lifetime of methane and ozone.[87] One recent study estimated the GWP20 of hydrogen at 37.3, indicating that hydrogen causes 37.3 times as much warming over a 20-year period as an equal mass of $CO_2$.[88] Accordingly, if electrolytic hydrogen produced via zero-emissions electricity were associated with a leakage rate of approximately 6.7%, it would cause more warming than the cleanest SMR/ATR hydrogen with 90% CCS does via $CO_2$ and methane emissions.[89] There are relatively few empirical studies of hydrogen leakage rates, especially for emerging hydrogen technologies and end uses, but one survey of the literature concludes that 4% of electrolytic hydrogen may escape during production, another 2% could escape during transportation and storage, and another 3% may leak during end-use at the turbine.[90] These leaks are driven in part by hydrogen's small molecular size.[91]

The indirect warming effects of leaked hydrogen are relevant to the 2040 target, not only for the reasons articulated in Section III.A concerning lifecycle emissions, but also because the CLCPA defines "greenhouse gas" in a way that includes hydrogen. The term encompasses "any . . . substance emitted into the air that may be reasonably anticipated to cause or contribute to anthropogenic climate change."[92]

The Commission may conclude, after a thorough analysis of the evidence on leakage, that even electrolytic hydrogen produced via zero-emissions resources would not qualify as a zero-emissions resource. Or the Commission may conclude that this cleanest type of hydrogen does

[87] EPA Proposed Rule, *supra* note 56, at 33304, 33306.
[88] Maria Sand et al., *A Multi-Model Assessment of the Global Warming Potential of Hydrogen*, 4 COMMC'NS EARTH & ENV'T 1, 5 (2023).
[89] As mentioned in Section III.B.1, the least-emitting SMR/ATR hydrogen with 90% CCS has production emissions of 2.5 kg $CO_2e$/kg $H_2$. Dividing 2.5 kg $CO_2e$/kg $H_2$ by the GWP20 of 37.3 kg $CO_2e$/kg $H_2$ yields 6.7%. This, this percentage of hydrogen leakage causes the same amount of warming as the least-emitting SMR/ATR hydrogen with 90% CCS.
[90] ZHIYUAN FAN ET AL., CTR. ON GLOB. ENERGY POL'Y, HYDROGEN LEAKAGE: A POTENTIAL RISK FOR THE HYDROGEN ECONOMY (2022), https://perma.cc/L77T-TYKG.
[91] DOE HYDROGEN LIFTOFF REPORT, *supra* note 35, at 17.
[92] N.Y. ECL § 75-0101(7).

qualify if the hydrogen leakage remains below some de minimis threshold. If that were the case, the Commission should restrict zero-emissions hydrogen to hydrogen that both has production emissions of 0 kg $CO_2e$/kg $H_2$ and has been sourced via low-hydrogen-leakage pathways.

There are multiple ways that the Commission could structure a leakage limit. For example, it (perhaps in combination with NYSERDA) might establish a maximum leakage percentage, develop estimates of hydrogen leakage for different types of equipment, and require generators to verify that the hydrogen they burn does not exceed that threshold based on the hydrogen's path to the generator and the Commission's equipment estimates. Then, it would be important to establish an audit regime to groundtruth the earlier estimates.

## IV. Benefits to Disadvantaged Communities Should Be Quantified in Coordination with Other Agencies and Disadvantaged Community Stakeholders, and Should Be Tracked Using Holistic Mapping Tools

This section of Policy Integrity's comments responds to Question 11 posed by the Commission in the Order: "How might the benefits of a program to meet the Zero-Emission by 2040 Target be measured for the purpose of ensuring that, consistent with PSL § 66-p(7), it delivers 'substantial benefits' to Disadvantaged Communities?"[93]

The CLCPA requires that the Commission implement the 66-p(2) program in "a manner to provide substantial benefits for disadvantaged communities."[94] Separately, in new language added to the Environmental Conservation Law, the CLCPA sets an overall goal for disadvantaged communities to "receive forty percent of overall benefits of spending" on the goals of the statute, and "no less than thirty-five percent of the overall benefits of spending."[95]

At this time, the communities that are to be the focus of these goals have been identified. In March 2023, the Climate Justice Working Group[96] finalized its disadvantaged community criteria.[97] The Commission accepted this set of criteria in its Order Directing Energy Efficiency and Building Electrification Proposals, and has stated that it will use these criteria to assess progress on the CLCPA's disadvantaged communities benefits requirements.[98] The Commission now seeks public input on how to track benefits to ensure that "substantial benefits" flow to disadvantaged communities.

### A. The Commission should define and value benefits in coordination with the DEC

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[93] Order at 17.
[94] N.Y. Pub. Serv. Law § 66-p(7).
[95] N.Y. ECL § 75-0117.
[96] The Climate Justice Working Group was created by N.Y. ECL § 75-0111.
[97] *Disadvantaged Communities Criteria*, New York State, https://climate.ny.gov/Resources/Disadvantaged-Communities-Criteria (last visited Aug. 11, 2023).
[98] Case 14-M-0094, *Proceeding on Motion of the Commission to Consider a Clean Energy Fund* & Case 18-M-0084, *In the Matter of a Comprehensive Energy Efficiency Initiative*, Order Directing Energy Efficiency and Building Electrification Proposals (July 20, 2023) at 25.

Accurate accounting of benefits is essential for accountability as the Commission works to deliver substantial benefits to disadvantaged communities. The Commission should adopt clear definitions and measurement approaches for "benefits," both in coordination with DEC as discussed in Section II of these comments. As noted above, the CLCPA addresses disadvantaged-community-benefits goals in multiple sections, with the new Public Service Law section 66-p(7) requiring the Commission to ensure "substantial benefits" to disadvantaged communities from its CLCPA-related programs,[99] while the new Environmental Conservation Law section 75-0117 requires *all* state agencies to "invest or direct available and relevant programmatic resources in a manner designed to achieve a goal for disadvantaged communities to receive forty percent of overall benefits of spending" and requires that disadvantaged communities receive at least 35% of overall benefits of "spending on clean energy and energy efficiency programs, projects or investments."[100] Given these overlapping directives, the Commission should ensure that relevant definitions, benefits metrics, and tracking tools as applied to its section 66-p(2) program are compatible with those used by DEC for other CLCPA purposes.

Although Section 66-p(7) provides little specificity as to how disadvantaged communities might benefit from the 66-p(2) program (the renewable generation and zero-emissions electrical demand system program), there are clues in the Act. Section 66-p(7) specifies particular community benefits that could arise from other subsections of section 66-p, including the storage program (storage location in communities, and reduced peaker plant operation based on well-located storage) and from the solar deployment program (energy cost savings and community ownership of facilities are specifically contemplated).[101] And the Environmental Conservation Law provision establishing the goal that 40% of benefits from CLCPA spending flow to disadvantaged communities contains a more holistic list of benefits of potential benefits, including "housing, workforce development, pollution reduction, low income energy assistance, energy, transportation and economic development."[102]

The details of what should be recognized as benefits are more fully articulated in the scoping plan. In developing the scoping plan, the Climate Action Council must "identify measures to maximize reductions of both greenhouse gas emissions and co-pollutants in disadvantaged communities."[103] As required by the CLCPA, the Climate Action Council published its final CLCPA scoping plan (the Scoping Plan) in December 2022.[104] The Scoping Plan articulates the following list of strategies to deliver "concrete benefits to individuals in disadvantaged communities":

- Addressing energy affordability concerns and reducing energy burden;
- Reducing environmental burden from GHG emissions and co-pollutants;

[99] N.Y. Pub. Serv. Law § 66-p(7).
[100] N.Y. ECL § 75-0117.
[101] N.Y. Pub. Serv. Law § 66-p(7).
[102] N.Y. ECL § 75-0117.
[103] N.Y. ECL § 75-0103(14)(d).
[104] CLIMATE ACTION COUNCIL, SCOPING PLAN: FULL REPORT (2022).

- Ensuring full participation in the new clean economy and corresponding job growth, including through access to good quality jobs and union-based employment opportunities; and
- Ensuring access to New York State's significant and growing policies and programs that invest in clean local resources, like solar and energy efficiency.[105]

The Commission could also draw inspiration from the White House's Interim Implementation Guidance for the Justice40 Initiative (the Interim Justice40 Guidance).[106] The Interim Justice40 Guidance provides a list of covered Justice40 programs (e.g., climate change, clean energy) and a sample list of benefits of each type of program. The Interim Justice40 Guidance then directed each agency to publish its own final set of benefits criteria and metrics for measuring these benefits.[107] The Department of Energy has also published Justice40 guidance outlining units of measurement for different categories of benefits (e.g., energy saved, new clean energy job hires, dollars spent).[108]

Another useful model is California's Benefit Criteria Tables (created by the California Air Resources Board) for tracking benefits from its Cap and Trade Program.[109] California uses the Benefit Criteria Tables to ensure that each tracked project provides "direct, meaningful, and assured benefits [to disadvantaged communities] and meets an important community need."[110] The California Climate Investments 2023 Annual Report details the results from this benefits tracking, noting the percentage of total investments into projects located in and benefitting disadvantaged communities, as well as investments located outside of, but benefitting, disadvantaged communities.[111]

In sum, in coordination with DEC, the Commission should develop a definition of "benefits" relevant to the zero-emissions program that incorporates the energy-specific benefits specified in Section 66-p of the Public Service Law, as well as the broader benefits specified in Section 75-0117 of the Environmental Conservation Law and in the Scoping Plan. The Commission should also pull from federal guidance.

Importantly, the Scoping Plan includes directly recognizing the benefits of reduced emissions burden from GHGs and other emissions. To the extent possible, the Commission should monetize these reductions. With respect to GHG emissions, the Commission should work with DEC to describe the value of avoided climate damage to disadvantaged communities, recognizing that this is a developing area of inquiry and that, in the near term, the benefit of

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[105] *Id*. at 7.
[106] Memorandum from Shalanda D. Young, Director, Off. of Mgmt. & Budget, et al. to the Heads of Executive Departments and Agencies 4–6, M-21-28 (July 20, 2021), https://perma.cc/8F43-9PF4 [hereinafter Interim Justice40 Guidance].
[107] *Id.*
[108] U.S. DEP'T OF ENERGY, GENERAL GUIDANCE FOR JUSTICE40 IMPLEMENTATION (2023), https://perma.cc/A84Y-CEGF.
[109] California Climate Investments, 2023 Annual Report: Cap-and-Trade Auction Proceeds 23–24 (2023), https://perma.cc/8DLB-ALLY.
[110] *Id*. at 24
[111] *Id.*

avoided climate harm to specified communities may need to be described qualitatively. Regarding other emissions, as the CLCPA expressly recognizes, these emissions can have a significant impact that can disproportionately harm disadvantaged communities. Reductions in local pollutants such as sulfur dioxide, nitrogen oxides, and fine particulate matter provide external health benefits such as reduced morbidity and reduced risk of premature mortality.[112] Policy Integrity's 2018 report, Valuing Pollution Reductions, provides guidance for quantifying local air pollution avoided through progress towards the CLCPA's zero-emissions goals;[113] it is appended to these comments.

### B. The Commission should develop a stakeholder engagement plan

In order for any benefits metric to prove useful, the affected stakeholders—i.e., disadvantaged communities—must be involved in the development and application of the metric. As such, the Commission must develop a plan for engaging those communities on how to define "benefits" and track them. The Climate Action Council's Scoping Plan affirms this need for community engagement, setting a goal of "ensuring an inclusive process and full participation by disadvantaged communities and their representatives in the ongoing work of developing and implementing climate action policies and programs."[114]

Again, the Interim Justice40 Guidance is a useful reference point. It instructs each agency to develop a stakeholder engagement plan and to especially require stakeholder input if benefits include investments outside of the community.[115]

Additionally, although the Climate Justice Working Group has developed disadvantaged communities criteria that the Commission has accepted, the Commission should expect communication on these criteria to be an ongoing, iterative process. The Climate Justice Working Group's disadvantaged communities criteria provide a robust and inclusive definition.[116] But "disadvantaged communities," especially in the context of environmental justice, is a dynamic and evolving term. Ideally, New York agencies would create mechanisms by which communities could self-identify as disadvantaged communities and apply for recognition. For example, Illinois's Solar for All mapping tool provides an option for communities to self-identify as environmental justice communities through an application.[117] Because environmental and other societal burdens can be difficult to measure seamlessly, the disadvantaged communities criteria should not close the door to dialogue with stakeholders on further disadvantaged community designations. The Commission should work with DEC and

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[112] Nicholas Z. Muller et. al., *Measuring the Damages of Air Pollution in the US*, 54 J. OF ENVT. ECON. AND MGMT. 1, 8–13 (2007); Dallas Burtraw et al., *Costs and Benefits of Reducing Air Pollutants Related to Acid Rain*, 16 CONTEMP. ECON. POL'Y 379, 397–99 (1998).

[113] JEFFREY SHRADER ET AL., INST. FOR POL'Y INTEGRITY, VALUING POLLUTION REDUCTIONS (2018), https://perma.cc/A8V2-WLFR.

[114] CLIMATE ACTION COUNCIL, SCOPING PLAN: FULL REPORT 7 (2022).

[115] Interim Justice40 Guidance, *supra* note 106, at 7–10.

[116] *See* NEW YORK STATE CLIMATE JUSTICE WORKING GROUP, DRAFT DISADVANTAGED COMMUNITIES CRITERIA AND LIST TECHNICAL DOCUMENTATION (2022); *Disadvantaged Communities Criteria*, New York State, https://climate.ny.gov/Resources/Disadvantaged-Communities-Criteria (last visited Aug. 11, 2023).

[117] ILLINOIS POWER AGENCY, ENVIRONMENTAL JUSTICE COMMUNITY SELF-DESIGNATION PROCESS (2019), https://perma.cc/4GHW-DSBJ.

other relevant agencies to enable a mechanism through which communities that feel they have been missed can apply for disadvantaged community recognition.

### C. Benefits should be tracked utilizing a mapping tool

The most effective way for the Commission to track and visualize the benefits from progress towards the zero-emissions goal, and to ensure that energy-system investments are planned with an awareness of the need for benefits to accrue to disadvantaged communities, is through a robust mapping tool. The Environmental Conservation Law requires that the Climate Action Council "maintain a website that includes public access to . . . greenhouse gas limit information."[118] The Commission and other New York agencies can effectively ensure public access to information about emissions reduction benefits by visualizing this information through a mapping tool.

As previously noted, the Climate Justice Working Group recently finalized its disadvantaged communities criteria. In finalizing these criteria, the Working Group also released an interactive mapping tool visualizing all of the disadvantaged communities in New York.[119] The tool allows viewers to identify which communities meet each of the dozens of individual criteria and which qualify as disadvantaged communities. Additionally, the Commission's recent Order Directing Energy Efficiency and Building Electrification Proposals discusses working with "Program Administrators to have systems in place that will geo-code all projects receiving place-based incentives through the EE/BE programs."[120] With the disadvantaged communities map already in existence, and plans to geo-code project investments already in place, the Commission and other agencies should combine these efforts and develop a mapping tool to track investments benefitting disadvantaged communities. The Commission should implement the plan of geo-tagging project investments as an additional map layer over the existing disadvantaged communities mapping tool. Going forward, the Commission should ensure mutual compatibility between these benefits mapping tools, disadvantaged communities mapping tools, and mapping tools addressing aspects of energy infrastructure that are relevant to New York's clean energy transition readiness, such as grid readiness for distributed energy resources (i.e., hosting capacity), vehicle electrification, and building heat electrification.

Several other states utilize similar mapping tools to inform and track funding goals in disadvantaged communities. California uses the CalEnviroScreen mapping tool to inform the fulfillment of its disadvantaged community and low-income community funding requirements in the state's cap and trade program.[121] Additionally, Minnesota uses its mapping tool, Understanding Environmental Justice in Minnesota, to inform grant allocation, and Illinois Solar for All tracks its requirement that 25% of funding be used towards environmental justice

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[118] N.Y. ECL § 75-0103(17).
[119] *Disadvantaged Communities Criteria*, New York State, https://climate.ny.gov/Resources/Disadvantaged-Communities-Criteria (last visited Aug. 11, 2023).
[120] Case 14-M-0094, *Proceeding on Motion of the Commission to Consider a Clean Energy Fund*, Order Directing Energy Efficiency and Building Electrification Proposals (July 20, 2023) at 25.
[121] California requires that at least 35 percent of all Cap-and-Trade auction proceeds in the form of California Climate Investments projects, per *Senate Bill 535* (Chapter 830, Statutes of 2012) and *Assembly Bill 1550* (Chapter 369, Statutes of 2016), benefit disadvantaged communities and low-income communities and households, collectively referred to as priority populations.

communities through a mapping tool.[122] New York should utilize its mapping tool similarly to ensure it is directing benefits to disadvantaged communities. Publicly available mapping tools that visualize investments made and benefits conferred in disadvantaged communities, and that juxtapose locational information about community needs with energy system resources and needs, will facilitate the identification of opportunities to achieve community benefits through energy transition measures, as well as shoring up transparency and public understanding of how the CLCPA is working to benefit communities.

[122] *Id.*

Institute *for* Policy Integrity
NEW YORK UNIVERSITY SCHOOL OF LAW

ELECTRICITY POLICY INSIGHTS

# Valuing Pollution Reductions

*How to Monetize Greenhouse Gas and Local Air Pollutant Reductions from Distributed Energy Resources*

March 2018
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# Executive Summary

Distributed energy resources (DERs)—grid-connected, small-scale electric generators such as rooftop solar installations, micro-turbines, combined heat and power systems, customer backup generators, and distributed energy storage systems—are a growing component of the U.S. electric system. As DERs have become more prominent, state electric utility regulators have begun efforts to more accurately compensate DERs by paying for each of the benefits that they provide.

One such benefit is the avoidance of environmental and public health damages from air pollution (including local air pollution and greenhouse gas emissions) that would have been caused by generation resources that have been displaced by the DERs. This report lays out a practical methodology for calculating this environmental and public health value. It identifies existing tools that states can use, with varying degrees of specificity, accuracy, and complexity, to monetize these pollution reductions. State utility regulators can use the steps outlined here, weighing tradeoffs between accuracy and administrability, to implement their own program to compensate DER for environmental and public health benefits. Regulators can monetize air pollution reductions that DERs provide by using a five-step method:

**Step 1** determines what generation will be displaced by DERs. The most accurate methods for determining displaced generation require working with grid operators and, potentially, local distribution utilities, to obtain needed data on which bulk system generators would have operated in the absence of DERs. If sufficient data is not available, utility regulators can use electricity system simulation models to estimate which resources would have operated in the absence of DERs.

**Step 2** quantifies the emissions rates for displaced generators. Emissions rates of existing resources vary widely, and therefore, the magnitude of the environmental and public health benefits of DERs will as well. Emissions rates depend on a generator's attributes, including fuel type (for example, coal, oil, natural gas, or renewable), electricity generation technology (for example, inefficient steam boilers or efficient combined-cycle technology), pollution control equipment, and operational practices like capacity factor.

Emission rates of existing generators can be determined based on those generators' historical, measured emissions rates, or can be estimated using engineering analyses, given known information about fuel type, generation technology, pollution control equipment, and operational practices. Databases of historical emissions rates for specific plants and of emission factors broken out by generator attribute (such as fuel type, generation technology, and pollution control equipment) are also available.

**Step 3** calculates the monetary value of the damages from emissions identified in Step 2. Air pollutants cause damage to human health, impair ecosystems, harm crops, and make it harder for workers to be productive. Given knowledge of the emissions rate for a power generator, utility regulators can calculate those damages as a function of:

- The type of the pollutant. Particulate matter, especially fine and ultra-fine particulates, cause severe health damages, including death. Oxides like $SO_2$ and NOx break down into particulate matter and combine with other pollutants to form asthma-causing ozone pollution. Toxic heavy metals like mercury and lead cause rapid health deterioration even at low concentrations. Greenhouse gases lead to climate change. Researchers have developed monetized damages estimates per unit of emissions for each of these pollutants.

- The location of emissions. Each unit of a pollutant emitted in population-dense areas or in areas with highly vulnerable populations will cause more damage. Emissions also interact with environmental conditions such as prevailing winds to carry pollutants away from the point of emissions. Damage estimates can be modified to account for these concerns.

- The timing of emissions. Some pollutants, such as ozone, only form when precursors are exposed to direct sunlight. Therefore, emissions that occur at night or in winter may cause less damage than those during the day or in the summer. Granular damage estimates account for these timing issues.

A method that accounts for all of these factors would lead to the most accurate calculations of damage per unit of emissions. However, data constraints and ease of use might make alternative, less granular methods more desirable. There are multiple tools produced by various researchers as well as EPA that provide estimates of pollution damages at the county level, and many of these tools allow for partial customization to meet specific needs of regulators.

**Step 4** uses the emissions rates from Step 2 and damage estimate per unit of emissions from Step 3 to monetize the value of avoided emissions from displaced generation. Adjustments are needed if existing policies already put a price on emissions of some or all of the pollutants covered in Steps 1-3.

**Step 5** takes into account any emissions produced by the DER itself. DERs such as diesel generators or combined heat and power generators emit pollutants. To arrive at an accurate environmental and public health value, those emissions and the damage they cause must also be taken into account. If damage per unit of generation from the DER is high enough, then the net environmental and public health value of the DER could be negative.

Distributed energy resources can provide substantial value to a state by reducing air pollution from conventional electric generators and the resulting environmental and public health damages. DERs can be particularly valuable to the extent that they avoid local air pollution imposed on vulnerable populations. As state utility regulators implement new compensation policies for these resources, those policies should include payment for DERs' environmental and public health value.

This report presents a straightforward five-step methodology that can be used to calculate this value in a technology-neutral manner while relying on existing, readily accessible tools. The methodology outlined in this report is flexible enough to accommodate a variety of data and resource constraints. State regulators can weigh the tradeoffs between accuracy and administrability of different methods to calculating environmental value, pick the tools that are most accurate given the tradeoffs, and then update their methodology when feasible.

While more comprehensive reforms such as an economy-wide tax on greenhouse gases and local air pollutants are needed to fully value the environmental and public health benefits of all DERs, this methodology would allow utility regulators to implement a DER compensation scheme that incentivizes DERs when and where they are most beneficial to the society.

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# Introduction

The electric grid is quickly evolving from its traditional structure, where electricity is generated by large power plants located far from end-users, into a multi-dimensional platform. The modern grid allows a variety of new distributed resources that are located near end-users, such as solar panels, energy storage, and demand response, to provide a multiplicity of electricity services. With rapid innovation and declines in costs, these "distributed energy resources" (DERs) are becoming an integral part of the modern grid, and thus, creating new challenges for regulators.[1]

As technology is transforming the grid, policymakers around the nation are working to reform utility regulation in order to harness the full benefits that these technological changes offer. A number of states have initiated proceedings to implement compensation schemes for electricity generated from DERs, or a subset of DERs, that reflect all of the benefits that those resources provide.[2]

DERs help reduce the need for generation from large-scale generators interconnected to the transmission system ("bulk system generators") such as fossil-fuel-fired power plants, which are often costly to build and highly polluting. Depending on the type of DER, they do so in two ways: by reducing customer demand at a given time, or by actually generating electricity. DERs such as demand response and energy efficiency reduce customer demand for electricity at a particular time. Other DERs, such as distributed solar, generate electricity, which can then be used by consumers to offset grid purchases and/or can be exported to the grid. Energy storage can provide benefits by shifting consumer demand, by charging and discharging at different times.

By avoiding the need for generation from the bulk system, DERs can provide many benefits to grid such as avoided energy costs, avoided or deferred capacity costs, and reduced line losses.[3] This report, however, focuses on one regularly overlooked category in utility regulation: environmental and public health benefits.

Bulk system generators often burn fossil fuels—coal, natural gas, and petroleum—or biogenic fuels—agricultural and wood waste, municipal solid waste, animal waste, and landfill gas—and in doing so, they emit air pollutants. When DERs avoid the need for such bulk system generation, they can help reduce air pollution, benefiting society at large. Currently, however, these benefits are not explicitly valued.

## Air pollutants emitted by power plants

Combustion of fossil fuels and biogenic fuels results in the emission of air pollutants, which fall into several categories. Air pollutants that affect human health and are dispersed in the ambient air are referred to under the federal Clean Air Act as "**criteria pollutants**." These include particulate matter ($PM_{10}$), fine particulate matter ($PM_{2.5}$), sulfur dioxide ($SO_2$), nitrogen oxides (NOx), and carbon monoxide (CO). These pollutants also combine in the atmosphere with each other and with volatile organic compounds (VOCs) to make other "secondary" criteria pollutants, including $PM_{2.5}$ and ozone.

In addition, combustion releases **greenhouse gases**—including carbon dioxide ($CO_2$) and nitrous oxide ($N_2O$)—that alter the climate and so cause a wide range of disruptive health, social welfare, and environmental effects.

Finally, combustion of some fuels results in emission of **hazardous air pollutants** (HAPs), also referred to as "air toxics," which cause significant damage even in small amounts. This category includes mercury and ammonia.

Air pollution is a textbook example of what economists call an "externality." Externalities are costs or benefits of market transactions that are incurred by parties other than the market participants, and thus are not taken into account by market participants. When externalities are present, market prices do not reflect the external costs and benefits of production or consumption, and therefore fail to provide an economically efficient signal for the true social value of the particular good or service, leading to an inefficient outcome. For example, because fossil-fuel-fired power plants are not paying for the environmental and public health damages their electricity generation causes, we get more air pollution than is socially desirable.

When negative externalities are present, social welfare can be increased by imposing a tax on the source of the externality—in this case, the emission of air pollutants—based on the amount of external damage caused. In the absence of efficient pollution taxes, alternative policies can help improve the efficiency of market outcomes.

One such policy approach is to pay generating resources that reduce air pollution. DERs provide environmental and public health benefits by displacing generation from other resources that would have emitted more air pollution.[4] Therefore, utility regulators can improve social welfare by ensuring that low and zero-emitting DERs are paid for the environmental and public health benefits they produce by displacing higher-emitting generation.

Appropriately valuing these benefits involves identifying the extent to which air pollution is avoided due to DERs, and then monetizing the economic, health, and climate damages those emissions would have caused. This report lays out a practical, technology-neutral methodology for identifying those values. Utility regulators can incorporate this methodology into proceedings aimed at establishing compensation structures for DERs.

It is important to note that, ideally, the same framework would be used to compensate all types of DERs for all the value they provide. However, because the price signals for load reductions manifest as avoided electricity purchases (at the retail electricity rate that customers pay), such comprehensive compensation would require complementary retail rate reforms in order to internalize the externalities.[5] Addressing this is beyond the scope of this report.

The methodology outlined in this report, therefore, is appropriate for compensating energy supplied to the grid by DERs. This limitation likely leads to an underestimation of the environmental and public health benefits of DERs that reduce on-site electricity consumption. However, despite the limitation of the methodology outlined here, compensating even just injections to the grid for the environmental and health benefits DERs provide would significantly improve social welfare.

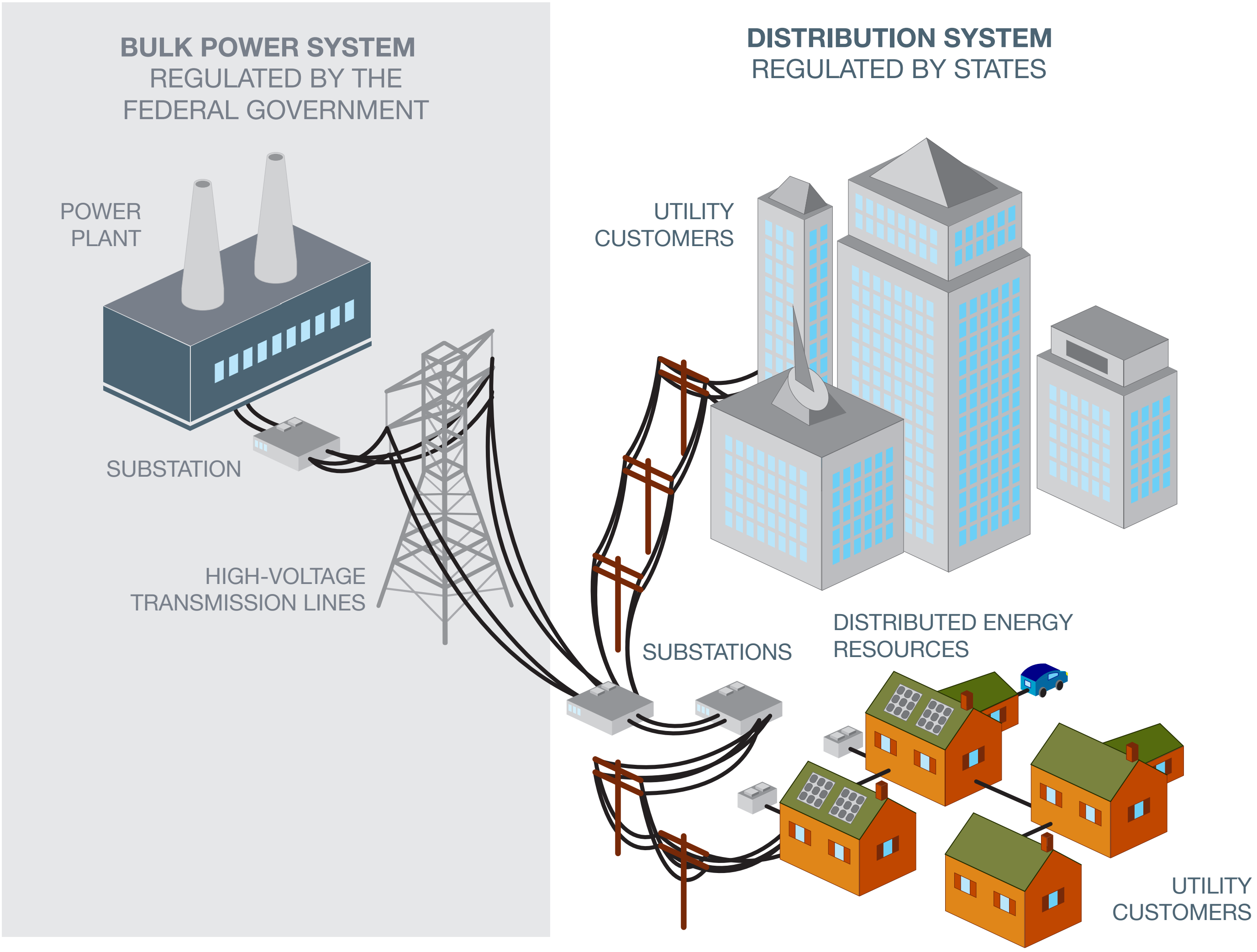
## A brief overview of distributed resources, utility regulators, and grid operators

The regulation of electricity is divided between the federal government and the states.[6] Federal regulators have primary responsibility over interstate transmission and wholesale electricity, or the bulk power system, and state regulators have primary responsibility over the distribution system.

State regulators, commonly called "public utility commissions" or "public service commissions," are responsible for regulating local distribution utilities and setting retail rates, as well as deciding on other state-level policies such as DER compensation, renewable portfolio standards, and energy efficiency programs.

In much of the country, the bulk power system, consisting of most generators and large transmission lines, is regulated by the Federal Energy Regulatory Commission and operated by grid operators called "independent system operators" ("ISOs") or "regional transmission organizations ("RTOs"). ISOs/RTOs ensure that supply and demand of the bulk power system are constantly balanced using complex algorithms that take into account the location of both generators and demand, the costs of generation, and congestion on the transmission system. Grid operators dispatch resources from least expensive to most expensive (taking into account the congestion on the transmission system), until demand has been met.

**Figure 1: Regulatory Domains of the Electric Grid**



# Valuing Environmental Benefits of Distributed Energy Resources – An Overview

Public Utility Commissions can calculate the environmental and public health value of DERs based on emissions avoided by the DER and the monetary value of the damage that those emissions would have caused. These two values will depend on the location of the DER and the avoided emissions, the time of day and year when emissions are avoided, and the type of pollutants avoided.[7]

DERs in different locations or generating at different times will displace different sources of generation, with various levels of emissions. Because different generators use a variety of fuel types, electricity generation technologies, control equipment, and operation practices that result in a wide range of air pollutant emissions rates, the type of generators displaced is an important driver of the value. DERs are worth more to society when they offset generation from higher-emitting sources.[8]

DERs are also more valuable when they reduce air pollution in areas with high population density and more vulnerable populations. The time of year also matters because NOx and VOC emitted in the summer carry greater health consequences, due to their role in the formation of ozone in the presence of sunlight. Therefore, DERs that can reduces pollutants in such areas and times are more valuable.

Finally, different pollutants cause different levels of public health and climate damage. If a DER offsets a generator that emits more damaging pollutants, it should receive a higher payment to reflect its environmental and public health value.

Any approach should take into account not only the generation displaced by a DER but also the emissions created by the distributed resource. For example, behind-the-meter DER generators include oil, gas/coal combined heating and power, and storage systems charged by fossil-fuel-fired generation resources. For emitting DERs, payment should be reduced based on their emissions and could potentially be negative if the negative impact of emissions from the DER is higher than the value of emissions avoided by that DER.

## Key Terms

**Emissions rate**

The emissions rate is the amount of pollution emitted by a generator per unit of generation. If a generator emits 1 metric ton of $SO_2$ and generates 1 megawatt-hour (MWh) of electricity, then its emission rate of $SO_2$ is 1 metric ton/MWh, or 1 kilogram (kg)/kWh. The emissions rate can be affected by, among other things, installation of pollution control equipment, changes in the efficiency of the generator, or use of different fuels by generators that have fuel flexibility.

**Damage per unit of avoided emissions**

The damage per unit of avoided emissions is the monetized value of the harm that the pollution would have done had it been emitted. For instance, each kilogram of $SO_2$ released by a generator causes roughly $50 of damage. Therefore, if a DER avoids the emission of one kilogram of $SO_2$ by displacing generation of a fossil fuel power plant, then it would avoid $50 of damage.

**Environmental value of displaced generation**

The value of displaced generation is the dollar value of damages avoided, per unit of displaced generation. It is the product of the emissions rate and the damage per unit of avoided emissions.

Harnessing all the benefits DERs can provide requires compensating them for their environmental and public health value in a technology-neutral way that can take into account these different factors, while balancing accuracy and administrability. To achieve this goal, regulators must first identify the generation that is displaced by DERs, determine the emissions avoided by this displacement based on the emissions rates of the displaced resources, calculate the monetary damages per unit of avoided emissions, and then calculate the monetary value of the net damages avoided by DERs.

Below, we outline the necessary steps and then explain each step in detail.

**Methodology Outline for Valuing the Environmental Benefits of DERs:**

1. Identify the generation that is displaced by a DER
2. Calculate emissions rates (kg/kWh) of the displaced resource
3. Calculate the damage per unit ($/kg) of avoided emissions
4. Monetize the value of avoided damage from displaced generation ($/kWh)
5. Subtract any damages from the DER itself from the displaced generators' damages, to calculate *net* avoided damages

# Step 1: Identify Displaced Generation

Distributed energy resources produce environmental and public health benefits by displacing generation from emitting power generators. The first step in calculating the value of those benefits, then, is to identify what generation will be displaced by a DER.

If sufficient grid operation and market information is available, it is possible to identify, with a reasonable degree of precision, the specific generator or generators that would have operated in the absence of DERs. If such data is not available, there are techniques that can be used to approximate which generators were displaced by DERs.

This section outlines three techniques for identifying displaced generation: (1) using counterfactual dispatch scenarios, (2) identifying the marginal generator, and (3) using electric market simulation models. These options are explained in order of decreasing levels of precision and decreasing information requirements.

All of these methodologies will identify those generators that have been displaced by DER resources *in the short run*. That is, these methodologies identify which of the *existing* resources would have generated in the absence of the DERs. They do not account for the potential effect that DERs have on the longer-term entry and exit incentives for emitting resources. Installation of DER capacity may contribute to the retirement of an existing fossil fuel-fired generator or may avoid the need for a new fossil fuel-fired generator. Therefore, methodologies presented in this section likely understate the extent to which DERs reduce emissions. Complex methodologies have been developed to account for these emissions effects; however, incorporating these effects into a DER valuation methodology is beyond the scope of this report.[9]

## Running Counterfactual Dispatch Scenarios

**Overview.** It is possible for market operators to identify all of the generating resources that would have operated in the absence of DERs with precision and confidence. A market operator can run a counterfactual dispatch scenario in which the operator runs its regular dispatch algorithm while assuming no DERs. The generators that would have operated in this counterfactual dispatch scenario but were not actually dispatched are the generators that were displaced by DERs. These identified resources can be used in Steps 2-3 to calculate the avoided damages attributable to DERs.[10]

**Advantages.** The primary advantages of this approach are that it is accurate, granular, and flexible. Because it relies on actual grid operations and market data used to make dispatch decisions, this method can accurately capture which resources would have operated in the absence of DERs. Because this approach can identify the specific generators that have been displaced, it will also provide specific information on the location of displaced emissions, which is useful for calculating accurate public health damages in Step 3.

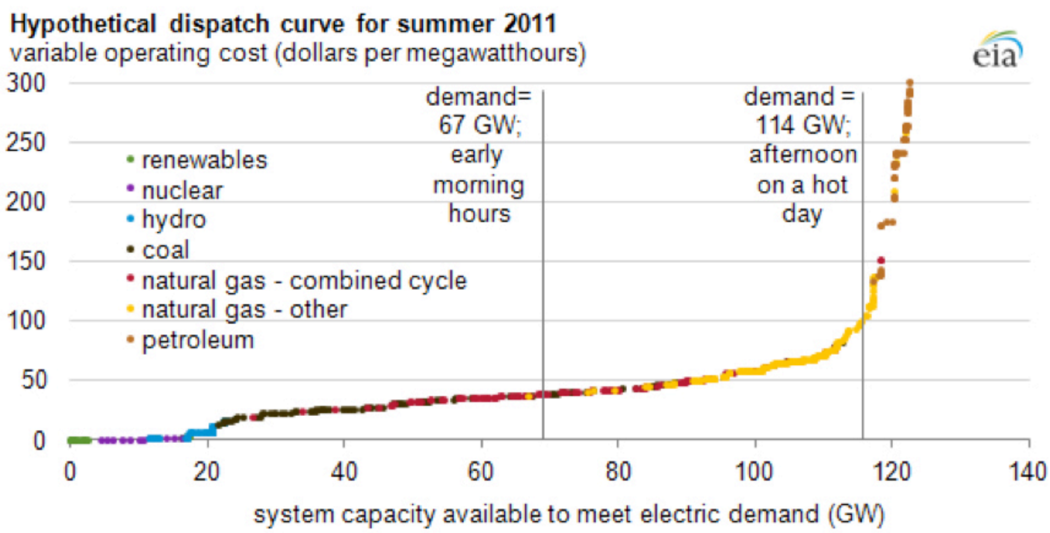
Counterfactual dispatch scenarios could be run as often as the grid operator reruns its dispatch algorithm. However, this approach is also flexible and can be updated less frequently if the administrative costs of frequently identifying counterfactual dispatch outweigh the benefits. For example, if there is limited variability in which resources are displaced over short intervals, grid operators could run counterfactual dispatch scenarios once per hour; during key parts of the day (such as during periods that typically have high electric demand and periods with low electric demand, or periods with high DER injections and periods with low DER injections); or during key times over each season of the year.

**Limitations.** The primary limitation of this approach is its significant data requirement. Regulators will have to work with distribution utilities to obtain the information—location, timing, and magnitude of DER penetration—needed for counterfactual dispatch scenarios, and then work with grid operators to produce counterfactual dispatch scenarios.

## Identifying the Marginal Generator

**Overview.** An alternative approach to identifying displaced generation is to use information from the grid operators on marginal generators. Grid operators usually dispatch generators based on their cost of operation, as well as technical constraints of the system, until the total generation is high enough to meet the demand. The "marginal generator" for a given interval is the last generator that is needed to satisfy demand at that interval. Additional DERs at this time will reduce the need for generation from the marginal generator, and therefore avoid emissions from the marginal generator. States can work with grid operators to identify the generator on the margin at the time of DER operation, which can provide an accurate up-to-date estimate of which generators DERs are displacing.

Figure 2: Illustrative Market Supply Curve[11]




*Source: Energy Information Administration (2012)*

*Figure 2 is an illustrative market supply curve, which shows available generators in ascending order of marginal cost from left to right. Different levels of demand are illustrated by the vertical lines. The marginal generator for a given level of demand is the generator at the intersection of the vertical line and the supply curve. Based on this curve, when load is at its minimum, a gas generator with a relatively low bid will be on the margin. Any DER at this time will reduce the need for generation from that gas generator. When load is at its maximum, the marginal generator may be an oil-fired generator. DER will replace generation from the oil-fired generator.*

Because the transmission system can be congested, the marginal generator will often be location dependent. If transmission lines are congested, electricity cannot be transmitted from distant locations even if there are available cheap generators, and therefore grid operators must rely on more expensive local resources. Take, for example, the New York Independent System Operator. When there is no congestion, a DER in New York City can indeed displace a system-wide marginal generator, which can be located anywhere in the state. However, the transmission lines going in and out of New York City are often congested. During periods of such congestion near New York City, the marginal generator displaced by a DER in New York City will likely be local and different from the marginal generator displaced by a DER located in other parts of the state. States should therefore identify marginal generators at a level of geographic granularity appropriate given the level and location of congestion on the system.

If real-time information is not available from grid operators, regulators could identify marginal generators by matching load levels with generators on representative dispatch curves, such as the one outlined in Figure 2 above.[12] Such use of historical dispatch curves rather than actual dispatch curves for a given interval reduces the accuracy of this measure but it can be done with less involvement of the grid operator. These curves can be constructed using grid operator data, based on historical information on generator operation and energy bids. To most accurately reflect the generation mix available at a particular time, regulators should use historical dispatch curves applicable for times of day and seasons to reflect variations in renewable energy and seasonal outages.

**Advantages.** While identifying the marginal generator will require working with the grid operator, this approach requires significantly less involvement and data from the grid operator. This approach also will not require specific information from distribution utilities on the location, timing, and magnitude of DER load and generation profiles.

**Limitations.** This approach assumes that the magnitude of DERs is not large enough to change the marginal resource. Currently the level of DER penetration is small enough to meet this requirement in most contexts. In addition, especially during high-demand times when a small generator is on the margin, the next resource that would be marginal if that small generator is displaced may have quite similar emission characteristics. However, as DER penetration increases, it is possible that DERs will begin to change which generators are on the margin. This will reduce the accuracy of this approach as compared to the counterfactual dispatch scenario approach.

## Electric Grid Dispatch Modeling

**Overview.** A number of sophisticated models of the electric grid have been developed that can be used to simulate the dispatch of generators under a variety of conditions.[13] These models generally incorporate databases of generators (including the location, size, fuel type, and other operational characteristics) and transmission, assumptions about fuel and other operational costs of generation, and assumptions about electric demand to simulate operation of a given electric grid. Regulators can use these dispatch models to identify the resources that have been displaced by DERs, similar to how a grid operator would identify displaced generation through counterfactual dispatch scenarios. The electric model would be run both with and without DERs to identify the resources that have been displaced.

Regulators should perform model runs under a variety of assumed operating conditions (e.g., varying levels of electric demand, transmission congestion, and DER availability). They can then use the simulation that best matches the appropriate real-world circumstance.

**Advantages.** The primary advantage of this approach is that it can be used without involvement of the ISO/RTO or distribution utility. While the relevant models are complex and require expertise to use, Public Utility Commissions can develop this expertise rather than having to rely on outside entities for ongoing data requirements.

**Limitations.** Because these models rely on assumptions, rather than realized outcomes, they are not likely to be as accurate as the first two approaches outlined. In addition, this approach will be even less likely to incorporate any sectoral changes over time including generator entry and exit and generator outages, unless the model used is updated to reflect these changes.

## An Approach to Avoid: Grid-Average Generators and Grid-Average Emissions rates

While there are many acceptable options to identify generators that will be displaced by DERs, regulators should *not* assume that DERs displace all generators in equal amount (either numerically or generation-weighted). Similarly, regulators should not use grid average emission factors when determining the avoided emissions attributable to DERs. Assuming DERs displace all resources equally or using *average* emissions rates will incorrectly include substantial zero-emission generators that are unlikely to be affected by DERs. Use of averages will also miss significant temporal and locational variation in the amount of air pollution displaced by DERs. Research has shown that using average emissions rates significantly misstates emission impacts of new resources.[14] While this approach is computationally easy, and therefore appealing, using grid averages will not lead to accurate estimates.

# Step 2: Identify Emissions Rates of the Displaced Generation

Once the resources that are displaced by DERs have been identified, the next step is to determine the emissions rates of those displaced resources. These emissions rates are necessary to determine the economic benefits of avoiding emissions from each kWh of the displaced emitting generation. Table 1 presents average emissions rates of select criteria and greenhouse gas pollutants by fuel burned.

**Table 1: Average Emissions Rates of Select Pollutants for Generators in 2016**[15]

| Fuel Type | NOx (kg/MWh) | $SO_2$ (kg/MWh) | $CO_2$ (kg/MWh) |
|---|---|---|---|
| Oil | 2.92 | 2.86 | 862.80 |
| Coal | 0.75 | 1.08 | 1003.38 |
| Biomass | 1.58 | 0.67 | 211.06 |
| Gas | 0.16 | 0.00 | 405.94 |

## Generator Features Affecting Emissions rates

Emissions rates are a function of (1) the type of fuel combusted, (2) the combustion and electric generation technology, (3) any pollution control equipment, and (4) environmental and operational considerations.

### *Fuel Type*

The type and amount of pollutants emitted by electricity generators is primarily a function of the type of fuel used. Some plants are designed to burn only one type of fuel. Others, called "dual fuel" plants, are able to switch between fuels depending on fuel availability and price. Dual fuel plants generally can burn either natural gas or oil-based fuel (e.g., diesel fuel).

Uncontrolled combustion of coal, oil and wood biomass emits relatively large quantities of most criteria pollutants, HAPs, and greenhouse gases.[16] Combustion of gas, including natural gas and landfill gas, primarily emits NOx, CO, VOCs, and $CO_2$, with little to no direct emissions of PM, $SO_2$ and HAPs.[17] On the other end of the spectrum, nuclear, hydroelectric, solar, and wind generation do not emit any air pollution.

### *Generation Technology*

For a given fuel type, the primary determinant of the emissions rate is the efficiency by which a combustion technology converts fuel into electricity, called the generator's "heat rate".

## Key Term

**Heat rate** is a measure of power plant efficiency. It is a measure of the amount of energy, embedded in the combusted fuel, measured in British Thermal Units, that it takes to generate a kWh of electricity.[18] The higher the heat rate, the *less* efficient the plant.

Steam boilers generate electricity by combusting fuel to produce heat, which warms water to produce steam that turns an electric turbine. Steam boilers generally have high heat rates.[19] In other words, they are not efficient. Steam boilers primarily use coal (and almost all coal plants use steam boilers), but they can also combust natural gas, fuel oil, or biomass.[20]

Stationary internal combustion engines (ICE), which generally burn fuel oil, have similar heat rates to steam boilers and are most often used as "peaker plants" when demand is particularly high, for backup power, or as distributed generation.[21]

Combustion turbines use heat produced from fuel combustion to turn a turbine that generates electricity. They use liquid or gaseous fuel, including natural gas, fuel oil and biogenic fuels (e.g., landfill gas).[22] Combustion turbines can range in efficiency and often function as peaker plants.

Finally, highly efficient combined-cycle plants combine the technologies to produce more electricity for the same amount of fuel.[23] In a combined-cycle plant, a combustion turbine produces electricity and heat, while the excess heat produces steam that generates more electricity. These plants primarily use natural gas (and much less often fuel oil).

### *Pollution Control Equipment*

Emissions rates can also vary significantly depending on whether a plant has installed air pollution control technology. Almost all plants can implement some pollution control equipment, but there is significant variation in the type and effectiveness of installed equipment. For instance, flue gas desulfurization technology can reduce $SO_2$ concentrations of coal plant emissions by 98%, while catalytic reactions reduce NOx pollution by 80%.[24] Pollution control equipment can also negatively affect the efficiency of power plants.[25]

### *Operational and Environmental Considerations*

A variety of environmental and operational considerations affect emissions rates. These include:

- **The age of the plant.** Plant efficiency generally declines with age.
- **The utilization of the plant.** Power plants that are operating below full capacity are generally less efficient and so have higher emissions rates.
- **Ambient weather conditions.** Ambient weather conditions including temperature, humidity, and pressure can affect the efficiency of a power plant.[26]

These operational and environmental considerations vary over time, while other features like fuel type, generation technology, and pollution control equipment are relatively static. Therefore, it is not possible to know a particular generator's emissions rate without measuring, in real time, its emissions and generation. Even though such data is rarely available, there are a number of existing or easy-to-develop tools that states can use to determine reasonably accurate emissions rates for generators.

## Methods for Determining Emissions rates

States can use one of two primary options for determining reasonably accurate emissions rates: (1) historical, measured emissions rates of the generator, and (2) engineering estimates of a generator's emissions rates based on design characteristics and operational assumptions.

### *Historical Emissions Rates*

Historical emissions rates calculate a given generator's emissions rate for each pollutant based on measured historical emissions and measured historical generation.

**Historical Emissions.** Generators above a specific size threshold are required to directly measure and report the volume of emissions for some pollutants to state environmental agencies and/or the U.S. EPA Clean Air Markets Division (CAMD). Continuous emission monitors are used to measure and report NOx, $SO_2$, and $CO_2$ emissions from generators subject to certain federal environmental program requirements.[27] For pollutants where continuous emission measurement is not feasible or is particularly expensive (such as for PM), generators calculate and report emissions through monitoring of parameters that have a known relationship with emissions, such as operational characteristics of plant systems (temperature, pressure, liquid flow rate, pH), through periodic emissions testing, or based on quantities of fuel consumed and the technology used to generate electricity.[28]

**Historical Electric Generation.** Generators are required to measure and regularly report various characteristics and operational performance of their plants to the U.S. Department of Energy's Energy Information Agency (EIA).

Dividing historic emissions by historic generation yields historic emissions rates. This calculation should be done with as high degree of granularity as possible in order to yield representative emissions rates for a generator's operational performance. For example, for a dual fuel generator, dividing annual total emissions of $SO_2$ by annual generation will not yield an accurate $SO_2$ emissions rate because $SO_2$ is only emitted in the hours that the generator burns fuel oil. Significant emissions rate changes for a generator can be captured by more daily or hourly emissions rate calculations.

### *Engineering Estimates*

Engineering estimates of emissions rates are based on assumptions about known characteristics of generators. Accurate engineering estimates use the considerations identified above (fuel type, heat rate of generating technology, emission control technology, and environmental and operational considerations) to develop emissions rates that can be applied to generators with similar characteristics. Because of this, engineering estimates are sometimes referred to as "emission factors."

### *Selecting Between Historical Emissions and Engineering Estimates*

Short of real-time continuous measurements, historical measured emissions rates are generally the best measure of a particular generator's emissions rate. Therefore, they should be used when available.

However, measured historical emissions rates are not always available for all sources. Existing databases are limited to those generators that exceed certain size and operational thresholds. Smaller generators, newer generators, or generators that did not operate over the historical period used to set emissions rates are not included in certain databases. In addition, because it is difficult to directly measure certain pollutants such as PM and air toxics, historical emissions rates for all pollutants may not be known for a given generator.

Finally, lack of temporal granularity of may produce misleading emissions rate estimates. In particular, the use yearly-average emissions rates may be problematic for generators that do not operate consistently over the course of a year, such as dual fuel peaking plants that may burn oil instead of natural gas when natural gas is unavailable or particularly expensive.

Where historical emissions rates are not available at all, or lack sufficient granularity, engineering estimates should be used.

## Existing Tools and Databases

There are a number of existing databases that regulators can use to determine emissions rates. Different tools may be appropriate for different pollutants or for different desired levels of granularity.

This section outlines tools that fall into a number of categories: (1) Databases of generator-specific historical measured emissions; (2) databases of generator-specific historical measured generation, which, together, can be used by a state to develop generator-specific historical emissions rates; (3) databases of engineering estimates of emission factors; and (4) integrated databases that combine data from other sources to produce readily available emissions rates.

### Table 2: Databases for Calculating Emission Rates

| Tool | Data type | Pollutants covered | Covered sources | Data source | Update Frequency (last data year) |
|---|---|---|---|---|---|
| Historical Emissions Databases | | | | | |
| EPA CAMD | Generator-specific hourly emissions (can be aggregated) | NOx, $SO_2$, $CO_2$ | Boilers > 25MW; combustion turbines, combined-cycle plants, & ICE online after 1990 | Mandatory source-level reporting based on continuous monitoring | Monthly (Sept. 2017) |
| National Emissions Inventory | Unit-specific annual emissions | $SO_2$, NOx, $PM_{10}$, $PM_{2.5}$, CO, VOC, $NH_3$, Hg, HCl | Power plants with criteria pollutant emissions over certain thresholds | State environment office reporting, supplemented by EPA CAMD data and emission factors | 3 years (2014) |
| Historical Electric Generation Databases | | | | | |
| EIA Form 923 | Unit-specific monthly electric generation and fuel consumption | n/a | Sources > 1 MW | Operator-level reporting | Monthly (Oct. 2017) |
| Engineering Estimate Databases | | | | | |
| EPA AP-42 | Engineering-based estimates by fuel and technology type | $SO_2$, NOx, $PM_{10}$, $PM_{2.5}$, CO, VOC, $CO_2$, $CH_4$ | Boilers, combustion turbines, and ICE using coal, natural gas, fuel oil, and biomass | EPA tests of representative technology | Infrequent (1998-2008) |
| National Energy Technology Lab | Engineering estimates | $CO_2$, $SO_2$ | Modern highly-efficient natural gas combined-cycle plants | Department of Energy engineering analysis of modern plants | Infrequent (2010) |
| Integrated Databases | | | | | |
| eGrid | Unit-specific annual emissions and electric generation | NOx, $SO_2$, $CO_2$ | Electric generating units that report electric generation data on EIA-923 | Emissions: EPA CAMD and AP-42 Generation: EIA-923 | Sporadic, generally 1-4 years (2016) |
| Argonne National Labs GREET | Attribute-based emission factors using statistical analysis of historic emissions rates and open literature review | $CO_2$, $CH_4$, NOx, $SO_2$, CO, VOC, $PM_{10}$, $PM_{2.5}$ | Boilers, combustion turbines, combined-cycle plants, ICE burning coal, nat. gas, fuel oil, and biomass, with various pollution control equip. | EPA eGRID, AP-42, open literature | Sporadic (2012 for full update, 2017 for limited update) |

## *Generator-Specific Historical Emissions Databases*

EPA maintains a number of databases of power plant emissions. However, no single database contains information on all important pollutants. Combining datasets is necessary to get a full picture of generator emissions.

### EPA Clean Air Markets Division

**Overview.** EPA's CAMD collects emission data from large air pollution sources, including power plants, in order to administer a number of federal environmental programs. Electric generators subject to reporting requirements include steam generators with at least 25 MW capacity, non-steam generators – gas turbines, combined cycles, internal combustion engines – that came on-line after 1990, and independent power producers/co-generators that sell over a specific amount of electricity.[29] These generators report hourly emissions of NOx, $SO_2$, and $CO_2$, collected from CEMs, to EPA on a quarterly basis. The hourly data can then be aggregated into daily, monthly, or seasonal data.

**Advantages.** Using hourly emission data would allow state utility regulators to calculate emissions rates that take into account environmental and operational characteristics. Because the data is collected from continuous monitoring, it is also more accurate than data collected through other means.

**Limitations.** The biggest limitation is that CAMD does not include historical data on a number of key pollutants, such as PM. CAMD only recently began collecting data on mercury, hydrogen chloride, from some coal and oil-fired steam generators.[30]

### National Emissions Inventory

**Overview.** The National Emission Inventory (NEI) is a database of annual emissions for a wide variety of sources, including power plants with a potential to emit criteria pollutants above a 100 tons per year threshold.[31] NEI data includes generator-specific emissions of $PM_{10}$, $PM_{2.5}$, VOCs, CO, HAPs, $SO_2$ and NOx emissions.[32] Data is based primarily on data reported to EPA from state environmental agencies, supplemented and modified by data that EPA itself collects and other EPA assumptions.[33] New data is collected by EPA every three years, and released three years later after it goes through a substantial quality assurance process. The 2014 National Emissions Inventory was released in 2017.

**Advantages.** The primary advantage of NEI data is that it contains emissions of a wider variety of air pollutants than CAMD, including PM.

**Limitations.** Infrequent updating is the primary limitation of the NEI. The NEI is updated only every 3 years, on a 3-year delay. Therefore, accurate emissions rates will not be available for sources built or substantially modified after 2014. In addition, NEI contains only annual (and for NOx, summer season) emissions.[34] Therefore, emissions rates calculated using this data source will be limited to annual average emissions rates (and, for NOx, ozone season average emissions rates), and will have limited accuracy for plants whose emissions rates vary with operational changes, such as mid-year changes in fuel used.

## *Generator-Specific Historical Generation Databases*

### EIA-923

**Overview.** Operators of electric generators greater than 1 MW report net electric generation (as well as fuel consumption) to the Department of Energy's Energy Information Agency (EIA) on form EIA-923.[35] All generators report generation annually, and a large subset report generation on a monthly basis.[36] For generators that are not included as part of the sample, EIA imputes monthly generation data using statistical techniques.[37]

**Advantages.** EIA data is readily accessible online and practitioners consider it as the best source of widely available generation data.

**Limitations.** Emissions rates more granular than monthly averages are not available.

## *Engineering Estimate Databases*

### EPA AP-42

**Overview:** EPA has developed *AP-42 Compilation of Air Pollution Emission Factors* for a wide variety of pollutants and source categories. These factors are often used by EPA when measured data is not available and can be used by states to develop assumed emissions rates for sources where EPA data is not available.[38]

AP-42 provides emission factors for the following combustion technologies: steam boilers;[39] stationary combustion turbines;[40] and large stationary diesel and dual-fuel engines.[41] It generally includes emission factors for criteria pollutants and their precursors, HAPs, and greenhouse gases (including $CO_2$ and methane).

**Advantages.** AP-42 provides a standard set of widely used emissions factors. It is therefore easy to use when historical emissions data is not available.

**Limitations.** AP-42 emission factors have not been updated since the late 1990s and early 2000s. This is particularly an issue for generation technology that has seen significant advancements since the last AP-42 update, including natural gas combined-cycle combustion technology. In addition, recent analysis has shown that the factors do not capture the wide variety of emissions rates from actual facilities.[42]

### NETL Natural Gas Combined-Cycle Analysis.

**Overview:** In 2010, the Department of Energy's National Energy Technology Laboratory (NETL) evaluated the cost and performance of representative fossil fuel-fired power plants, including new NGCC power plants. As part of this report, NETL developed air pollution emissions rate estimates for a standard NGCC plant.[43] These emission factors have been used by academic researchers studying the economic costs of air pollution externalities from power plants.[44] For relatively modern, large NGCC plants, states could use generic emissions rates based on this research.

**Advantages.** Up-to-date and widely used emission factors for modern NGCC technology.

**Limitations.** Limited to emission factors for a single generation technology type.

## *Integrated Emissions and Generation Database*

There are two integrated databases that combine available emissions and generation data from the databases outlined above and other sources. These databases can help determine emissions rates with minimal additional work by utility regulators.

### EPA eGrid Database

**Overview.** EPA maintains the eGrid database[45], which contains annual average emissions data and annual average generation data for most electric generators, compiled from a variety of data sources. The primary source for generation data is EIA form 923.[46] The primary source of EPA's emission data is EPA CAMD.[47] For generators that do not report to CAMD, EPA calculates annual emissions by multiplying emissions factors from AP-42 by the plant's heat rate (as reported to EIA).[48]

**Advantages.** The primary advantage of eGrid is that EPA has already done the work to compile and validate relevant data from CAMD, AP-42, and EIA.

**Limitations.** eGrid does not include data on key pollutants, such as PM and air toxics. Because eGrid provides *annual* emissions and generation data,[49] eGrid data does not take into account emissions rate changes that could result from variation in the fuel used by a plant throughout the course of a year, changes in capacity factor, or other operational and environmental characteristics.

### Argonne National Laboratory GREET Emission Factor Database

**Overview.** Argonne National Laboratory (ANL) has developed a model for estimating lifecycle greenhouse gas and criteria pollutant emissions associated with various vehicle technologies: the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model.[50] In order to estimate lifecycle emissions of electric vehicles with this model, ANL has compiled a database of power sector emission factors broken out by relevant attributes such as fuel type, generation technology, and pollution control equipment.[51] The GREET emission factor database was developed using data from CAMD, EIA, AP-42 and the open literature.

**Advantages.** The GREET emission factor database includes emission factors for a wide variety of pollutants, including those not included in eGrid, such as $PM_{2.5}$. The database is broken out by many generator characteristics, so more accurate emissions rates can be identified, so long as relevant attributes of a given generator are known. It is updated more frequently than AP-42 (the last comprehensive update was in 2012, but limited updates were made in 2013 and 2017).[52] ANL conducted robust statistical analysis to arrive at emission factors.

**Limitations.** The GREET emission factor database includes general attribute-based emissions rates. Therefore, it is not as accurate as historical emissions rates for specific generators when such rates are available.

## Estimating Displaced Emissions if Step 1 is Not Feasible

The methodologies described in Steps 1 and 2 of this report identify the emissions avoided by a DER by identifying specific generators that would be displaced and determining the emissions rate of those generators. However, when it is not possible to identify specific generators due to lack of data, it is possible to estimate the emissions displaced by DER by using econometric techniques.

Academic researchers have been using regression analysis to directly estimate the grid's marginal emissions rates.[53] This method requires high-frequency data on emissions of the pollutant of interest and the quantity of electricity demand – the load – for a particular electric grid. A linear regression of emissions on load will yield the relationship between changes in measured emissions from all generators on the grid and changes in electricity demand. The marginal emissions rates at a given time and location can then be estimated based on the level of electricity demand at that location and time.

The granularity of this method depends on the granularity of the underlying data. For example, if data are available on zonal level emissions and load, then marginal emissions can be calculated to the zonal level for each season or time of day.

**Limitations:** Because marginal emissions rates are estimated for a given area, assumptions are required about where specifically emissions will occur. This will limit the accuracy of damage estimates outlined in Steps 3-4 below. In addition, this approach will not be responsive to changes in the electric sector such as short-run changes caused by generator outages and medium-run changes in the composition of generators over time. Therefore, this approach should be used only to the extent that utility regulators are not able to obtain information from grid operators and cannot use electric market models.

# Step 3: Calculate the Monetary Damages from Emissions

Air pollutants cause damage to human health, impair ecosystems, and harm crops and other production activities. The goal of this step is to find the monetary value of the damages from each unit of emissions identified in the previous step. Given knowledge of the emissions rate for a power generator, regulators can calculate damages as a function of the pollutants being emitted, the location where those emissions occur, the time of day and year when they occur, and ambient environmental conditions like weather and pollution concentrations. The most accurate calculation of damages would incorporate each of these elements.

## Relevant Factors for Calculating Monetary Damages

The sections below discuss the factors needed for calculating monetary damages from emissions, as well as the motivation for incorporating these different elements and the key issues related to granularity versus ease of administration.

### *Pollutants Emitted*

The previous section identified a number of pollutants emitted by fossil power generators. Each pollutant has its own relationship between exposure and impact, called the *dose-response function* or *damage function* in epidemiological and economic research. These different damage functions should be accounted for when calculating damage per unit of emissions for accurate assessment of the value of avoided emissions.

#### Toxic Heavy Metals

Toxic heavy metals like mercury or lead cause rapid health deterioration even for low concentrations and quickly become fatal. Heavy metals like mercury and lead can also decrease brain function, leading to marked reduction in IQ.[54] The harms also occur over long periods of time because heavy metals do not break down once they are released, leading to long-run harms as the public is exposed the pollutant over longs periods of time and permanent, negative health effects for individuals whose bodies cannot get rid of the toxins. Because the harm caused by these metals is so extreme, the damage per unit of emissions is correspondingly high.[55]

#### Sulfur Dioxide ($SO_2$)

Sulfur dioxide ($SO_2$) is a gas released during combustion of oil and coal that negatively affects the environment and human health. $SO_2$ irritates mucous membranes in the lungs, eyes, nose, and throat, exacerbating conditions like asthma.[56] $SO_2$ also breaks down into particulate matter. Fine particulates, especially those smaller than 2.5 micrometers, called $PM_{2.5}$, penetrate into the lungs, causing or exacerbating cardiovascular problems like asthma and heart disease. Fine particulate matter is also a primary contributor to haze and visibility reduction in much of the United States.[57] $SO_2$ is also a major contributor to acid rain.[58]

### Nitrogen Oxides (NOx)

Nitrogen oxides are gases including nitrogen dioxide, nitrous acid, and nitric acid. Collectively, these gases are referred to as NOx.[59] Like $SO_2$, NOx breaks down into particulate matter, causing cardiovascular health effects and contributing to haze.[60] NOx, along with other pollutants like VOCs, react with sunlight to create ozone pollution, which is a respiratory irritant that aggravates conditions like asthma.[61]

### Greenhouse Gases

Greenhouse gases, including carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$), lead to climate change.[62] Greenhouse gases exert a warming effect on the global climate. This warming is already having noticeable, damaging effects on the environment and the economy.[63] These damages are expected to increase in the future as further climate change occurs.[64]

## *Ambient Concentration*

Ambient pollution concentrations affect the amount of damage that results from additional pollution emissions. Some pollutants cause severe health effects at low concentrations, so even small emissions of such pollutants can be dangerous, depending on ambient levels. One such pollutant is mercury. Even small concentrations of mercury can cause mortality, so an increase in emissions of mercury in an area with a high pre-existing concentration can cause severe health effects.[65] In contrast, an increase in emissions of a pollutant like particulate matter will cause declining marginal damage as the ambient concentration rises.[66]

Pollutants can also interact, exacerbating effects. For instance, ozone creation is more likely in the presence of both VOCs and NOx.[67] Pollutant interaction makes it potentially important to account for ambient concentration of other pollutants when calculating damages per unit of emissions. Such interaction effects might be challenging to quantify in a way that is also easy to administer, so a reasonable alternative would be to incorporate damages that vary by location depending on the average or usual concentration of important ambient pollutants.

## *Pollution Transport*

Pollution can be carried away from the area where it is created through a process called pollution transport. Wind and water carry pollutants away from the point of emission, potentially exposing populations far from the emission source.[68] Rain washes particulate matter out of the air and into bodies of water.[69] Pollution transport models are useful for understanding this movement of pollutants from source to final location. For instance, lighter pollutants like fine particulates can be carried farther than heavier pollutants like $PM_{10}$, making modelling of transport for fine particulates relatively more important for correct damage estimation.[70]

## *Secondary Pollutants*

Related to pollution transport, pollutants break down and potentially create other, secondary pollutants as they travel through the atmosphere. As discussed above, $SO_2$ and NOx break down to create particulate matter. Ozone forms when sunlight reacts with oxides and organic compounds in the air.[71] Thus, ozone is less likely to form at night and is also less likely to form in the winter, making time of day and year important for damage from this pollutant.[72]

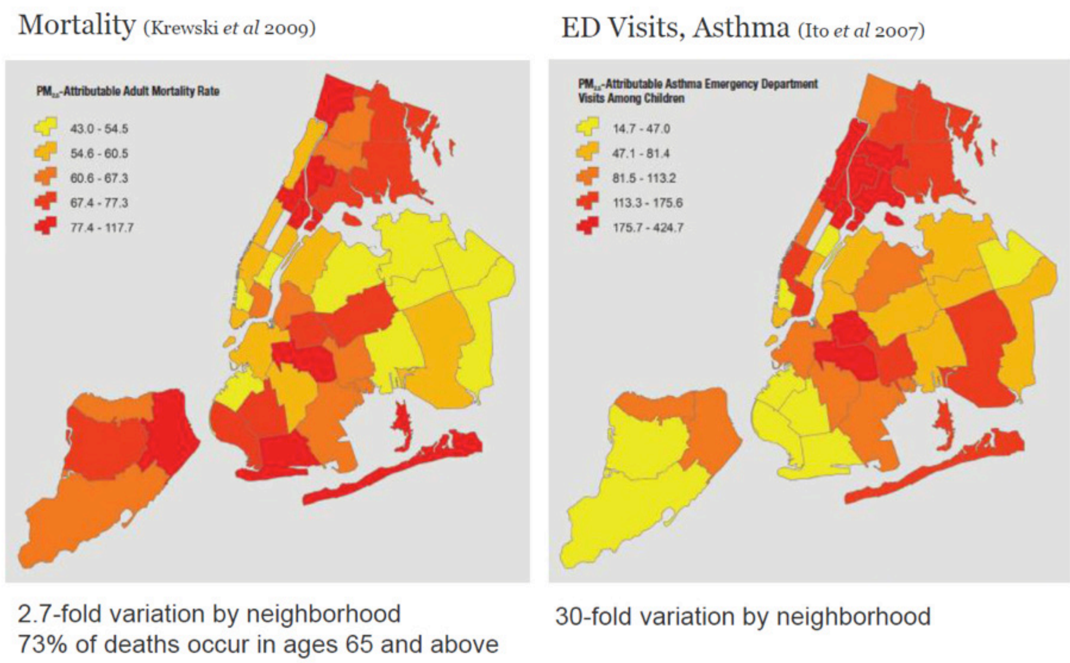
### *Exposed Population*

Pollution causes damage when individuals are exposed to that pollution, so the size of the exposed population is one of the most important drivers of changes in damage from pollution. Densely populated areas experience more damage from a given amount of pollution simply because more people are exposed to that pollution. For instance, $PM_{2.5}$ released in the eastern region of the United States causes between $130,000 and $320,000 in damages per ton according to EPA estimates. A ton of $PM_{2.5}$ emitted in the western part of the United States, however, causes $24,000 to $60,000 in damage.[73] The difference in these estimates is primarily attributable to differences in population density.

### *Population Health*

The healthiness of the exposed population also affects damage. Ozone created in an area with high asthma rates will cause more health damage than ozone released in an area with very few asthma sufferers. Overall health affects the vulnerability of individuals to mortality from pollutants. For example, Figure 3 shows that in New York City, $PM_{2.5}$-attributable mortality rate is higher in portions of Brooklyn than in southern Manhattan.[74]

**Figure 3**[75]




*Source: NYC Department of Health and Mental Hygiene Bureau of Environmental Surveillance and Policy (2013).*

*The left panel shows the relationship between $PM_{2.5}$ and adult mortality for neighborhoods in New York City. The same quantity of $PM_{2.5}$ causes about twice as much mortality in a neighborhood colored red versus yellow. The right panel shows the relationship between $PM_{2.5}$ and child emergency room visits for asthma in New York neighborhoods. For asthma, the same quantity of $PM_{2.5}$ causes about ten times more emergency room visits in a neighborhood colored red versus yellow. Both panels show that the damage from air pollution usually depends on local characteristics like population health.*

## Methodologies for Calculating the Damage per Unit of Emissions for Pollutants that Depend on Time and Location

Accounting for all of the factors that affect damages using custom models would lead to the most accurate calculations of damage per unit of emissions. However, data constraints and ease of use might make alternative, less granular methods more desirable. Table 1 shows examples of different damage calculation methods that tradeoff between these two goals of accuracy and administrability. The most granular methods use high-resolution population data with time-varying pollution transport models. Less granular methods make stronger assumptions or use more aggregated data to reduce the complexity of calculation.

### *Custom Solutions*

On the most granular side, policymakers could build a custom model that takes into account as many factors affecting damage per unit of emissions as possible. A recent example of such an approach is the Bay Area Clean Air Plan.[76] The Bay Area Air Quality Management District created a custom tool that translates emissions of multiple different pollutants into changes in pollution concentration throughout the Bay Area. The tool uses weather data to understand how pollutants are transported around the Bay Area, and it uses atmospheric chemistry models to understand how different primary pollutants cause secondary pollutants in the region. For instance, ozone is created by a complex interaction between different pollutants and sunlight, so the atmospheric chemistry models are important to understanding how ozone pollution can be addressed.

The model then uses population density to translate pollution concentration changes into human exposure. The exposure determines health effects according to the pollutant being considered and the health conditions of the exposed population.[77] The Bay Area Air Quality Management District focuses on PM, ozone, and greenhouse gas pollution, but in principle, any pollutants could be incorporated into a similar methodology.

One of the primary benefits of a custom method is the ability to incorporate variation in population density and population health. This ability is especially important for states that are characterized by a high degree of heterogeneity in population density. Pollutants emitted in areas near big urban cities would cause substantially higher exposure than the same pollutant emitted in more sparsely populated rural regions. This effect might be exacerbated if higher-emission power plants are located in the higher-population areas, leading to higher ambient pollution levels.[78] This correlated heterogeneity means that policymakers should avoid an approach that uses a state-wide average damage per unit of emissions, since such an approach would vastly understate damages in some areas of the state while overstating damages in others.

### *Estimating Air Pollution Social Impact Using Regression*

Estimating Air Pollution Social Impact Using Regression (EASIUR) is a model of the damages from emission of primary $PM_{2.5}$, $SO_2$, NOx, and $NH_3$. The damage estimates are based on mortality due to secondary particulate matter.[79] One of the primary benefits of EASIUR is easy-to-use but accurate modeling of pollution transport. EASIUR was created by taking high-resolution, detailed pollution transport model output from the Comprehensive Air Quality Model with Extensions (CAMx)[80] to derive simple estimates of pollution transport on a 36 by 36-kilometer grid for the United States.[81] As a result, EASIUR provides relatively accurate estimates of air pollution damage based on the location of emissions without the cost of complex and time-consuming modeling of detailed pollution transport. EASIUR also provides estimates of damages for three different stack heights—ground level, 150m, and 300m.

### *BenMAP*

BenMAP is a tool created by EPA to calculate and map damages from ozone and $PM_{2.5}$ in the United States. BenMAP does not include pollution transport modeling. Users specify the change in ambient concentration of pollution that they expect will occur due to a policy, and BenMAP monetizes the health impacts of that change based on population density and pollution damage functions derived from academic publications. It includes high-resolution population data (a 12 by 12-kilometer grid) and can be customized with user-defined population data, baseline health data, and pollution damage functions.[82]

### *Air Pollution Emission Experiments and Policy Analysis Model*

Air Pollution Emission Experiments and Policy analysis models county-by-county marginal damage estimates for $SO_2$, NOx, $PM_{2.5}$, $PM_{10}$, $NH_3$, VOCs. This model allows specification of stack height. This is important in locations like New York City, where the combination of low stacks and large population combine to create high marginal damages for peak generators that often have relatively high emissions rates.[83]

### *Co-Benefits Risk Assessment*

The Co-Benefits Risk Assessment (COBRA) tool from EPA uses a simple pollution source-receptor matrix and a subset of the BenMAP health damage functions to estimate county-level damages from the creation of secondary $PM_{2.5}$ from emissions of NOx, $SO_2$, $NH_3$, $PM_{2.5}$, and VOCs. Like BenMAP, COBRA can be modified with custom population, baseline health, and baseline emission data as well as custom damage functions. COBRA damages are based on mortality and morbidity due to nonfatal heart attacks and cardiovascular illness.[84]

Table 3: Tools to Calculate Damage per Unit of Emissions

| Tool | Geographic Granularity | Additional Data Requirement | Pollutants Covered | Notes | Source |
|---|---|---|---|---|---|
| Custom model | Variable | High | ozone ($NOx$,$VOC$), $PM_{2.5}$ (directly emitted $PM_{2.5}$, $NOx$, $VOC$, $SO_2$), air toxics | Geographic-specific damage estimates based on: • Air transport • Ambient concentrations • Population • Comorbidity | Bay Area Air Quality Management District Multi-Pollutant Evaluation Method (2017) |
| BenMAP | High (default); Variable (custom) | Medium (default); Varies (custom) | ozone, $PM_{2.5}$ | • Translates all pollutants into secondary PM & ozone • Driven primarily by mortality • Can input own data | U.S. EPA |
| EASIUR | 36 km | Low | $SO_2$, $NOx$, $NH_3$, $PM_{2.5}$ | • Detailed air transport model • Seasonal damages | Heo, Adams, and Gao (2016) |
| AP2 | County | Low | $SO_2$, $NOx$, $VOC$, $NH_3$, $PM_{2.5}$, $PM_{10}$ | • Accounts for air transport • Broader monetized damage categories | Muller, Mendelsohn, Nordhaus (2011) |
| COBRA | State or county | Low | $PM_{2.5}$ (directly emitted $PM_{2.5}$, $NOx$, $VOC$, $SO_2$) | • Recently updated (2017) • Previously used by NY PSC • Accounts for air transport • Driven primarily by mortality | U.S. EPA (2017) |

## Greenhouse Gases – Methodology for Calculating Damage per Unit of Emissions

Damages from greenhouse gases do not depend on the time or location of release, making the calculation of their damage per unit of emissions particularly straightforward.[85] The Interagency Working Group's Social Cost of Carbon is the best estimate of the damages caused by greenhouse gas emissions.[86]

The Social Cost of Carbon is the net-present value of damage caused by the emission of one metric ton of carbon dioxide today. The emissions of greenhouse gases like methane and nitrous oxide from electricity generation can be translated into carbon dioxide-equivalent units using methodologies developed by EPA.[87] The Social Cost of Carbon can then be used to calculate the damage per unit of emissions of all greenhouse gases.

The Interagency Working Group first developed the Social Cost of Carbon in 2010 and updated the estimate in 2013 and 2015.[88] In 2016 and 2017, the National Academies of Sciences issued two reports that recommended future improvements to the methodology.[89] In response to those reports, researchers at Resources for the Future and the Climate Impact Lab are working on further updates.[90]

The Interagency Working Group's estimate has been repeatedly endorsed by government reviewers, courts, and experts. In 2014, the U.S. Government Accountability Office reviewed the Interagency Working Group's methodology and concluded that it had followed a "consensus-based" approach, relied on peer-reviewed academic literature, disclosed relevant limitations, and adequately planned to incorporate new information through public comments and updated research.[91] In 2016, the U.S. Court of Appeals for the Seventh Circuit held that relying on the Interagency Working Group's estimate was reasonable.[92] And though the current Administration recently withdrew the Interagency Working Group's technical support documents,[93] experts continue to recommend that agencies rely on the Interagency Working Group's Social Cost of Carbon estimate as the best estimate for the external cost of greenhouse gases.[94]

# Step 4: Monetize the Avoided Externality from Displaced Generation

Once the displaced resource has been identified and both the emissions rates and the damage per unit of emissions are known, these two values can be multiplied to get the monetary value of avoided damages per unit of generation.

If other existing policies already internalize externalities, such as a cap-and-trade program, an additional step to take these policies into account is necessary. Failing to take these policies into account could lead to double counting of the benefits generated by pollution reduction. To see this, consider a case where bulk system generators are subject to a policy that requires payment per ton of $CO_2$ emitted. The cost of operation for such emitting generators will be higher, and therefore they would submit higher bids to the wholesale electricity market. These higher bids would result in a higher equilibrium price in the market, so any resource that did not emit $CO_2$ (or emitted less $CO_2$ than the marginal resource) would receive the benefit of this higher price. In this way, zero or low emitting resources—like a clean DER—would be incentivized to produce more, and high emitting resources would be incentivized to either reduce their emissions or to produce less. If DERs also received direct payments for the full environmental and public health externality of emissions on top of this price increase, the result would be double payment for the same benefits.

If the existing policies do not fully internalize the externality from pollution, then DERs should receive payment that is sufficient to achieve full internalization. States participating in the Regional Greenhouse Gas Initiative (RGGI), a cap-and-trade program run by nine states in the Northeast, provide a good example. Generators in these states that are larger than 25 megawatts must pay for emissions of $CO_2$ by purchasing emissions permits under RGGI.[95] If the generator displaced by a DER is a participant in RGGI, then the price in the wholesale market already incorporates a payment for $CO_2$ emissions, and the monetized value of avoided emissions should take that into account. Current and forecasted RGGI permit prices, however, are not sufficient to fully internalize the external damage from $CO_2$, so clean DERs should still receive a payment for $CO_2$ emissions that they avoid. The payment should be reduced to reflect the degree to which the $CO_2$ externality has been internalized by RGGI.

Numerically, consider a case where the displaced resource is a combined-cycle natural gas plant that emits one ton of $CO_2$ per MWh of generation.[96] If there were no policies that required the displaced generator to pay for carbon emissions, then the value of avoided damages from each kWh injection would be the emissions rate times the external damage per unit of emissions. The external damage caused by carbon dioxide, as discussed in the previous section, is given by the Social Cost of Carbon and the central estimate is currently around $46 per metric ton in 2017 dollars.[97]

$$\textbf{External value of avoided } \mathbf{CO_2} = 1\ \frac{kg\ CO_2}{kWh} \times 0.046\ \frac{\$}{kg\ CO_2e} = 0.046\ \frac{\$}{kWh}$$

Therefore, for every kWh of displaced generation, a zero-emitting DER would provide a benefit of roughly 5 cents by internalizing the externality from $CO_2$ emissions.

The payment for a concurrently existing cap-and-trade policy such as RGGI changes this calculation. The current RGGI price is around \$4 per metric ton of $CO_2$. If the displaced generator is paying for RGGI permits, then \$4 of the external cost of $CO_2$ has already been internalized, meaning that the uninternalized damage from $CO_2$ is \$46−\$4=\$42. The value of avoided damage from $CO_2$ in this case would be:

$$\textbf{External value of avoided } \mathbf{CO_2} \textbf{ with RGGI} = 1\,\frac{kg\ CO_2}{kWh} \times (0.046 - 0.004)\,\frac{\$}{kg\ CO_2} = 0.042\,\frac{\$}{kWh}$$

The value of avoided external damage falls to reflect the fact that some of the external damage from carbon has already been internalized.

As another example, consider an alternative policy that is being discussed in several jurisdictions: carbon pricing. If a carbon charge is levied on electricity sold in a state, the charge would raise the price that wholesale electricity generators pay for carbon emissions and hence help internalize the externality. If this charge is based on the Social Cost of Carbon, then the external value of avoided emissions of $CO_2$ would fall to zero since the externality would be fully internalized.

$$\textbf{External value of avoided } \mathbf{CO_2} \textbf{ with charge} = 1\,\frac{kg\ CO_2}{kWh} \times (0.046 - 0.046)\,\frac{\$}{kg\ CO_2} = 0.00\,\frac{\$}{kWh}$$

In practice, the benefits from implementing a carbon charge in the state would come from both the incentive it would provide to clean generation and the disincentive to emitting generation, leading to a higher likelihood of the displaced generator having a lower emissions rate as well.

When setting the level of payment for other pollutants, policies including the Cross-State Air Pollution Rule (CSAPR) for NOx and $SO_2$, the Mercury Air Toxics Standard (MATS), and other future policies should also be taken into account. In the case of a policy like the RGGI cap-and-trade program, discussed above, a positive permit price that results from a binding cap should be taken into account by reducing the payment to DERs in proportion to the amount of the environmental and public health externality that has been internalized. For other programs, like CSAPR, where the cap is currently not binding and the permit price has settled near \$0, no adjustment needs to be made.[98] If the cap binds in the future and prices rise above zero, then the payment to DERs would need to be adjusted.

The table below summarizes recent values of the damage per unit of generation from three different analyses done by different state and federal agencies. As the table shows, these different agencies come to similar conclusions regarding the value of avoiding these different pollutants.

### Table 3: Examples of Dollar Value of Average Damage per MWh[99]

| Pollutant | 2016 EPA RIA | New York DPS | Bay Area Clean Air Plan |
|---|---|---|---|
| $SO_2$ | \$76 to \$171 per MWh | \$52 to \$55 per MWh | \$77 per MWh |
| NOx | \$4 to \$12 per MWh | \$5 per MWh | \$3 per MWh |
| $PM_{2.5}$ | \$7 to \$16 per MWh | | \$22per MWh |

# Step 5: Monetize and Subtract DER Damages

The final step is to take into account any emissions generated by the DER itself. Distributed energy can come from non-emitting resources like solar panels or small wind turbines or it can come from emitting resources like combined heating and power generators, diesel generators, or small natural gas fuel cells. In fact, the Department of Energy estimates that the majority of DERs in the United States are emitting backup generators, and that in 2006, 42% of DER energy produced in the country came from combined heating and power.[100] If the DER emits pollutants, then those emissions and the damage they cause must be taken into account to accurately quantify the environmental and public health values of the resource. Damages from energy storage systems that are charged by emitting resources should be calculated similarly. In this case, damages from the DER's own emissions must be calculated and netted out from the value of emissions avoided by the DER. In cases where the DER does not emit, this additional step is not necessary, and the calculation of environmental value is simply the external value of avoided emissions calculated in the previous step.

## Step 5A: Monetize the Externality from DER

If the DER emits pollutants, then the externality associated with emission of those pollutants must be accounted for, in the same way that the value of emissions from displaced generation was calculated in Steps 2, 3, and 4. First, policymakers need to know the DER's emissions rate for each pollutant. Lack of data on emissions rates presents a unique challenge for calculating damages from DERs. Resources like eGrid and the National Emissions Inventory do not record emissions or generation for very small generators. Instead, policymakers will likely need to rely on engineering estimates of emissions rates. As an alternative, policymakers could also use EPA emissions standards for non-road generators to estimate emissions.[101] Note that fossil-fuel-burning DERs generally produce higher emissions per unit of generation than otherwise comparable, large generators because the latter benefit from returns to scale in generator efficiency.[102]

Second, the policymaker must determine the damage per unit of emissions given the DER's location, time, and pollutants emitted. Damages per unit of emissions from DERs will also likely be different than from a similarly located large generator given that large generators generally have tall stacks that allow pollutants to disperse their over a larger area. Moreover, since DERs are generally located near load centers, they are also generally located nearer to areas of relatively high population density.[103] Proximity to higher population will raise the damage per unit of emissions from emitting DERs.

Using these numbers, the value of damage per unit of electricity generation can be calculated for the DER in the same way that the value is calculated for larger generators. In particular, the value per unit of generation will be the sum across all pollutants of the emissions rate times the damage per unit of emissions.

## Step 5B: Subtract the Value of DER Emissions from the Value of Avoided Emissions

The last step for finding the environmental and public health value of DERs is to subtract the value of emissions from the DER calculated in Step 5A from the value of avoided emissions calculated in Step 4. Subtracting these two values must be the last step of the process. In other words, the dollar value of damages per unit of generation from the two resources should be calculated first, then the value of damage from the DER should be subtracted from the value of damage from the displaced resource. This procedure will correctly estimate the net environmental value of the DER by including differences in emissions rates and damage per unit of emissions discussed above. Incorrect calculations would net out either generation or emission before calculating the damages. Netting out generation first would not account for unique emissions by the two resources. Netting out emissions first would not account for the differences in location and exposed population between the two resources.

For instance, consider a case where the DER emits pollution in a high population area while the displaced resource would have emitted pollution in an area with lower population. The damage per unit of emissions is higher from the DER, but if the emissions are first subtracted from each other, then this difference between the two resources would be lost. In such a case, the DER would be erroneously incentivized to produce more electricity, increasing the damage experienced by the high population area.

If damage per unit of generation from the DER is high enough, then the net environmental value of the DER could be negative. This might be the case, for instance, if a diesel generator located in close proximity to a high-population area is displacing generation from a relatively clean natural gas plant located further from a populated area.[104] In these cases where the DER causes more environmental damage than it avoids, it should be penalized for that damage. In other words, the "compensation" for the environmental and public health value may be negative. Failing to do so would also fail to fully internalize the environmental externality associated with emissions.

# Example Calculation

To illustrate the calculation of the value of DER using all of the above steps, consider an example of DERs in New York State. New York's current generation mix primarily includes hydropower, nuclear, natural gas, oil, and renewables.[105] Figure 2 shows a representative dispatch curve for New York. During periods of low electricity demand, a DER might offset hydro or nuclear generators, resulting in no avoided emissions. During these periods, the environmental and health value paid to the DER would be zero for a zero-emitting DER and would be negative for any DER like a diesel generator that produces emissions.

During periods with near-average load, the marginal fuel is natural gas. Typical natural gas generators in New York emit relatively low levels of NOx and PM, and moderate levels of $CO_2$. They do not emit $SO_2$. As demand rises during periods of particularly high load, oil becomes the marginal fuel and the emissions per unit of generation rise. Currently, New York does not produce any power from coal. A small amount of biomass production occurs in the state, but biomass has, historically, not been the marginal fuel in any region of the state.[106] During the course of a single day, the marginal generator might change from zero-emitting nuclear, to gas, and to oil and back again as load shifts. Table 4 summarizes the emissions rates for typical gas and oil generators in the state. These emissions rates provide the necessary data for Step 2 of the method described above.

### Table 4: Average Emissions Rates for Fossil Fuel Generators in New York[107]

| Fuel Type | $SO_2$ (kg/MWh) | NOx (kg/MWh) | $CO_2$ (kg/MWh) | $PM_{2.5}$ (kg/MWh) |
|---|---|---|---|---|
| Oil | 2.10 | 2.62 | 1059.3 | 0.35 |
| Biomass | 0.16 | 2.71 | 481.7 | 0.02 |
| Gas | 0.00 | 0.12 | 397.3 | 0.02 |

The damages from emissions depend on both the location of the avoided emissions and the time of year. For this example, consider the damages from primary $PM_{2.5}$, $SO_2$, and NOx as given by EASIUR for two locations in the New York. These damages are shown in Table 5. Per unit of emissions, fine particulate matter is the most damaging of the three pollutants. In densely populated Queens County in New York City, damages per unit of particulate matter are much higher than damages in sparsely populated Franklin County. Moreover, pollution emitted in the two locations disperses to areas with much different populations. Emissions from a generator in Queens affect not only residents of Queens County, but other residents in New York City and Long Island. For these three pollutants, damages are higher in the spring and summer than in the winter or fall. In the EASIUR model, these different damages are largely a function of changes in pollution transport due to seasonal weather changes as well as seasonal differences in the rate at which primary pollutants become particulate matter.

The bottom of Table 5 shows the damages from emissions of $CO_2$.[108] As discussed above, damages from $CO_2$ do not depend on the time or location of the emissions. In this example, we have chosen the current Social Cost of Carbon minus a hypothetical $5 price for permits in the Regional Greenhouse Gas Initiative.

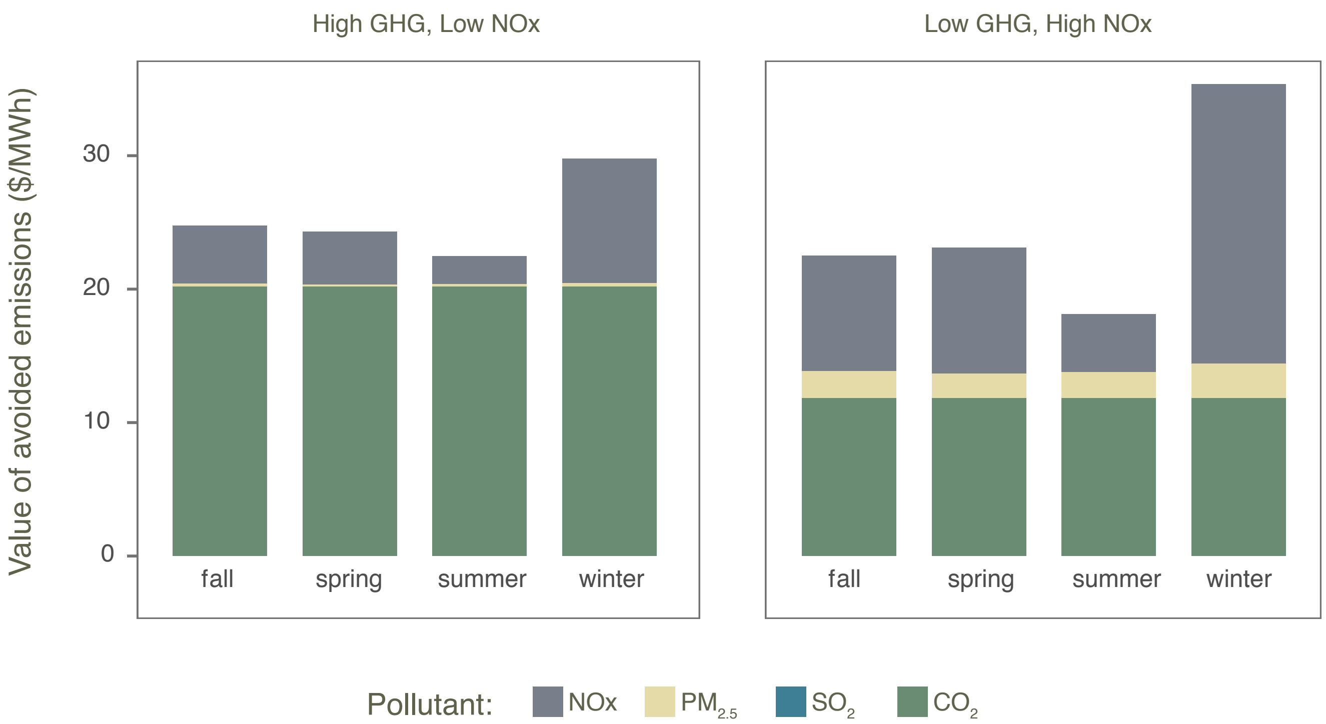
### Table 5: Damage Per Unit of Emissions in Two Regions of New York[109]

| $PM_{2.5}$ ($/kg) | | | | |
|---|---|---|---|---|
| Population | Winter | Spring | Summer | Fall |
| High | 355 | 872 | 712 | 316 |
| Low | 107 | 48 | 50 | 80 |
| **NOx ($/kg)** | | | | |
| Population | Winter | Spring | Summer | Fall |
| High | 19 | 133 | 38 | 38 |
| Low | 21 | 4 | 2 | 4 |
| **$SO_2$ ($/kg)** | | | | |
| Population | Winter | Spring | Summer | Fall |
| High | 12 | 102 | 71 | 21 |
| Low | 23 | 31 | 35 | 23 |
| **$CO_2$ ($/kg)** | | | | |
| Population | Winter | Spring | Summer | Fall |
| High | 0.04 | | | |
| Low | 0.04 | | | |

Putting together the emissions rates from Table 4 and the damage per unit of emissions in Table 5, the environmental and health value for a zero-emitting DER can be calculated. For example, if a typical gas-powered generator was on the margin in the high-population, downstate region in the spring, then a zero-emitting DER would create roughly 5 cents of value per kWh of generation. In the lower-population upstate region, this value would be lower—around 2 cents per kWh. If higher-emitting fuels like oil were on the margin, then the value of DERs would be even higher. Previous publications show that oil heating and power generation lead to particularly high environmental and health damages in the New York City area.[110] In contrast, if a zero-emitting resource like hydro power were on the margin, then a zero-emitting DER would create zero additional environmental value.

Figure 4 shows how the environmental and health value varies even among similar generators. The generator in the left panel is relatively inefficient—emitting a larger amount of carbon dioxide per unit of electricity generation than a typical plant in the state—but it is located in a sparsely populated area where NOx and $PM_{2.5}$ emissions reach a smaller population. The generator in the right panel is relatively efficient, but its emissions of local air pollutants reach a larger population, increasing the value of avoiding those emissions.[111]

### Figure 4: Value of Avoided Emissions from Two Natural Gas Plants




*The figure shows the value of avoided emissions for natural gas generators in New York state. The generator in the left panel emits more pollution per unit of generation than the typical gas generator in New York, but it is located in a sparsely populated area where NOx and PM2.5 emissions reach a smaller population. The generator in the right panel is located in a heavily populated area, so despite being relatively low emitting, its emissions of local air pollutants cause more health damage, increasing the value of avoiding those emissions.*

# Conclusion

Distributed energy resources can provide substantial value to a state by reducing the need for large-scale bulk system generation, thereby reducing pollutant emissions. The environmental and public health damage from this pollution is often imposed on vulnerable populations. As state utility regulators implement new compensation policies for these distributed resources, a key component of those policies should include payment for that value.

A straightforward five-step methodology, relying on existing or readily accessible tools, can be used to calculate the environmental and public health value of DERs. These tools can allow utility regulators to implement a compensation scheme that rewards DERs when and where they most enhance social welfare.

The methodology presented here is flexible enough to accommodate a variety of data and resource constraints. State regulators should weigh the tradeoffs between accuracy and administrability of different methods to calculating environmental and health value, pick the tools that are as accurate as possible given the tradeoffs, and then update their method when feasible.

# Endnotes

1 Different states have implemented different definitions of DERs. *See* Staff Subcommittee on Rate Design, Nat'l Ass'n Regulatory Util. Comm'rs, Distributed Energy Resources Rate Design and Compensation 43 (2016), https://pubs.naruc.org/pub/19FDF48B-AA57-5160-DBA1-BE2E9C2F7EA0.

2 *Id.* at 133-136, 142.

3 Richard L. Revesz & Burcin Unel, *Managing the Future of the Electricity Grid: Distributed Generation and Net Metering*, 41 Harv. Envtl. L. Rev. 43, 78-91 (2017), http://policyintegrity.org/files/publications/Managing_the_Future_of_the_Electricity_Grid.pdf [hereafter Revesz & Unel, *Distributed Generation*]; Richard L. Revesz & Burcin Unel, *Managing the Future of the Electricity Grid: Energy Storage and Greenhouse Gas Emissions*, 42 Harv. Envtl. L. Rev. (2018), http://harvardelr.com/wp-content/uploads/2018/03/revesz_unel.pdf [hereafter Revesz & Unel, *Energy Storage*].

4 In fact, every resource that avoids emissions—that is, any generating resource that emits less than the resource that would have generated instead—should be paid commensurate with the value of avoided health, climate, and economic damage. This report is specifically focused on DER because Public Utility Commissions in different states are presently focused on reforming the compensation structure of those resources. However, the methodology discussed could be applied more generally.

5 Revesz & Unel, *Distributed Generation*, *supra* note 3, at 101-108.

6 For more detail on the changing nature of federal-state divide over regulation of electricity, *see* Robert R. Nordhaus, *The Hazy "Bright Line": Defining Federal and State Regulation of Today's Electric Grid*, 36 Energy L.J. 203 (2015), http://felj.org/sites/default/files/docs/elj362/19-203-216-Nordhaus_FINAL%20%5B11.10%5D.pdf.

7 Revesz & Unel, *Distributed Generation*, *supra* note 3, at 85-86; Revesz & Unel, *Energy Storage*, *supra* note 3.

8 Revesz & Unel, *Distributed Generation*, *supra* note 3, at 85-86; Revesz & Unel, *Energy Storage*, *supra* note 3.

9 *See* Derik Broekhoff et al., World Resources Institute, Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects (2005), http://www.ghgprotocol.org/sites/default/files/ghgp/standards_supporting/Guidelines%20for%20Grid-Connected%20Electricity%20Projects.pdf.

10 To the extent that the counterfactual scenario identifies multiple generators that are offset by DERs, a generation-weighted average of displaced generators can be used in Steps 2-3.

11 *Electric Generator Dispatch Depends on System Demand and the Relative Cost of Operation*, Energy Info. Agency: Today in Energy (Aug. 17, 2012), https://www.eia.gov/todayinenergy/detail.php?id=7590.

12 *See* Broekhoff et al., *supra* note 9, at 63-65.

13 *See* Erin Boyd, Dep't of Energy Office of Energy Policy & Sys. Analysis, Overview of Power System Modeling 17-19 (2016), https://energy.gov/sites/prod/files/2016/02/f29/EPSA_Power_Sector_Modeling_020416.pdf. The models particularly well suited to this type of analysis are "grid operation models" (otherwise known as "unit commitment and dispatch models" or "production cost models"). Models primarily designed for policy assessments, screening, and data analysis are not as well suited to this use. This includes EPA's AVoided Emissions and geneRation Tool (AVERT), a "high-level gross analysis" tool intended to estimate the emissions implications of new renewable capacity. *Id.* at 8. Nor are "capacity expansion models," such as IPM, NEMS, Haiku, ReEDS, and PLEXOS, which simulate generation and transmission *investment* decisions. *Id.* at 9, 11.

14 Nathaniel Gilbraith & Susan E. Powers, *Residential Demand Response Reduces Air Pollutant Emissions on Peak Electricity Demand Days in New York City*, 59 Energy Policy 459, 461 (2013); Kyle Siler-Evans et al., *Regional Variations in the Health, Environmental, and Climate Benefits of Wind and Solar Generation*, 110 Proc. Nat'l Acad. Sci. 11768 (2012), www.pnas.org/cgi/doi/10.1073/pnas.1221978110.

15 *Emissions & Generation Resource Integrated Database* (eGRID), U.S. Envtl. Prot. Agency (Feb. 15, 2016), https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid [hereafter eGrid (2016)].

16 *See* Hao Cai et al., Updated Greenhouse Gas and Criteria Air Pollutant Emission Factors and Their Probability Distribution Functions for Electric Generating Units (2012), https://greet.es.anl.gov/publication-updated-elec-emissions.

17 *Id.*

18 *Frequently Asked Questions: What is the Efficiency of Different Types of Power Plants?*, U.S. Energy Info. Agency (May 10, 2017), https://www.eia.gov/tools/faqs/faq.php?id=107&t=3 (defining "heat rate").

[19] U.S. Energy Info. Agency, Electric Power Annual 2016 169 (2018), https://www.eia.gov/electricity/annual/pdf/epa.pdf.

[20] U.S. Envtl. Prot. Agency, Compilation of Air Pollutant Emission Factors Vol. I [hereafter AP-42] at 1.0-1 (5th ed. 1995), *available at* https://www3.epa.gov/ttn/chief/ap42/ch01/final/c01s00.pdf.

[21] *Id.* at 3.4-1, *available at* https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf.

[22] *Id.* at 3.1-1, *available at* https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s01.pdf.

[23] *Id.*

[24] Coal plants can install selective catalytic reduction technology that reduces $NO_x$ pollution by over 80%, flue gas desulfurization (aka "scrubbers") that can reduce $SO_2$ by up to 98%, and electrostatic precipitators and baghouse fabric filters that can drastically reduce PM emissions. Emanuele Massetti et al., ORNL/SPR-2016/772, Environmental Quality and the U.S. Power Sector: Air Quality, Water Quality, Land Use and Environmental Justice 24-27 (2017), https://energy.gov/sites/prod/files/2017/01/f34/Environment%20Baseline%20Vol.%202--Environmental%20Quality%20and%20the%20U.S.%20Power%20Sector--Air%20Quality%2C%20Water%20Quality%2C%20Land%20Use%2C%20and%20Environmental%20Justice.pdf. Combustion Turbines can utilize water injection, dry controls (varying the amount of air needed for combustion), and selective catalytic reduction technology. AP-42, *supra* note 22, at 3.1-7. For combined cycle plants and stationary ICE, there are not pollution control technologies that are in wide use, beyond technologies and operational practices to improve plant efficiency.

[25] Massett, *supra* note 25, at 110-111

[26] Felipe R. Ponce Arrieta & Electo E. Silva Lora, *Influence of Ambient Temperature on Combined-Cycle Power-Plant Performance*, 80 Applied Energy 261 (2004).

[27] *See* 40 C.F.R. part 75.

[28] *See* National Emission Standards for Hazardous Air Pollutants from Coal- and Oil-Fired Electric Utility Steam Generating Units, 77 Fed. Reg. 9,304, 9,370-72 (Feb. 16, 2012) (outlining compliance reporting options for the EPA Mercury and Air Toxics rule); *Stationary Source Emissions Monitoring*, , U.S. Envtl. Prot. Agency (last visited March 11, 2018), https://www.epa.gov/air-emissions-monitoring-knowledge-base/basic-information-about-air-emissions-monitoring#stationary.

[29] U.S. Envtl. Prot. Agency, The Emissions & Generation Resource Integrated Database Technical Support Document for eGRID with Year 2016 Data 18 (2018), https://www.epa.gov/sites/production/files/2018-02/documents/egrid2016_technicalsupportdocument_0.pdf [hereafter eGrid (2016) TSD].

[30] *See Air Markets Program Data*, U.S. Envtl. Prot. Agency (last visited March 11, 2018), https://ampd.epa.gov/ampd/.

[31] *2014 National Emissions Inventory (NEI) Data*, U.S. Envtl. Prot. Agency, https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data (last visited March 11, 2018) [hereafter NEI (2014)]; U.S. Envtl. Prot. Agency, 2014 National Emissions Inventory Version 1Technical Support Document at 1-1, 1-5, 3-1 (Dec. 2016), https://www.epa.gov/sites/production/files/2016-12/documents/nei2014v1_tsd.pdf [hereafter NEI TSD].

[32] *Id.*

[33] Where state data was not available, EPA supplements the NEI with emissions using data reported directly to EPA (from CAMD data) and by multiplying heat input data by predetermined emission factors (based on AP-42). EPA also performs some modifications to state-reported data, including PM emission data. NEI TSD, *supra* note 32, at 2-7.

[34] EPA defines the $NO_x$ ozone season as the period between May 1 and October 1. During this period, $NO_x$ emissions are more likely to lead to the formation of ozone. *See, e.g.* Finding of Significant Contribution and Rulemaking for Certain States in the Ozone Transport Assessment Group Region for Purposes of Reducing Regional Transport of Ozone, 63 Fed. Reg. 57,356 (Oct. 27, 1998).

[35] U.S. Energy Info. Agency, Form EIA-923 Power Plant Operations Report Instructions https://www.eia.gov/survey/form/eia_923/instructions.pdf [hereafter Form EIA-923 Instructions]. Power plant owners report additional facility-level information on EIA form 860, which can be used to supplement the generation information reported on EIA form 923. *Form EIA-860 Detailed Data*, U.S. Energy Info. Agency (Nov. 9, 2017), https://www.eia.gov/electricity/data/eia860/.

[36] Form EIA-923 Instructions, *supra* note 35.

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