Impacts of Voluntary Renewable Energy Demand on Deployment: A Market-Based Approach

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Prepared by:

Dr. Eric O'Shaughnessy

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Summary

Millions of electricity customers in the United States voluntarily buy renewable energy through a variety of market-based procurement strategies. This procurement is called “voluntary” to distinguish it from renewable energy procured to comply with state clean energy mandates. Renewable energy use for both voluntary and compliance purposes is legally tracked through the same market-based instruments. The legal foundation of the voluntary renewable energy market lets buyers signal support for more renewable electricity. Those market signals do not necessarily map directly to the deployment of new renewable energy projects. However, the voluntary market generates revenues and long-term demand signals that are likely to affect decisions to deploy projects. In public claims (e.g., corporate sustainability reports), some voluntary buyers imply that voluntary renewable energy procurement drives the deployment of new projects. As a result, market participants and observers have become increasingly interested in the impact of the voluntary market on new renewable energy projects.

Prior research on the impacts of voluntary renewable energy demand is primarily based on modeled outcomes of individual projects or of modeled energy systems. Project- and system-level modeling provide useful but limited approaches for characterizing the full impacts of voluntary renewable energy demand. Here, we develop an alternative approach that describes voluntary market impacts in terms of the estimated effects of voluntary market functions (revenues, de-risking through long-term contracts, and long-term demand signals) on the renewable energy development industry in the aggregate. We analyze observed market-level metrics in four categories:

- **Market size.** Voluntary market sales have grown for over two decades, reaching about 319 million megawatt-hours (MWh) in 2023, or about 44% of all U.S. non-hydropower renewable energy sales.
- **Long-term contracts.** Voluntary buyers have collectively signed long-term contracts to procure energy from over 70 gigawatts (GW) of renewable energy capacity.
- **Voluntary market revenues.** An estimated $3 billion to $5 billion of voluntary market revenues accrued to the U.S. renewable energy industry from 2014 to 2023, in addition to about $5 billion to $10 billion in power sales in voluntary long-term contracts.
- **Voluntary buyer public commitments.** Hundreds of non-residential institutions have made credible public commitments to voluntarily procure renewable energy.

Based on these metrics, we estimate that the voluntary market drove 17–60% of non-hydropower renewable energy deployment outside of state clean energy mandates from 2014 to 2023, or 7–25% of all renewable energy deployment. These results suggest that the voluntary market is a key component of the U.S. renewable energy transition. We suggest that analysis

from multiple perspectives can support a more comprehensive and accurate understanding of the role of the voluntary market in the renewable energy transition.

1. Introduction

Millions of U.S. retail electricity customers voluntarily buy renewable energy through various market-based procurement strategies. This procurement is called "voluntary" to distinguish it from renewable energy procured to comply with state clean energy mandates. In this report, we use the term "voluntary demand" to refer to all voluntary procurement of renewable energy, and we use the term "voluntary market" to refer to the ecosystem of market exchanges of renewable energy between generators, market intermediaries, and end users. Voluntary market exchanges do not necessarily imply that buyers caused new renewable energy capacity to be added to the grid (Harvard Law 2024). However, the voluntary market provides additional revenues and long-term demand signals that are likely to affect the supply of renewable energy. Voluntary demand can therefore have a real-world impact on renewable energy deployment. **In this report, we explore the degree to which the voluntary market supports the deployment of new renewable energy projects.** We provide further clarity on concepts of impact in Section 2. Voluntary market stakeholders are exploring other impacts, including effects on grid emissions, environmental impacts, and social impacts. These other related impacts are important considerations for future work but are outside the scope of this report.

The voluntary market's impact on renewable energy deployment has become an area of growing interest among scholars, voluntary buyers, policymakers, and other market stakeholders. Voluntary market impacts have primarily been analyzed through modeled outcomes of individual projects or energy systems (Langer, Brander et al. 2024). Project- and system-level modeling can be powerful tools for understanding voluntary market impacts and informing the decisions of voluntary buyers. However, as will be discussed in Section 2, these modeling approaches have important limitations that affect the interpretation of results from prior studies.

Voluntary market impact research in this vein to date has supported the conclusion that broad classes of voluntary procurement strategies are not impactful (Brander 2024, Langer, Brander et al. 2024). However, this conclusion conflicts with perceptions among practitioners that voluntary demand drives renewable energy deployment (Horwitz, Fratzscher et al. 2024, O'Shaughnessy 2024), and is difficult to reconcile with basic observations of the voluntary market. By any estimate, the voluntary market has pumped billions of dollars of additional revenues on a cumulative basis into the renewable energy industry and underpins credible renewable energy procurement commitments by some of the world's largest electricity users. Economic theory would suggest that these revenues and long-term demand signals should affect supply decisions in a competitive market context such as renewable energy development.

In this report, we aim to describe voluntary market impacts in terms of the estimated effects of voluntary market functions (e.g., revenues, long-term demand signals) on the renewable energy development industry in the aggregate. For simplicity, we refer to this approach as market-level analysis. In contrast to prior research, market-level analysis ensures that market inputs (e.g., revenues) are mapped to market outputs (e.g., deployment), as is consistent with economic theory for behavior in competitive markets. The following section provides further background on voluntary market impacts, existing research, and market-level analysis.

2. Background: Voluntary market and impact research

Renewable energy use (both voluntary and compliance) is legally tracked through market-based instruments known as renewable energy certificates (RECs). RECs represent legal claims to the clean energy attributes of renewable energy generation and are the legal basis for all renewable energy use claims in the United States (Jones 2023, Harvard Law 2024). The purchase of renewable energy, as substantiated by RECs, verifies that renewable energy was generated and used, not that new renewable energy capacity was deployed (i.e., added to the grid). Voluntary demand is only one of the many factors that drive renewable energy deployment. As a result, a unit of voluntary demand cannot generally be mapped to an additional unit of renewable energy generation on a 1:1 basis. Still, voluntary demand serves market functions that should affect supply decisions in the competitive market context of renewable energy development. This section explores those market functions, how previous research has estimated voluntary market impacts, and our motivation for developing a new estimation approach.

2.1 Voluntary renewable energy market functions

Renewable energy developers face the challenge of proposing projects that can generate enough expected revenues to offset initial investment and operating costs to yield long-term profits. Forecasted profits allow developers to raise capital to cover the up-front construction costs of new projects, typically through debt and equity financing. Public subsidies (e.g., tax credits) and the long-term decline of solar and wind construction costs have improved project financial viability (Wiser, Rand et al. 2021). However, lower costs do not necessarily equate to greater profit, and renewable energy project development remains a competitive business with tight financial margins (Christophers 2024). Despite decades of falling costs, renewable energy developer profit margins have remained stable over the past decade and remain far lower than the profit margins of fossil fuel companies (Elliott 2024).

In the competitive market context of renewable energy development, economic theory suggests that supply decisions are affected by market signals such as price and long-term demand. Voluntary demand is one of the many factors that affect those market signals and can influence renewable energy development and investment decisions. Voluntary demand involves at least three market functions that can drive development decisions:

- **Revenues.** Voluntary demand provides a revenue source for renewable energy projects. Economic theory suggests that those revenues must affect renewable energy development decisions in a competitive market context. However, a unit of voluntary demand cannot be mapped to a unit of additional renewable energy supply on a 1:1 basis. Rather, voluntary market revenues affect the context in which renewable energy development and investment decisions are made.

- **De-risking through long-term contracts.** Future revenue streams are inherently uncertain and investments in renewable energy projects are inherently risky. Project developers seek to “de-risk” project finances as much as possible, primarily by fixing revenues through long-term contracts (Beiter, Guillet et al. 2023). In 2023, long-term contracts supported more than 90% of new off-site renewable energy capacity (Barbose 2024). Certain voluntary procurement strategies such as long-term power contracts and long-term REC contracts can help developers de-risk their projects and obtain investment.
- **Long-term demand signals.** Voluntary buyer commitments to procure renewable energy can create signals that affect developer and investor expectations for future revenues. Certainty around future demand can affect the long-term strategies of investors in ways that are not necessarily captured in analysis of current revenues (Birch and Siebert 1976). Insofar as voluntary commitments enhance perceptions of stable long-term demand, such commitments should facilitate project developer access to finance and drive deployment.

2.2 Review of impact research to date

Economic theory suggests that the voluntary market functions outlined above—revenues, de-risking, and long-term demand signals—affect the decisions of renewable energy developers and investors, and thus ultimately affect deployment. Analyzing the impacts of voluntary demand on renewable energy deployment could help inform voluntary buyer decisions and frameworks that shape the voluntary market.

In a review of studies analyzing voluntary market impacts, Langer et al. (2024) found that scholars have largely explored voluntary market impacts through financial modeling of individual projects (i.e., project-level modeling) (Gillenwater 2008, Gillenwater 2013, Gillenwater, Lu et al. 2014, Brander, Gillenwater et al. 2018) or through energy systems modeling (i.e., system-level modeling) (Olson, Patel et al. 2024, Xu, Ricks et al. 2024). Langer et al. note that studies have generally analyzed impact in terms of whether certain actions cause outcomes that would not have occurred in counterfactual scenarios without those actions. We will refer to this framework as counterfactual analysis, though the literature often uses the term “additionality” to describe the same concept.

Project- and system-level modeling to date have yielded diverse conclusions about the impacts of different voluntary market procurement strategies. For the purposes of this report, we summarize two key conclusions and claims that have emerged from these analyses:

- Many studies conclude that REC revenues do not meaningfully drive renewable energy project development decisions (Gillenwater 2008, Gillenwater 2013, Gillenwater, Lu et al. 2014, Brander, Gillenwater et al. 2018), a conclusion that is often cited in the broader discourse (O’Shaughnessy 2024). A core assertion in these conclusions is that REC prices are lower than the volumetric prices of other revenue streams such as power or tax credits. Scholars also note that investors may discount the value of future revenues obtained from RECs sold through near-term market exchanges (as opposed to through long-term contracts). Under those assumptions, scholars argue, REC revenues do not meaningfully drive renewable energy deployment.

- Recent system-level modeling suggests that voluntary long-term contracts do not add renewable energy capacity beyond what would have otherwise occurred without that voluntary demand (Xu, Ricks et al. 2024). The core assumption behind that conclusion is that the voluntary market primarily supports projects that would have otherwise been supported by other market activity, or that those projects displace projects that would have otherwise been built.

A critical examination of these conclusions is outside the scope of this study (see O'Shaughnessy and Sumner (2023) and O'Shaughnessy (2024) for a discussion of limitations of these conclusions). For the purposes of this study, it suffices to acknowledge that project- and system-level modeling are both useful but incomplete approaches for measuring and describing voluntary market impacts. To further highlight the need for alternative methodologies, we briefly discuss some of the key strengths and limitations of existing approaches.

2.2.1 Project-level modeling: Strengths and limitations

Project-level modeling is particularly useful for informing the project-level procurement decisions of voluntary market intermediaries or voluntary buyers that directly engage with specific projects. Market intermediaries could be utilities, competitive retail electricity suppliers, REC marketers, or other parties that procure power and RECs from specific projects and resell that renewable energy in retail products. Those intermediaries could use project-level analysis to identify opportunities to maximize the project-level impacts of their procurement decisions. Similarly, relatively large voluntary buyers that directly engage with specific projects (e.g., through power purchase agreements, or PPAs) could use project-level analysis to optimize their decisions around which projects to support.

The key limitation of project-level modeling is that the approach treats the voluntary market as a series of isolated transactions. Yet markets are highly complex systems that involve the interactions of many actors with idiosyncratic goals. Due to that complexity, markets have properties that cannot be observed in isolated transactions and only emerge from the interactions of component parts (Harper and Lewis 2012). A simple example is the effect of project-level profitability. In some cases, voluntary market revenues (e.g., REC revenues) may increase the profits of projects that were already profitable. Project-level modelers have argued that such revenues are not impactful, as they do not play decisive roles in project outcomes. However, the aggregate profit margins of renewable energy development are relatively meager (Elliott 2024). Revenues that increase profits for already-profitable projects may bolster the overall viability of individual renewable energy developers or the industry in the aggregate. More broadly, for developers, the existence of the voluntary market creates additional revenues and transactional flexibility that facilitate the process of financing projects (Horwitz, Fratzscher et al. 2024, O'Shaughnessy 2024). Project-level analysis can reach erroneous conclusions by ignoring impacts that cannot be observed at the level of individual transactions.

2.2.2 System-level modeling: Strengths and limitations

System-level analysis is particularly useful for academic research on the impacts of the voluntary market on renewable energy deployment. System-level methodologies based on counterfactual analysis will yield the closest approximation to the change in renewable energy deployment that results from the voluntary market accounting for all relevant factors, such as market displacement (Cannon, Gagnon et al. 2024). System-level analysis could ultimately influence the procurement strategies of large buyers and inform the design of renewable energy products for small buyers seeking to maximize impacts. System-level analysis can help buyers identify procurement strategies that minimize the displacement of other market activity and thus maximize the degree to which buyers fundamentally change renewable energy deployment outcomes.

The key limitation of system-level modeling to date is the reliance on a counterfactual of “market-driven” projects (Langer, Brander et al. 2024, Xu, Ricks et al. 2024) that does not, in our view, usefully approximate reality. The concept of the counterfactual market has never been precisely defined but appears to stand for market activity based on the sale of undifferentiated energy rather than *renewable* energy as a premium green product, implying revenues from wholesale power markets or contracts with regulated utilities outside of state clean energy mandates. System-level modeling has been used to argue that voluntary demand (Langer, Brander et al. 2024, Xu, Ricks et al. 2024) and compliance demand (Deschenes, Malloy et al. 2023, Feldman and Levinson 2023) have limited impacts on renewable energy deployment relative to the counterfactual market. The conclusion that billions of dollars in REC revenues from compliance and voluntary markets have limited impact is difficult to square with the highly competitive, low-margin nature of renewable energy development. Further, while system-level research assumes that “market-driven” projects are deployed (Langer, Brander et al. 2024), proposed projects in the real world must still clear a gauntlet of deployment barriers such as permitting challenges, interconnection delays, supply chain issues, financial market volatility, and local opposition. Available evidence suggests that the counterfactual market has not played a key role in renewable energy deployment to date. Developers and investors frequently avoid exposure to undifferentiated power markets by seeking de-risked revenue streams such as long-term power and REC contracts with voluntary buyers (Christophers 2024, Olson, Patel et al. 2024). In 2023, less than 10% of new off-site renewable energy project capacity came online without some form of long-term contract in place (Barbose 2024). Projects may, to some degree, obtain de-risked revenues through long-term contracts with wholesale electricity suppliers such as utilities. Yet utility demand likely cannot replace voluntary demand in terms of the pace and scale of enabled deployment (O’Shaughnessy 2024), and developers may prefer contracts with voluntary buyers who are often more willing to accept investor-friendly contractual terms (Christophers 2024). For these reasons, we argue that previous system-level conclusions likely underestimate the impact of the voluntary market by overestimating deployment supported in the counterfactual market.

2.3 Study motivation: Market-level analysis

As noted in the preceding section, project- and system-level modeling have produced results that suggest that certain types of voluntary procurement strategies do not meaningfully drive the development of new renewable energy projects. These conclusions are internally consistent in frameworks that analyze the voluntary market as a series of isolated transactions (project-level modeling) or as an interchangeable component of energy systems (system-level modeling). However, these conclusions contradict economic theory, which would suggest that development decisions in a competitive market context cannot be immune to the revenues, de-risking, and long-term demand signals provided by the voluntary market.

Our objective is to develop an alternative approach for exploring voluntary market impacts that addresses some of the limitations of project- and system-level modeling. Our alternative is to treat voluntary demand as a component of a broader competitive market of renewable energy development. Within the boundaries of that competitive market, the voluntary market functions defined in Section 2.1 (revenues, de-risking, long-term demand signals) necessarily affect the revenue expectations and long-term strategies of renewable energy developers and investors. We therefore estimate voluntary market impacts in terms of the expected effects of voluntary market functions on the renewable energy development industry in the aggregate. For simplicity, we refer to our approach as market-level analysis.

Market level analysis: An approach that estimates the impacts of the voluntary market on renewable energy deployment in terms of the expected effects of voluntary market functions (revenues, de risking through long term contracts, and long term demand signals) on the renewable energy development industry in the aggregate. The approach ensures that voluntary market inputs are mapped to renewable energy market outputs.

The core distinguishing feature of the market-level analytical framework is that market inputs must result in market outputs. Under the framework, voluntary actions that create market signals in the form of revenues, de-risking through long-term contracts, or long-term demand signals must have some effect on renewable energy development in the aggregate. Such effects are not necessarily perceptible at the level of individual projects, but economic theory suggests that all market signals affect the supply decisions of the renewable energy development industry in the long run. The analytical challenge in market-level analysis is to quantify the relationship between voluntary market inputs and the market output of project development. The approach we apply in this report is to quantify that relationship using assumptions around the responsiveness of renewable energy supply to changes in revenues, also known as the price elasticity of supply. Other potential methods could be applied in the future.

Market-level analysis is a causal framework; the approach does not assume a 1:1 attribution of voluntary demand to renewable energy supply. However, unlike most prior voluntary market impact models, that causal framework is not premised on counterfactual change or what is often termed "additionality" in the literature.[1] Market-level analysis estimates the volume of *observed* renewable energy deployed that is caused by *observed* voluntary market activity, independently from what could have occurred in a counterfactual scenario. To illustrate this distinction with a simple example, suppose a voluntary buyer signs a long-term power and REC contract that enables a developer to obtain financing and build a project. In that example, market-level analysis would assign impact to the voluntary buyer's action, as the observed action causes the real-world project outcome. However, the project would not necessarily have been built in a counterfactual without that buyer's action (e.g., the project could have obtained a contract with a different buyer). For this reason, we speak in terms of how the voluntary market "drives" renewable energy deployment, rather than in counterfactual terms about how the market "adds" renewable energy capacity. We discuss the appropriate interpretation of our results in Section 3.5.

Market-level analysis, project-level modeling, and system-level modeling ask and answer different questions and can all be usefully applied in different contexts (Table 1). Market-level analysis assigns impact to the real-world actions that drive real-world deployment. As a result, market-level analysis may be a particularly useful tool for relatively small voluntary buyers who seek to understand how their participation in the voluntary market can drive renewable energy deployment in the aggregate. Project- and system-level counterfactual modeling remain important tools for certain buyers and in academic exercises in specific contexts.

Table 1. Three Approaches to the Measurement of Voluntary Market Impacts

Approach		Insights and Applications	Limitations
Project	How do voluntary market actions affect the outcome of an individual project?	Demonstrates how impacts may vary across procurement strategies and across individual projects; can inform project-level decisions to optimize voluntary buyer decisions	Does not account for impacts that only emerge across multiple transactions (see Section 2.2.1)
System	How does the voluntary market affect the capacity deployed in an energy system?	Quantifies the impacts of the voluntary market on projects, accounting for the displacement of other market activity; particularly useful for large buyers seeking to maximize system-level change	Relies on a theoretically constructed baseline "market" that may mischaracterize market activity in the real world (see Section 2.2.2)
Market	What is the renewable energy development market output that can be expected from voluntary market inputs?	Characterizes and quantifies the aggregate impacts that should be plausibly associated with observed voluntary market activity; informs the marginal contributions of individual actions to aggregate market impacts	Not suitable for analysis of additionality

[1] A third approach would be to estimate impact through statistical identification in empirical models. This approach has been rarely applied in the literature and may not be a viable approach given the substantial methodological challenges of statistical identification in this context (O'Shaughnessy and Sumner 2023).

In the following section, we develop a market-level analysis by describing the effects of voluntary demand on renewable energy supply in terms of four aggregate market metrics.

3. Voluntary market metric analysis

The following four sub-sections describe four categories of voluntary market metrics that inform our market-level analysis. Each sub-section begins with a summary that defines the metric, describes why the metric matters in theory, and summarizes the results. Methodological details for the analyses in this section can be found in the Methodological Appendix. We present results using the best available data. In certain cases, we focus on data from 2014 to 2023, both to produce estimates that reflect a decade of voluntary market activity and to emphasize results on more recent and reliable voluntary market data. In Section 3.5, we explore how the four market-level metrics can help describe the impacts of the voluntary market on renewable energy deployment.

3.1 Market size

What it is: Number of customers buying voluntary renewable energy and the total volume of voluntary market sales (MWh).

Why it matters: Market size correlates with key mechanisms that drive project development, such as voluntary market revenues and market signals for long term demand stability. The size of the voluntary market should thus correlate with the market's overall impact on renewable energy supplies.

Summary of results: In 2023, around 9.7 million customers procured around 319 million MWh of renewable energy in the U.S. voluntary green power market. Voluntary market sales accounted for around 44% of all U.S. non hydropower renewable energy generation in 2023. Voluntary demand has consistently grown for over two decades.

All else equal, one would expect aggregate voluntary market functions (revenues, de-risking through long-term contracts, and long-term demand signals) to scale with the size of the voluntary market. More voluntary demand will thus generally equate to greater impacts on the renewable energy industry and on deployment.

In 2023, about 9.7 million customers procured around 319 million MWh of voluntary renewable energy (O'Shaughnessy, Jena et al. 2024).[2] Those numbers suggest that the voluntary market procured RECs equivalent to around 44% of all U.S. non-hydropower renewable energy generation, and around 8% of all U.S. retail electricity sales. In the decade from 2014 to 2023, about 1.7 billion MWh of renewable electricity was sold in the voluntary market. Annual data

[2] These estimates are compiled by the National Renewable Energy Laboratory based on a mixture of survey data, data from market intermediaries, and estimates from data compilers such as the U.S. Energy Information Administration. Market values should be interpreted as point estimates based on the best available data.

show that the U.S. voluntary renewable energy market has consistently grown over time (Figure 1).

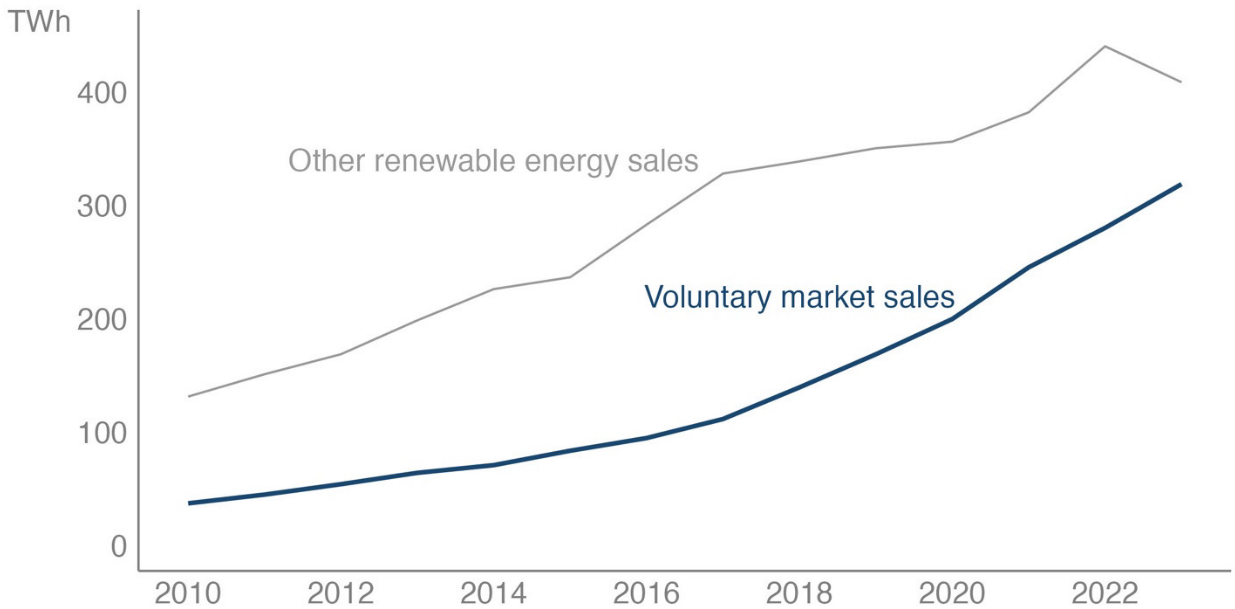

Figure 1. Voluntary renewable energy sales, 2010–2023. Based on data from O'Shaughnessy et al. (2024).

Voluntary renewable energy demand and supply exhibit important regional variation (Figure 2). Voluntary buyers are distributed throughout the United States, with leading sources of demand concentrated in states with community choice aggregation (California, Massachusetts, New York, Ohio), competitive retail electricity markets (e.g., Pennsylvania, Texas), and strong participation in utility green pricing programs (e.g., Oregon, Washington). Voluntary renewable energy supply, in contrast, is much more concentrated. Three states—Kansas, Oklahoma, and Texas—account for more than half of voluntary renewable energy generation.

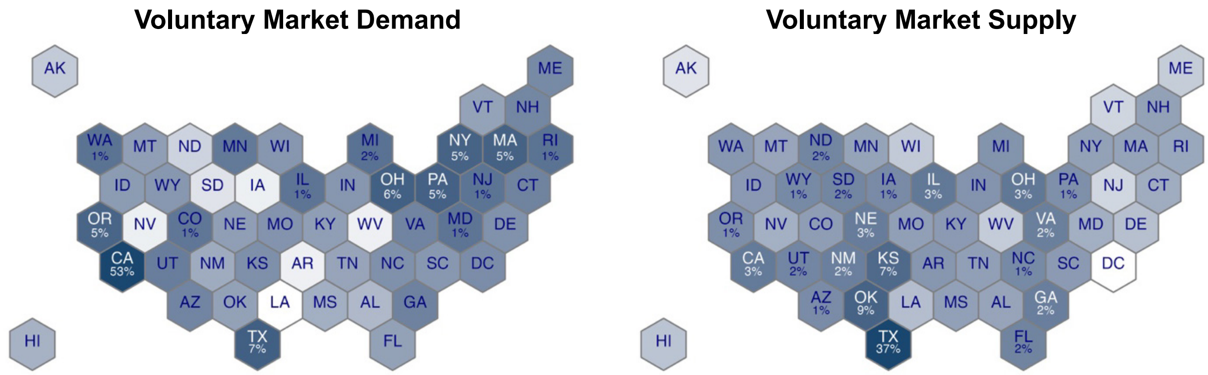

Figure 2. Distributions of voluntary market shares in terms of demand (left) and supply (right) by state in 2023. Based on data from O'Shaughnessy et al. (2024).

The spatial distribution of voluntary renewable energy generation can help clarify the relationship between voluntary market size and deployment impacts. A striking characteristic of the spatial distribution illustrated in Figure 2 is the concentration of voluntary demand in states without binding renewable energy mandates, commonly known as renewable portfolio standards (RPS). About 72% of voluntary renewable energy procured in 2023 derived from 23 states without binding RPS (though generators in some of these states may be able to sell renewable energy into adjacent states with RPS requirements). That correlation is not coincidental. In RPS states, voluntary buyers compete with regulated electricity suppliers for scarce REC supplies. Unlike voluntary buyers, regulated electricity suppliers are mandated to procure RPS-compliant RECs at whatever price is required to achieve compliance.[3] As a result, REC prices are generally higher in RPS states, as regulated suppliers procure renewable energy from generators with increasingly higher costs. That correlation is reinforced by the fact that development costs are generally higher in regions with binding RPS requirements (e.g., the Northeast) and lower in regions without binding RPS requirements (e.g., Oklahoma and Texas). Regulated suppliers generally outbid voluntary buyers for scarce RECs in RPS states, suppressing voluntary demand in those states or pushing voluntary buyers to procure RECs from other regions. Further, voluntary buyers with facilities in RPS states may procure power from local renewable energy generators but "swap" the RPS-compliant RECs for lower-priced RECs from regions without binding RPS requirements. In non-RPS states, in contrast, competition for RECs occurs primarily among voluntary buyers. As a result, voluntary REC demand can complement compliance REC demand by filling in the gaps in non-RPS states.

[3] Some states allow regulated suppliers to pay fees in lieu of buying RECs, but those fees are typically priced in ways that incentivize suppliers to bear higher REC prices than those typically observed in voluntary REC benchmark prices.

3.2 Voluntary power and REC contracts

What it is: Renewable energy project capacity supported by long term power and REC contracts with voluntary buyers.

Why it matters: Voluntary long term power and REC contracts de risk renewable energy project revenues, facilitating project access to investment and ultimately driving deployment.

Summary of results: At least 230 voluntary buyers have signed long term contracts for around 72 GW of solar and wind power. We estimate that operational projects will generate around 137 million MWh of renewable power in 2024.

Most renewable energy projects depend on stable or "de-risked" revenues from long-term contracts for power (Christophers 2024). Power buyers in these contracts are mostly utilities and other retail electricity suppliers. However, voluntary demand for long-term power contracts has grown rapidly over the past decade (Barbose 2024, O'Shaughnessy, Jena et al. 2024). Long-term power contracts de-risk projected project revenues in ways that help projects obtain investment (see Section 2.1). As a result, a near consensus among scholars is that voluntary long-term contracts are impactful (Bjørn, Lloyd et al. 2022).

Voluntary contractual procurement strategies include PPAs, utility-sleeved contracts, and long-term "unbundled" REC contracts. In a PPA, a buyer signs a long-term contract to procure the power and REC output of a project over a specified term, typically around 10 to 20 years. PPAs come in two main varieties. In a "physical" PPA, the project sells output to the buyer at a contractually determined rate. In a financial or "virtual" PPA, the project sells output into a wholesale market and hedges those sales through a financial agreement with a buyer. The project financial implications of physical and financial PPAs are largely the same: both contract structures de-risk future power revenues. In both cases, the contracts must include project RECs for buyers to make valid claims to renewable energy use. A utility-sleeved contract is essentially a physical PPA where a utility acts as an intermediary between a project and the contractual buyer. A long-term unbundled REC contract is a contract where the buyer only procures RECs sold separately or "unbundled" from the underlying power with no contract for the power. Unlike data on PPAs and utility-sleeved contracts, data on long-term unbundled REC contracts were not available for this analysis.

The growth of PPAs and utility contracts serving voluntary demand is evident from multiple sources. Here, we rely primarily on voluntary power contract data compiled by S&P Global (S&P 2024). The S&P data suggest that at least 230 voluntary buyers had signed long-term power contracts in the United States for over 72 GW of solar or wind power by the end of 2024. That estimate is comparable to a similar estimate from the Clean Energy Buyers Association that voluntary buyers signed over 77 GW of long-term power contracts from 2014 through the end of 2023. Until 2020, voluntary long-term contracts were primarily signed to procure wind power, but there is a clear shift toward solar contracts in subsequent years (Figure 3). Based on state-level capacity factors for solar and wind, we estimate that voluntary contracted capacity generated about 137 million MWh of renewable power in 2024.

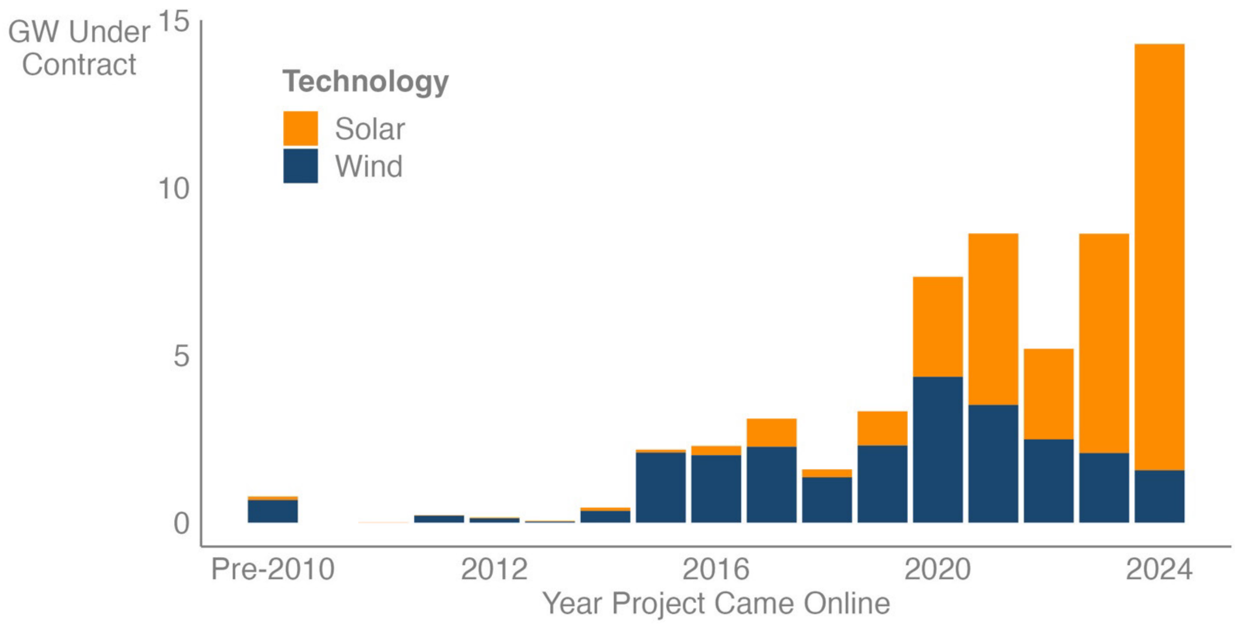

Figure 3. New renewable energy capacity supported by voluntary PPAs. Based on data from S&P (2024).

The S&P data suggest that output from projects with voluntary long-term contracts grew from about 5 million MWh before 2014 to 109 million MWh by the end of 2023, indicating that those projects added around 104 million MWh over the course of the decade. Using different data, O'Shaughnessy et al. (2024) estimate that around 148 million MWh of renewable energy was procured through voluntary long-term contracts in 2023. For comparison, data from the U.S. Energy Information Administration suggests that nationwide solar and wind output increased by around 453 million MWh over the same time period (Figure 4). By these estimates, about 23% of solar and wind output added to the grid over the past decade was supported by voluntary long-term power contracts, and about 34% of all off-site renewable energy capacity brought online in 2023 was supported by voluntary long-term power contracts.

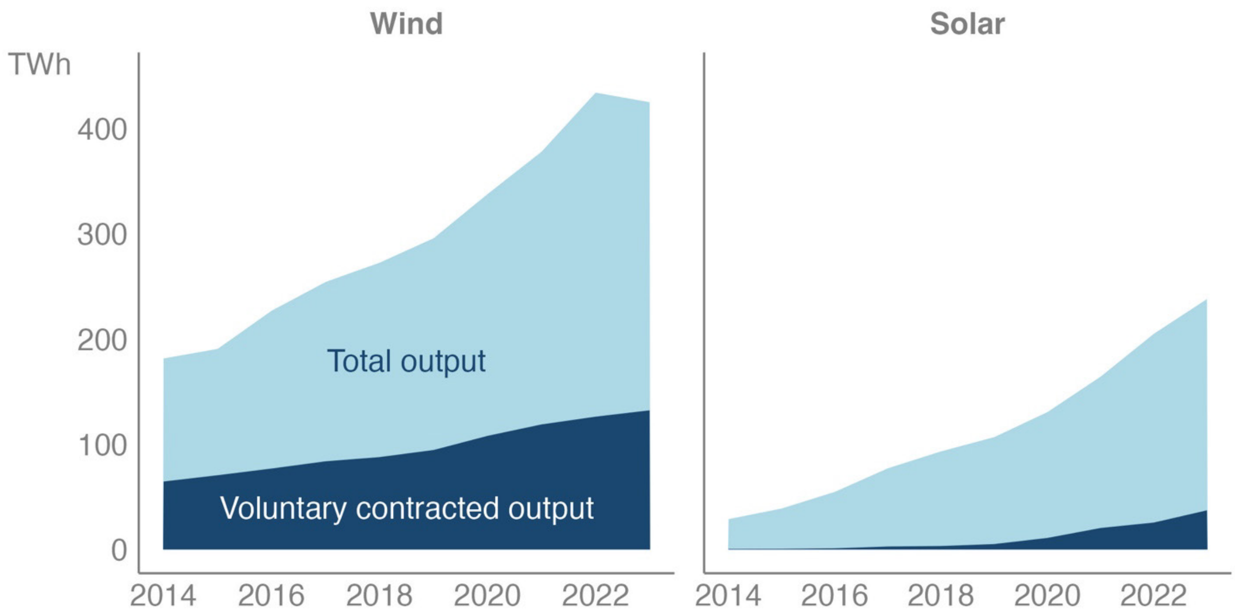

Figure 4. Renewable energy output under voluntary long-term contracts. Based on data from S&P (2024) and the U.S. Energy Information Administration.

3.3 Voluntary market revenues

What it is: Additional revenue streams for renewable energy projects from voluntary RECs and voluntary long term power contracts.

Why it matters: Voluntary demand provides revenues for renewable energy projects additional to other sources such as power sales. Economic theory indicates that those added revenues affect renewable energy supplies in the competitive market context of project development.

Summary of results: We estimate that $2.7 billion to $4.9 billion in voluntary REC revenues accrued to renewable energy projects from 2014 to 2023, in addition to around $5 billion to $9 billion in power revenues from projects under long term contracts with voluntary buyers.

Renewable energy developers and investors are profit-driven companies operating in a competitive market environment. Economic theory suggests that voluntary market revenues necessarily affect the decisions of renewable energy developers and investors. Voluntary market revenues are primarily a function of voluntary demand and REC prices in the case of RECs procured outside of long-term contracts. In the case of long-term contracts, voluntary market revenues also, in most cases, include revenues determined through fixed power prices in long-term voluntary power contracts (we explain in further depth in Section 3.3.2 why some power revenues are not necessarily attributable to voluntary market demand). We develop separate estimates of these two revenue streams in the following two sub-sections. All estimates are in inflation-adjusted 2023 dollars.

3.3.1 Voluntary REC revenues

Voluntary REC prices vary over time and space in response to trends in the supply of and demand for RECs. There is no database that tracks REC prices across all individual REC transactions. Instead, we must rely on market benchmarks such as average reported wholesale REC prices. Market benchmark prices are imperfect reflections of real REC prices. One issue is that benchmark prices exclude transactions where RECs are not separately monetized, such as in long-term bundled power contracts where buyers pay a single price for power and RECs. Further, benchmark average prices skew toward the prices of wind RECs, and especially the prices of relatively low-priced wind RECs from Kansas, Oklahoma, and Texas. Average prices also do not reflect variation in REC prices across markets, buyers, and transactions.

With those caveats in mind, Figure 5 illustrates benchmark prices from 2010 to 2024 for two commonly reported price indices: 1) benchmark prices for wind RECs sold in the Western Electricity Coordinating Council (WECC) interconnection; and 2) benchmark prices for “national” wind and solar RECs, meaning wind RECs traded throughout the United States generated primarily outside of RPS states. National REC benchmark prices hovered around \$0.5 to \$1.5 (in nominal terms) for much of the past decade before jumping above \$2 in 2021 and, at times, above \$4 in 2022. Available data suggests that REC benchmark prices have fallen below their 2022 peak but remain above pre-2021 levels. We estimate that the generation-weighted average voluntary REC price across the full time period is in the range of \$2.2 to \$3.7 (see Methodological Appendix).

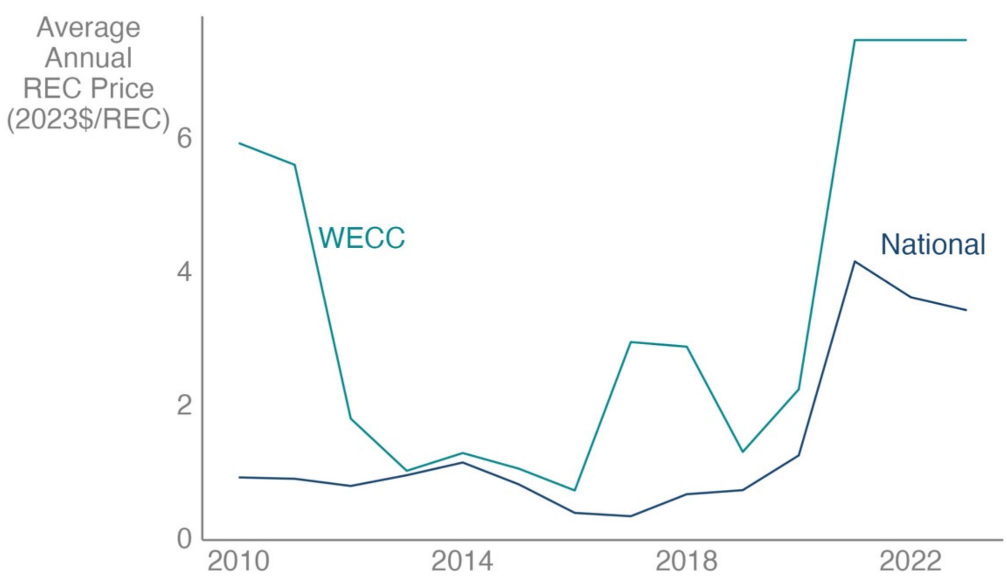

Figure 5. Annual averages for REC benchmark prices. See Methodological Appendix for details on derivation.

Figure 6 depicts ranges of estimated annual voluntary REC revenues accruing to renewable energy projects based on ranges of assumptions around REC prices, contractual terms, and transaction costs (see Methodological Appendix). In 2023, we estimate that around $870 million to $1.4 billion in voluntary REC revenues accrued to renewable energy projects. Lenoir & Wilson (2024) estimate that voluntary REC revenues could reach as high as $1.7 billion in 2024 and grow to $7.6 billion by 2033.[4] We estimate that cumulative REC revenues over the decade from 2014 to 2023 are in the range of $2.7 billion to $4.9 billion. The relatively large jump in estimated REC revenues from 2020 to 2021 depicted in Figure 6 is attributable to the spike in voluntary REC prices depicted in Figure 5. The upper-bound estimates from 2021 to 2023 assume that voluntary buyers did not alter their REC procurement practice in response to that price spike. However, given that many voluntary buyers face fixed renewable energy procurement budgets, it is likely that some buyers avoided those higher REC prices by changing procurement strategies, such as by buying relatively lower-priced RECs generated in prior years or by buying lower-priced RECs from large hydropower generators (Zemanek 2021). The lower-bound estimates from 2021 to 2023 reflect that possibility by assuming that the higher prices only applied to new REC demand while all pre-existing REC demand paid REC prices based on 5-year rolling averages (see Methodological Appendix for further clarity).

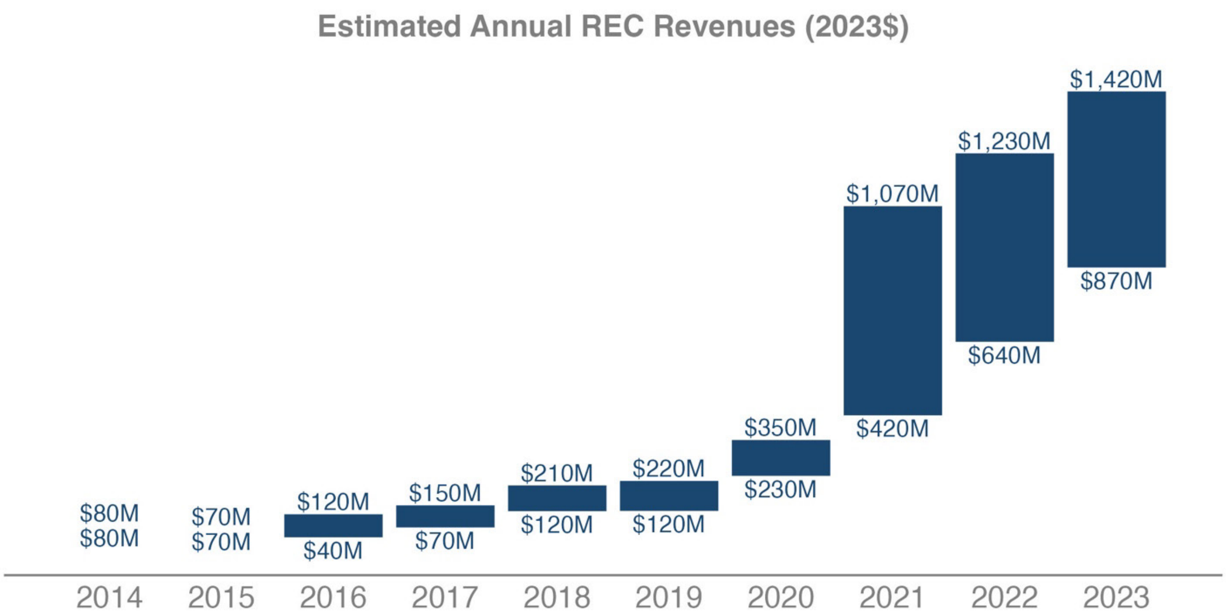

Figure 6. Estimated annual voluntary REC revenues. See Methodological Appendix for details on derivation.

The potential impacts of REC revenues could possibly be best understood in relative terms. Figure 7 depicts average annual REC prices as shares of average annual PPA prices across distinct regions (see Methodological Appendix for methodological details). The analysis is imperfect in several ways, including that annual REC trading prices may not reflect the REC prices accruing to

[4] The estimate by Lenoir & Wilson is based on estimated differences between total REC sales and compliance REC sales. That estimate includes some procurement by retail electricity suppliers above their RPS requirements as a form of "voluntary" procurement, though the authors of that estimate note that growth in voluntary REC revenues is driven largely by growing corporate demand.

projects with PPAs. However, the analysis generally suggests that REC revenues constitute around 2–5% of power revenues until 2020 before increasing to 10–15% in recent years. Those estimates generally agree with observations from interviewees in O'Shaughnessy (2024) that RECs typically compose around 5–10% of project revenues. We estimate that the generation-weighted average share of revenues across the full time period is 8–14% (see Methodological Appendix). For reference, the median annual financial return for renewable energy developers has hovered around 2% for the past decade (Elliott 2024), suggesting that REC revenues have a meaningful impact on renewable energy developer finances.

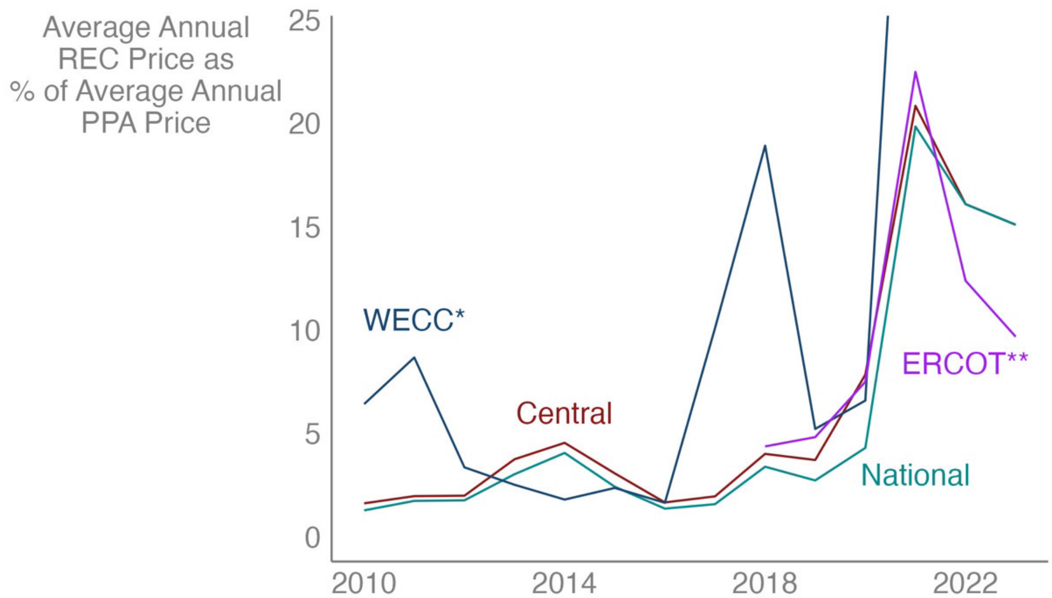

Figure 7. Average annual REC prices as percentages of annual average wind PPA prices.
*** The figure is cropped at 25% for visual clarity but note that benchmark WECC prices from 2021 to 2023 imply that RECs compose more than 25% of project revenues.**

**** Data only available for Electric Reliability Council of Texas (ERCOT)-specific prices beginning in 2018.**

3.3.2 Contracted power revenues

With PPAs, voluntary buyers provide long-term power revenues in addition to REC revenues. We estimate the volume of these power revenues as another way of describing the impacts of voluntary demand on project development. The rationale for analyzing these revenues is that the willingness of voluntary buyers to sign long-term power contracts is typically contingent on the ability to access RECs via those contracts (Christophers 2024, O'Shaughnessy 2024). As a result, the de-risked power revenues from these projects can be understood as an ancillary benefit of the voluntary market. One key exception is PPAs with REC swaps, where the voluntary buyer signs a long-term power contract with one project but procures RECs from a different project, typically in a region with lower REC prices. Feedback from customers in the U.S. Environmental Protection Agency's (EPA's) Green Power Partnership suggests that REC swaps typically occur in cases of long-term contracts for solar projects in states with solar generation mandates, primarily limited to the northeastern United States (though participants in the Partnership are not necessarily representative of all buyers of long-term contracts).

Figure 8 depicts a range of estimated annual revenues from voluntary PPAs from 2014 to 2023 (see Methodological Appendix for derivation details). The upper end of the range is based on estimated power revenues from all long-term contracts signed by voluntary buyers, some of which may reflect revenues from projects with REC swaps. The lower end of the range is limited to revenues from Kansas, Nebraska, Oklahoma, and Texas, where relatively low REC prices would suggest that REC swapping is minimal in long-term contracts. According to that range, we estimate voluntary PPAs generated around $1.2 billion to $2.6 billion in power revenues in 2023, or around $4.7 billion to $9.5 billion over the full time period.

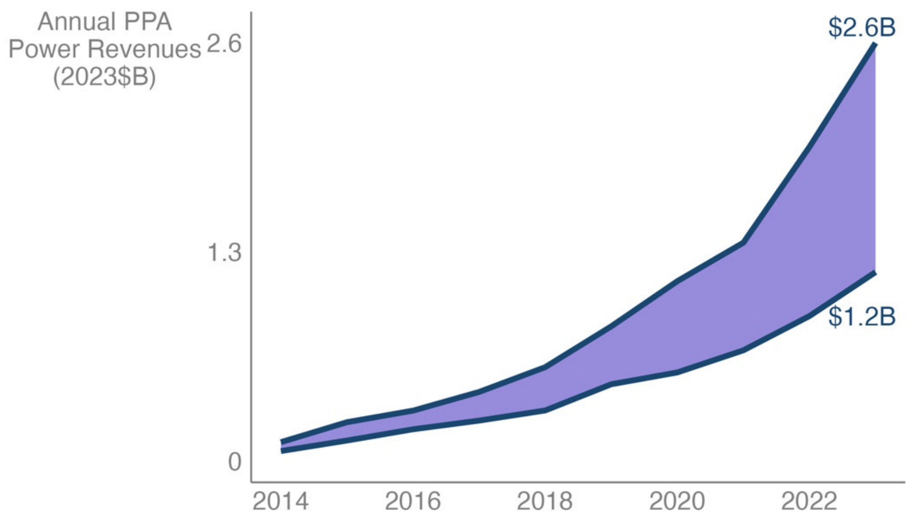

Figure 8. Estimated annual power revenues from voluntary PPAs signed from 2014–2023. See Methodological Appendix for details.

3.4 Voluntary buyer public commitments

What it is: Public commitments by buyers to procure specified levels of renewable energy.

Why it matters: Voluntary buyer commitments signal long term demand stability. That stability can improve developer and investor confidence, facilitate long term planning, and ultimately increase investment and deployment in the long term.

Summary of results: Hundreds of companies have made credible long term commitments to procure renewable energy, with most companies committing to procuring the equivalent of 100% of annual electricity use. By any estimate, these public commitments equate to future demand for renewable energy supply on the order of dozens of gigawatts of capacity.

Many large retail electricity buyers such as corporations, local governments, universities, and nonprofit institutions have made public commitments to procure renewable energy. These public commitments do not directly translate to increased renewable energy supply in the same way as, say, signing long-term power contracts. However, public commitments could provide long-term signals of stability in the demand for renewable energy. Perceptions of demand stability are fundamental to investment decisions (Birch and Siebert 1976). Project developers can confidently expand their business only with the knowledge that renewable energy demand will be strong for the foreseeable future. Similarly, investors require stable long-term revenues that ensure stable long-term financial returns. Public commitments could bolster perceptions of market stability and create a more conducive environment for renewable energy development and investment.

Renewable energy commitments can come in many forms. Here, we summarize data on public renewable energy commitments in four venues: RE100, the Clean Energy Buyers Association, EPA's Green Power Partnership, and the public commitments of data center operators. Note that many buyers have made commitments across several of these venues, and the estimates below should not be interpreted as additive.

RE100 is a consortium of companies that have made public commitments to power their operations entirely through renewable electricity. As of the end of 2024, RE100 comprised 403 companies with worldwide annual electricity use of 481 million MWh, or about 1.7% of global electricity generation (RE100 2024). Figure 9 depicts the target years for 98 RE100 companies headquartered in the United States. Most of those companies reported being at least halfway toward 100% renewable electricity use as of 2022, with 15 companies having already achieved 100% renewable energy by 2022.

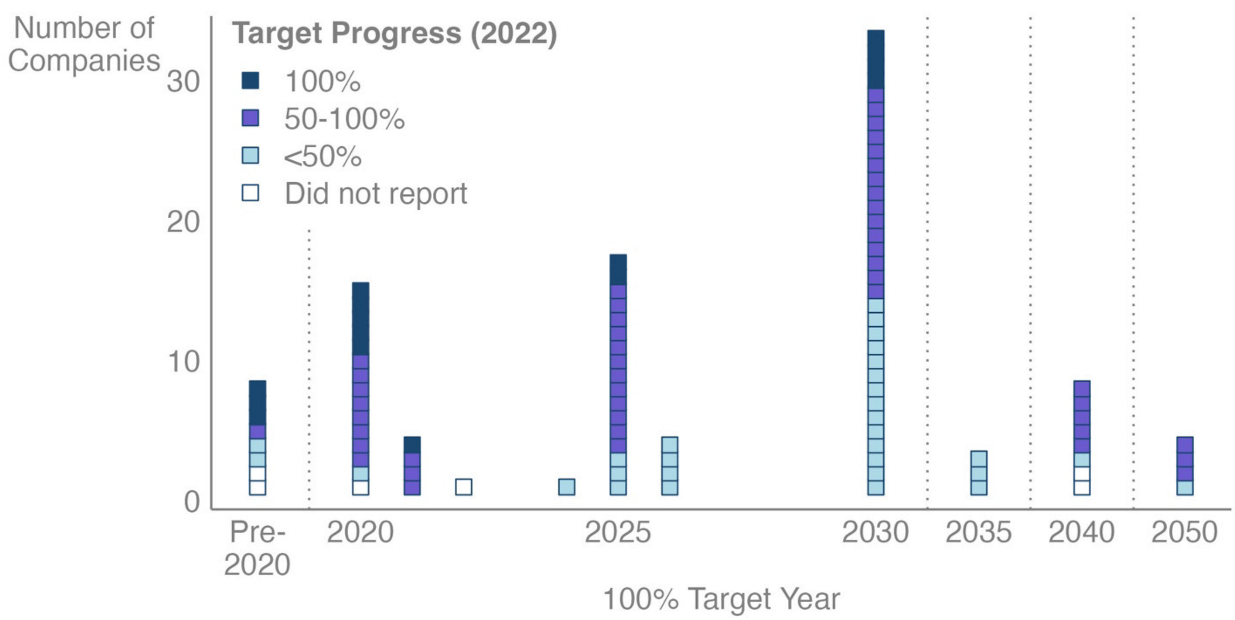

Figure 9. 100% renewable energy target years for U.S.-headquartered companies in the RE100 partnership. Based on data from RE100 (2024).

The Clean Energy Buyers Association is a U.S.-based consortium of large clean energy buyers. The Association has set a target of achieving a 90% carbon-free U.S. electricity system by 2030 through voluntary renewable energy procurement. As of September 2024, the Association comprised 420 members. As of the end of June 2024, Association members had collectively signed contracts for 43 GW of operational capacity and had committed to procuring a total of 84 GW of capacity in the coming years (CEBA 2024).

The Green Power Partnership is a voluntary program led by EPA to encourage voluntary renewable energy procurement. As of September 2024, the Green Power Partnership comprises 630 companies and 89 communities committed to best practices in voluntary renewable energy procurement. Since its inception in 2001, members of the Green Power Partnership have procured over 650 million MWh of voluntary renewable energy. At least 262 partners have made public renewable energy procurement commitments (the Partnership does not require partners to report commitments, and the number of commitments reflects a lower-bound estimate of the number of commitments in the Partnership). Collectively, those commitments reflect about 90 million MWh of annual electricity use, or about 102 million MWh when including carbon-free (not necessarily renewable) commitments.

Finally, data center providers represent a large share of voluntary renewable energy commitments (S&P 2024). In 2023, just five data center providers—Amazon, Apple, Google, Meta, and Microsoft—accounted for over half of corporate renewable energy demand (Wilson 2023). All five of the key data center providers have made public commitments to procure 100% renewable or carbon-free electricity. Those commitments ensure significant future investments in renewable energy as more data centers are built. One analysis suggests that data centers could add between 50 and 250 million MWh of new electricity demand between 2023 and 2030 (Aljbour and Wilson 2024). There are merited concerns about the emissions impacts of that increased demand. Notwithstanding those concerns, the public commitments of the key data center providers suggest that most or all that increased demand will either be powered by or matched with renewable energy supply.

3.5 Market-level analysis

In this section, we aim to translate the market-level metrics from Sections 3.1–3.4 into causal statements about the impacts of the voluntary market on renewable energy deployment. Before proceeding, we reiterate that all methodologies for estimating voluntary market impacts, including market-level analysis, have substantial limitations. We therefore provide ranges of estimated impacts rather than point estimates to better reflect the uncertainty of the results.

To briefly summarize the preceding four sections, market-level metrics indicate that 1) voluntary market sales have grown for over two decades, reaching about 319 million MWh in 2023, representing about 44% of all U.S. non-hydropower renewable energy sales; 2) voluntary buyers have collectively signed long-term contracts to procure energy from over 70 GW of renewable energy capacity; 3) an estimated $3 billion to $5 billion of voluntary REC revenues accrued to the U.S. renewable energy industry in the decade from 2014 to 2023, in addition to about $5 billion to $10 billion in power sales to voluntary buyers with long-term power contracts; and 4) hundreds of non-residential institutions, including some of the country's largest electricity customers, have made credible public commitments to voluntarily procure renewable energy. These market-level metrics provide some indication of the ways in which the voluntary market affects the revenue expectations and long-term planning of renewable energy developers and investors. The challenge in market-level analysis is to quantify those effects.

At a minimum, the voluntary market has provided a stable source of additional revenues for the U.S. renewable energy industry. Our analysis in Section 3.3 suggests that renewable energy generators sold around $2.7 billion to $4.9 billion worth of RECs to voluntary customers from 2014 to 2023. We estimate that voluntary REC revenues increased renewable energy project market revenues by around 8–14% during that decade (for those projects that sold voluntary RECs, see Methodological Appendix). The impacts of those revenues on renewable energy supply depends on the price elasticity of renewable energy supply, i.e., how much a percent change in price drives a change in the supply of renewable energy capacity. Only one study, to our knowledge, attempts to estimate the price elasticity of renewable energy supply. Johnson (2011) estimates supply elasticity to compliance REC prices of 2.7, meaning that a 1% increase in prices drives a 2.7% increase in renewable energy supply. The assumption that renewable energy supply is price elastic—i.e., a 1% increase in price drives at least a 1% increase in supply— is consistent with the highly competitive nature of renewable energy development. The assumption is further supported by the principle in economics that supply can more effectively increase in response to long-term market signals (i.e., supply tends to be more elastic in the long term). Consistent growth in voluntary demand and public voluntary buyer commitments likely strengthens long-term developer confidence in voluntary demand, allowing developers to more effectively factor voluntary market revenues into long-term strategies. We therefore assume that the price elasticity of renewable energy supply is in the range of 2 to 3. Assuming that voluntary REC revenues increased project revenues by around 8–14% in the decade from 2014 to 2023 (see Methodological Appendix), our analysis suggests that voluntary REC revenues drove around 17–43% of renewable energy deployment outside of RPS mandates over that decade. Given that voluntary market sales comprised about 41% of all non-hydropower renewable energy sales over the decade, these estimates suggest that voluntary REC revenues drove around 7–18% of overall renewable energy deployment as an estimated lower-bound range.

The preceding analysis provides a lower-bound estimate of the impacts of the voluntary market on renewable energy deployment by focusing exclusively on voluntary REC revenues. A realistic upper-bound estimate should account for all other plausible pathways through which voluntary demand can drive renewable energy deployment. A key quantifiable pathway is voluntary REC buyer demand for long-term power contracts. For the sake of developing an upper-bound estimate, we assume that all sales through long-term contractual mechanisms (PPAs and utility renewable contracts) represent incremental renewable energy sales contingent on voluntary market transactions.[5] That assumption is supported by the observations that 1) developers and investors strongly prefer the de-risked revenues of long-term contracts over selling power directly into wholesale markets (Christophers 2024), 2) project developers often prefer contracts with voluntary buyers who are more willing to sign long-term contracts with favorable, fixed-price terms for developers,[6] and 3) most buyers would not be willing to sign long-term power contracts in the absence of a voluntary renewable energy market (O'Shaughnessy 2024). For all other procurement strategies, we apply the same assumptions described in the preceding paragraph. An upper-bound estimate based on our analysis is that voluntary demand drove around 43–60% of renewable energy deployment outside of RPS, or about 18–25% of all deployment (see Methodological Appendix for details).

Overall, this analysis suggests that the voluntary market drove around 260 million to 940 million MWh of renewable energy generation from 2014 to 2023, or about 7–25% of all renewable energy generated in the decade (Figure 10).

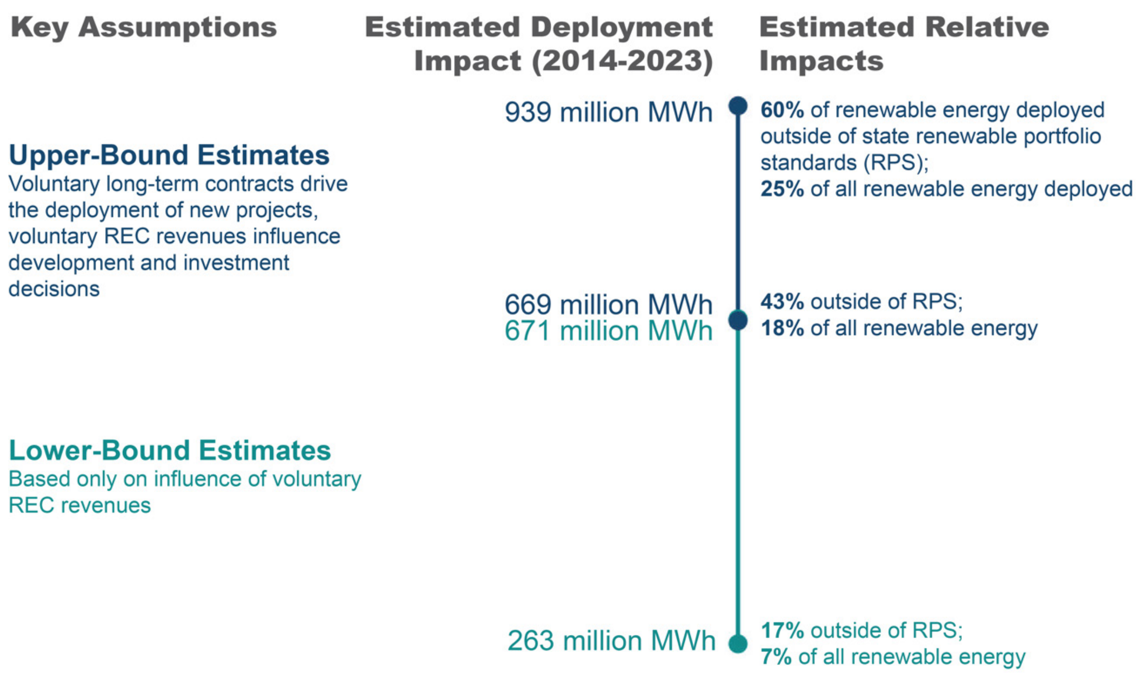

Figure 10. Estimated range of market-level impacts on renewable energy deployment (2014–2023).

To reiterate points established in Section 2, these estimates are not based on counterfactual analysis, meaning that the estimates do not necessarily reflect how much renewable energy

[5] Some scholars conceptually separate the impacts of long-term power contracts from the impacts of voluntary REC demand by arguing that it is the *power* contract rather than the REC contract that drives project impact (Bjørn et al. 2022). However, as noted in Section 3.2, most voluntary buyers are only willing to sign long-term power contracts for renewable energy, meaning that the long-term power revenues are contingent on voluntary REC demand (Christophers 2024; O'Shaughnessy 2024).

[6] The S&P power contract data support that narrative. Based on physical PPA contractual data (similar data were unavailable for virtual PPAs) for 1,004 solar and wind projects, the S&P data suggest that about 73% of contracts with voluntary buyers use fixed prices, compared to 56% of contracts with retail electricity suppliers.

was added relative to a counterfactual scenario without the voluntary market. Developers could have adapted in different ways to leverage different revenue sources in a counterfactual scenario without the voluntary renewable energy market. As a result, at least some of the deployment that we estimate was driven by the voluntary market could have otherwise been driven by some other factor. Nonetheless, as discussed in Section 2.2.2, the highly competitive, low-margin nature of renewable energy development suggests that voluntary demand reflects a largely additional driver of renewable energy deployment that would not be easily replaced in a counterfactual world without a voluntary renewable energy market.

4. Conclusion

In this report, we develop an approach to estimating voluntary market impacts on renewable energy development based on market principles. We estimate voluntary market impacts in terms of the expected effects of voluntary market functions (revenues, de-risking through long-term contracts, and long-term demand signals) on the renewable energy development industry in the aggregate. We implement a market-level analysis built around four market-level metrics:

- Voluntary market sales have grown for over two decades, reaching about 319 million MWh in 2023, representing about 44% of all U.S. non-hydropower renewable energy sales.
- Voluntary buyers have collectively signed long-term contracts to procure energy from over 70 GW of renewable energy capacity.
- An estimated $3 billion to $5 billion of voluntary REC revenues accrued to the U.S. renewable energy industry in the decade from 2014 to 2023, in addition to about $5 billion to $10 billion in power sales to voluntary buyers with long-term power contracts.
- Hundreds of non-residential institutions, including some of the country's largest electricity customers, have made credible public commitments to voluntarily procure renewable energy.

We submit that these metrics render implausible claims that the voluntary market is categorically not impactful. Arguments that voluntary demand is not impactful imply that the expectations and calculations of developers and investors are unaffected by 1) more than two decades of consistent growth in voluntary demand; 2) the emergence of corporate demand as a key source of demand for long-term power contracts; 3) an infusion of billions of dollars of REC and contracted power revenues into the industry; and 4) credible, public renewable energy procurement commitments of many of the world's largest corporations.

Based on the market-level metrics, we estimate that the voluntary market drove around 260 million to 940 million MWh of renewable energy generation in the decade from 2014 to 2023, equating to around 17–60% of renewable energy generated outside of RPS mandates, or about 7–25% of all renewable energy generated in the decade. Those relatively wide ranges reflect the uncertainty underlying the analysis. However, by any measure, the exercise suggests that the voluntary market has played and will continue to play a quantitatively meaningful role in the renewable energy transition.

We conclude by suggesting that the development and implementation of multiple methodologies can help describe voluntary market impacts from multiple perspectives. Like other methods to estimate voluntary market impacts, the market-level analysis presented in this report is a useful but limited methodology. Project-level modeling can help inform the project-level decisions of voluntary buyers and market intermediaries. System-level modeling can inform voluntary buyer decisions or market frameworks where counterfactual change (i.e., additionality) is a key criterion. Market-level analysis helps describe how voluntary demand can drive renewable energy deployment in the aggregate. Future research can explore new methods for analyzing voluntary market impacts that can help inform the decisions of voluntary buyers and maximize the real-world impacts of voluntary renewable energy demand.

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Methodological Appendix

REC revenue analysis

We compile REC price data from the Lawrence Berkeley Lab (Wiser, Bolinger et al. 2022) and S&P (2024). The Berkeley Lab data include REC benchmark prices from 2010 to 2021 (the Berkeley Lab estimates are based on data compiled by Marex Spectron) and the S&P data provide REC benchmark prices from 2021 to 2024. From those two sources, we compile annual benchmark prices for national voluntary RECs and WECC RECs as depicted in Figure 7. We also compile annual average prices for RECs in RPS states. We based RPS state REC prices on averages of market benchmarks excluding benchmarks labeled as "RPS" and excluding solar RECs (which tend to trade at substantially higher prices in RPS states). We convert nominal REC prices into 2023 dollars based on consumer price index inflation factors.

REC benchmark prices reflect wholesale prices, i.e., prices before the addition of any markups charged by market intermediaries for REC resales to end-use customers. At least some revenues for RECs sold outside of long-term contracts must be diverted to various transaction costs involved in selling RECs, such as broker and certification fees. Claims that transaction costs offset significant portions of REC revenues (Gillenwater 2008, Brander, Gillenwater et al. 2018, Langer, Brander et al. 2024) have not been substantiated with empirical evidence and such claims are incompatible with the competitive nature of the renewable energy development industry (O'Shaughnessy 2024). Evidence from other comparable contexts (e.g., mutual funds, investment services, mortgages) suggests that transaction costs such as broker fees are typically on the order of 1–5% of prices (Blume 1993, Livingston and O'Neal 1996, Ferrell 2011, Ambrose and Conklin 2014). Gillenwater (2008) states that REC certification and brokerage fees separately range from 3–5%, i.e., the two fees together would amount to 6–10% of REC revenues. We use that range to assume that 6–10% of revenues for RECs procured outside of long-term contracts are spent on transaction costs across the scenarios described in Table A.1.

Finally, we require assumptions about how to map annual REC benchmark prices to annual REC sales. That mapping is not straightforward, given that RECs retired in one year may reflect transactions through long-term contracts with prices fixed in a prior year. In the case of PPAs, we assume that REC prices are fixed at market benchmark prices in the years that projects came online. In the case of unbundled RECs, data from the EPA's Green Power Partnership suggest that only about 20% of unbundled REC transactions occur through contracts of greater than one year, representing around 15% of unbundled REC sales. Based on that data, we make the simplifying assumption that all unbundled RECs sell at the benchmark prices of the same year as the sale.

As depicted in Figure 5, REC prices spiked in 2021 and have remained relatively high through 2023. Given that some voluntary buyers face fixed budgets for renewable energy procurement, it is likely that at least some buyers changed their procurement strategies to avoid these higher prices. For instance, some buyers may have switched from buying Green-e certified RECs that tend to sell at slightly higher prices to buying non-certified RECs (Green-e is the largest REC certification program in the United States; the program certifies RECs that meet various standards). We attempt to account for these possible changes in procurement strategies in our lower-bound estimates of REC revenues. We assume that only "new" demand for RECs procured outside of long-term contracts from 2021 to 2023 directly faces the higher benchmark REC prices from 2021 to 2023 (i.e., only the incremental demand above 2020). We assume that "existing" demand faces an REC price based on the average of the prior five years (including the year of the purchase).

To estimate a plausible range of REC revenues, we develop lower- and upper-bound estimates as described in Table A.1.

Table A.1. REC Price Assumptions

Assumption	Lower Bound Scenario	Upper Bound Scenario
REC price year: RECs procured outside of long-term contracts	REC prices are assumed to reflect market REC prices in the year of the transaction. For 2021–2023, incremental demand (i.e., above 2020 levels) faces current-year benchmark prices, while existing demand (i.e., 2020 level) faces a 5-year average REC price.	REC prices are assumed to reflect market REC prices in the year of the transaction.
REC price year: long-term contracts	REC prices are assumed to be fixed in the year the project came online.	REC prices are assumed to be fixed in the year the project came online.
REC price basis	WECC benchmark in WECC states, national benchmark in all other states.	WECC benchmark in WECC states, state average price in RPS states (excluding solar RECs and benchmarks specifically designated as RPS), national benchmark in all other states.
Assumed transaction costs for RECs procured outside of long-term contracts	10% of market benchmark prices.	6% of market benchmark prices.

PPA revenue analysis

The Lawrence Berkeley Lab compiles annual PPA price data for wind power projects (Wiser, Millstein et al. 2024) and solar power projects (Seel, Mulvaney Kemp et al. 2024). We used those data to compile annual average voluntary PPA prices based on 1) the regional breakdown of voluntary PPA demand and 2) the generation shares of voluntary wind and solar projects. We estimated the confidence intervals depicted in Figure 8 based on standard deviations in reported project-level prices.

Elasticity analysis

Based on the REC and PPA revenues derived as explained in the prior sections, we estimate that demand-weighted average voluntary REC price is in the range of $2.2 to $3.7 from 2014 to 2023. We estimate that the demand-weighted average PPA price for projects supported by voluntary RECs—accounting for the regional distribution of voluntary demand—was about $25.8. Together, these estimates imply that voluntary REC revenues increased market-based project revenues (i.e., excluding non-market revenues such as production tax credits) by around 8.4–14.4%. The impact of that revenue increase on renewable energy supply depends on the price elasticity of renewable energy supply. Only one study, to our knowledge, attempts to estimate the price elasticity of renewable energy supply. Johnson (2011) estimates supply elasticity to compliance REC prices of 2.7, meaning that a 1% increase in prices drives a 2.7% increase in renewable energy supply. Based on that estimate, we assume that the price elasticity of renewable energy supply is in the range of 2 to 3. Applying the lower-bound elasticity to the lower-bound REC revenue increase yields 2*8.4%=16.8%, while applying the upper-bound elasticity to the upper-bound REC revenue increase yields 3*14.4%=43.2%. These calculations are the basis for our lower-bound estimated range that voluntary demand drove around 17–43% of the deployment of renewable energy projects outside of RPS (i.e., projects that were not supported by compliance REC revenues).

The upper-bound estimated range follows the same process applied only to RECs procured outside of long-term contracts. For uncontracted RECs, we estimate a demand-weighted average REC price in the range of $1.7 to $3.4 from 2014 to 2023, implying a 6.7–13.3% increase in market-based project revenues. Applying the same price elasticity assumptions described above yields an estimated increase in renewable energy supply from projects supported by uncontracted RECs in the range of 13.5–39.8%. For the upper-bound range, we assume that all sales supported by voluntary long-term contracts were additional. From 2014 to 2023, total voluntary market sales were 1,558 million MWh, of which 530 million MWh were contracted RECs and 1,028 million MWh were uncontracted. Applying the estimated impact of uncontracted RECs (13.5–39.8%) implies renewable energy supply of (13.5–39.8%)*1,028=138–408 million MWh. Adding those sales to the 530 million MWh of contracted sales implies total renewable energy supplies of 669 million to 939 million MWh, or about a 43–60% increase.

The estimated demand-weighted average REC price ($2.2 to $3.7) in the decade from 2014 to 2023 is considerably higher than historical REC benchmark prices prior to 2021. That discrepancy is primarily because the average is weighted toward years with greater demand, meaning that the higher prices from 2021 to 2023 play a proportionally larger role in the weighted average (the discrepancy is also partly explained by converting from nominal to 2023 dollars). From 2014 to 2020, we estimate that the demand-weighted average voluntary REC price was in the range of $0.9 to $1.6. Many studies that conclude that voluntary RECs are not impactful are based on financial analyses with REC prices in that lower range. However, even at that lower range of REC prices, a market-level perspective suggests that the potential impacts of RECs are not negligible. REC prices in the range of $0.9 to $1.6 imply a 3.6–6.3% increase in market-based project prices (based on demand-weighted average PPA prices). Applying a price elasticity of supply range of 2 to 3 implies that those added revenues increase renewable energy supply outside of RPS by around 7–19%.

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