Status and Trends in the U.S. Voluntary Power Market: 2023 Data

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2 National Renewable Energy Laboratory

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Glossary

Buyer: For this report, we use the term "buyer" to broadly refer to any customer who procures voluntary renewable power, including residential, commercial, industrial, and governmental electricity users.

Compliance: Throughout this report, the term "compliance" always refers to compliance by load-serving entities with state mandates for renewable energy procurement (see Renewable portfolio standards).

Community Choice Aggregation (CCA): A CCA is a legal entity formed to procure power on behalf of a defined geographic area. Some CCAs procure voluntary power on behalf of their customers.

Load-serving entities: Suppliers of retail electricity, including utilities, competitive retail electricity suppliers (in restructured markets), and CCAs.

Participation/sales: Throughout this report, the term "participation" refers to the number of voluntary customers whereas "sales" refers to megawatt-hours (MWh) (renewable energy certificates [RECs]) of renewable electricity voluntarily bought and sold.

Power purchase agreement (PPA): A long-term contract for power and/or REC procurement between a renewable energy project and a retail electricity customer.

Renewable energy certificate (REC): A contractual mechanism representing the energy attributes of 1 MWh of renewable electricity generation.

Renewable portfolio standards (RPS): State laws requiring load-serving entities to procure a minimum specified quantity of renewable energy.

Voluntary renewable power: Renewable energy procured by retail electricity customers above and beyond what is otherwise provided by load-serving entities.

Executive Summary

Voluntary renewable power, for this report, refers to renewable energy procurement by retail electricity customers above what is otherwise provided by load-serving entities. This report is part of an annual series of reports synthesizing trends in the U.S. voluntary renewable power market. In 2023, about 9.7 million retail electricity customers procured about 319 million megawatt-hours (MWh) of voluntary renewable power (Figure ES-1), representing a 17% increase over sales in 2022. Estimated voluntary renewable power market sales represented about 44% of renewable energy sales excluding large hydropower and about 8% of all U.S. retail electricity sales in 2023. Most of the remainder of U.S. renewable energy sales reflects renewable energy procured by load-serving entities to comply with state renewable energy mandates.

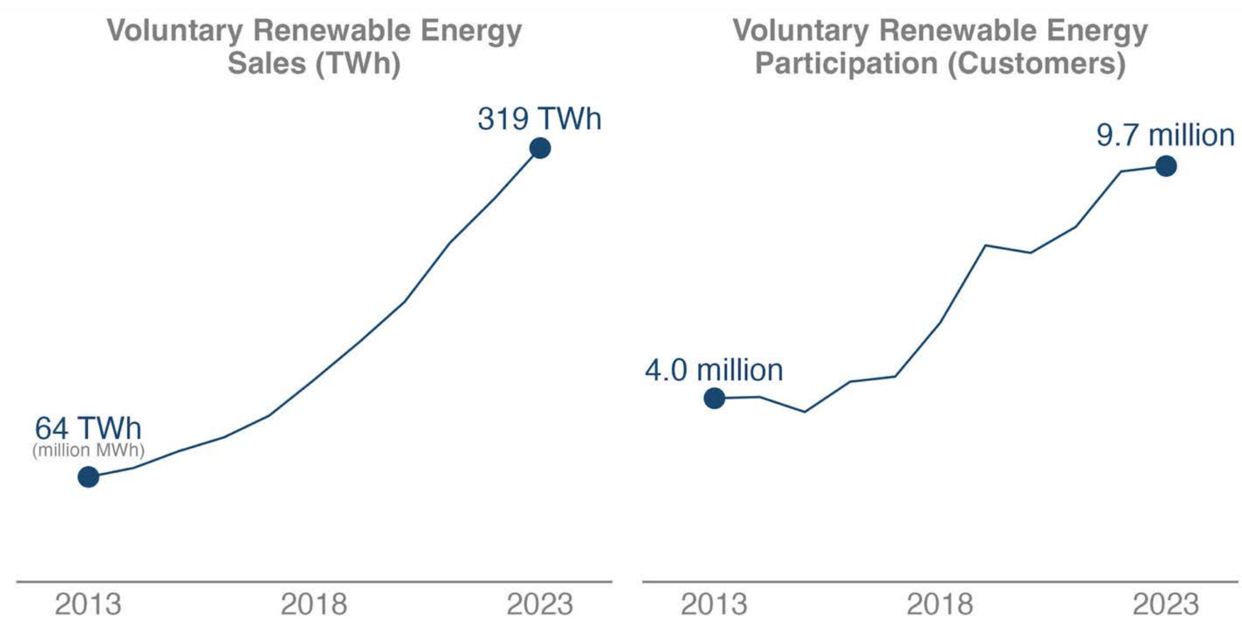

Figure ES-1. Voluntary renewable power sales (left) and participation (right), 2013–2023.

MWh = megawatt-hours
TWh = terawatt-hours

The U.S. voluntary renewable power market is undergoing a clear shift toward long-term contracts, driven primarily by increasing corporate renewable power procurement. In 2023, we estimate that renewable energy certificates (RECs) procured through long-term contracts likely exceeded RECs procured through near-term transactions for the first time. In this year's report, we explore two other topics of interest that could affect future trends in the U.S. voluntary renewable power market. First, we explore how increasing grid energy storage could affect REC accounting practices. We discuss early proposals for how REC accounting frameworks could adapt to storage energy efficiency losses and temporal shifting of renewable energy generation. Second, we explore how extended and expanded tax credits provided under the Inflation Reduction Act could increase voluntary renewable power sales and impact voluntary renewable power demand.

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1 Introduction

Many retail electricity customers demand more renewable energy than what is otherwise provided through the standard-offer service of their local load-serving entity (e.g., utilities, competitive retail electricity suppliers). These customers have various options to use renewable energy, all of which require the purchase and retirement of renewable energy certificates (RECs), which are accounting mechanisms that represent the clean energy attributes of renewable energy generation.[1] Procurement of this kind of renewable energy by retail electricity customers is commonly known as "voluntary" demand, in contrast to "compliance" demand, which refers to procurement by load-serving entities to comply with state mandates such as renewable portfolio standards (RPS).[2] For this report, the term voluntary "renewable power" refers exclusively to renewable energy procurement by retail electricity customers above RPS obligations. This report summarizes the state of the U.S. voluntary renewable power market. For similar information on the compliance market, see Barbose (2024).

In this report, we summarize data on the various products through which retail electricity customers—including residential, commercial and industrial, and institutional (e.g., government) customers—purchase voluntary renewable power. This report focuses on voluntary renewable power sales and participation in calendar year 2023.[3] Note that, though the renewable power products vary substantially in terms of cost structures, contractual commitments, availability, and other factors, all renewable power products ultimately serve as a conduit through which RECs are bought and retired on behalf of customers. The inclusion of RECs in all renewable power products ensures that the associated renewable energy use cannot be double counted and claimed by other voluntary buyers or by a retail electricity supplier for RPS compliance.

In some cases, retail electricity suppliers sell power as a single product that includes voluntary renewable power in addition to a portion of renewable energy used for RPS compliance. In these cases, we factor out the portion of renewable electricity supply that was required to meet RPS obligations. This report does not include renewable power use where no explicit REC transaction occurs and therefore no usage data are available. This lack of data/absence of REC transaction occurs when customers own on-site systems and "retain" the RECs so that RECs are never formally retired. Voluntary renewable power output from on-site systems likely amounts to less than 5% of off-site voluntary renewable power sales (Sumner et al. 2023).

We present voluntary renewable power market data and trends in Section 2. In Section 3, we discuss how the trend of increasing energy storage could affect the voluntary renewable power market. In Section 4, we discuss how extended and expanded tax credits under the federal Inflation Reduction Act could enable continued growth in voluntary renewable power demand.

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[1] For more information on RECs, see EPA (2018), and Jones (2023). Note that RECs are a subset of a broader class of certificates commonly referred to as environmental attribute certificates (EACs). We continue to use the term RECs to specify that our data refer exclusively to certificates from renewable energy generation.

[2] An emerging third category is procurement by load-serving entities outside of RPS, e.g., a utility buying more renewables (and retaining the RECs) than required by RPS. Although such procurement was historically rare, most U.S. customers are now served by utilities with voluntary decarbonization targets (Smart Electric Power Alliance 2023), suggesting that procurement outside RPS is likely increasing. For now, we continue to apply the term "voluntary" exclusively to procurement by or on behalf of retail electricity customers.

[3] For reports on previous years, see https://www.nrel.gov/analysis/green-power.html.

2 Voluntary Renewable Power Market Sales and Participation

In this section, we summarize data and trends in the voluntary renewable power market through various visualizations. Numeric values for all figures in this section are publicly available in a workbook format at https://www.nrel.gov/docs/libraries/analysis/nrel-green-power-data-v2023.xlsx?sfvrsn=5775598f_2. We report trends over the full decade from 2013 to 2023. For data from earlier years, visit the National Renewable Energy Laboratory (NREL) renewable power page at https://www.nrel.gov/analysis/green-power.html.

The U.S. voluntary renewable power market has grown consistently and substantially over the past decade. We estimate that about 9.7 million customers procured about 319 million megawatt hours (MWh) of voluntary renewable power in 2023, up from 4 million customers and 64 million MWh in 2013 (Figure 1).

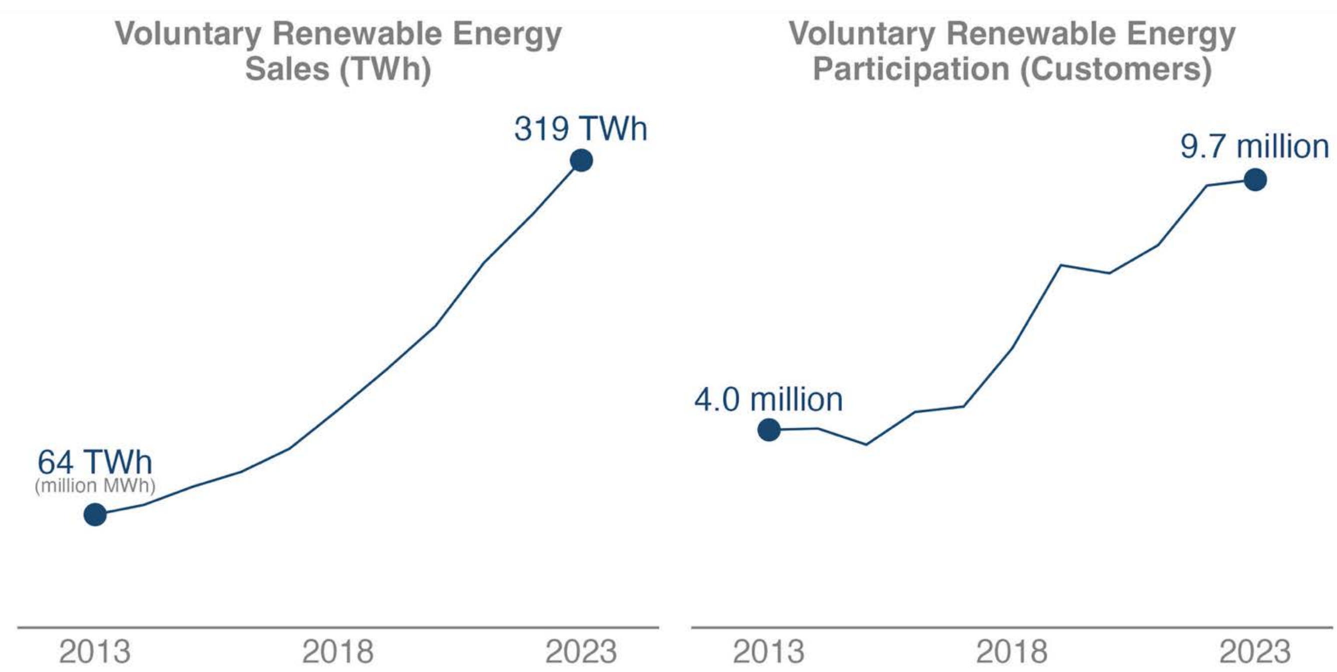

Figure 1. Voluntary renewable power sales (left) and participation (right), 2013–2023.

MWh = megawatt-hours
TWh = terawatt-hours

By 2023, voluntary voluntary power sales accounted for about 44% of all renewable energy sales in the United States, excluding large hydropower, based on data from the U.S. Energy Information Administration (EIA) (2024a). Further, voluntary sales accounted for about 48% of RECs retired in 2023 for voluntary or compliance purposes (Figure 2). As a result of sustained voluntary demand—particularly among large corporate customers, and most notably in recent years among datacenter operators—voluntary REC sales could possibly overtake compliance REC sales in the near future (Lenoir & Wilson 2024).

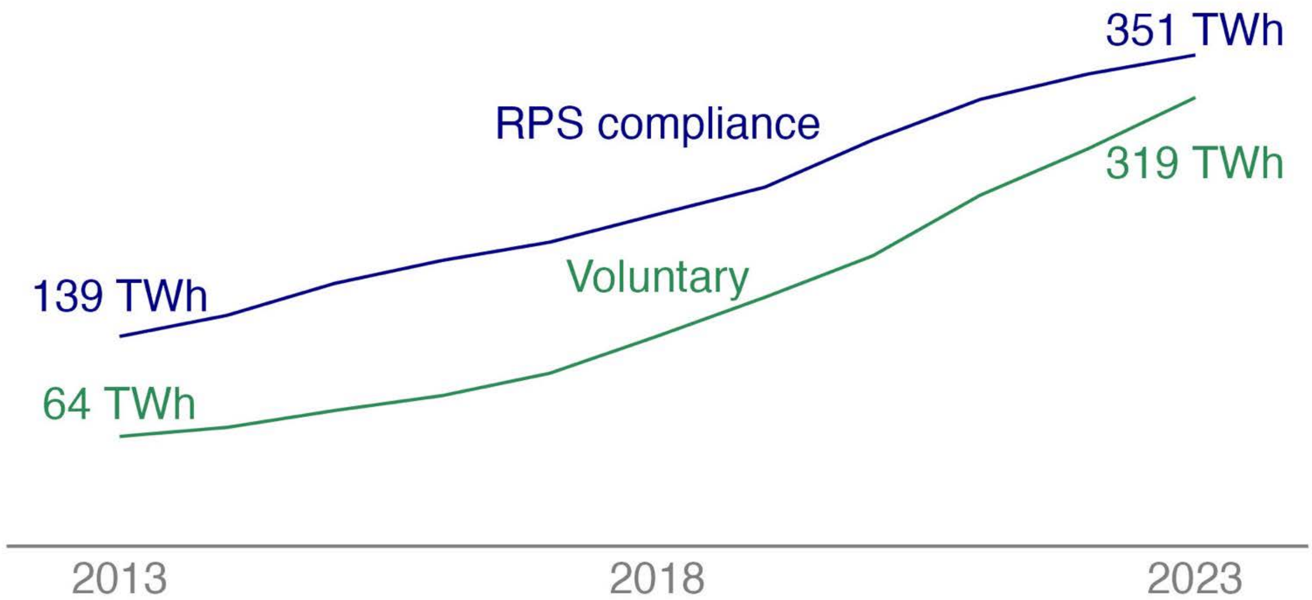

Figure 2. Renewable energy sales in voluntary and compliance markets, 2013–2023.

Compliance estimates based on data from Barbose (2024); TWh = terawatt-hours.

The voluntary renewable power market comprises six products through which retail electricity customers can buy RECs. Table 1 defines each of these products and summarizes our primary data sources for estimating sales for each product.

Table 1. Voluntary Renewable Power Product Definitions

Product	Description	Data Sources
Utility green pricing	A program wherein utilities retire RECs on behalf of residential and small commercial customers (includes community solar).	Survey, EIA (2024b)
Utility renewable contracts	Sales through utility green tariff programs wherein utilities procure power and retire RECs from specific renewable energy projects on behalf of non-residential customers who participate on a contractual basis; sales through bilateral contracts between utilities, developers, and customers.	Survey, Bloomberg New Energy Finance (BNEF; 2024)
Competitive suppliers	Nonutility retail electricity suppliers in states with restructured electricity markets that retire RECs on behalf of their customers.	EIA (2024b)

Unbundled RECs	Sales of RECs separated or “unbundled” from the underlying power.	Center for Resource Solutions (CRS; 2024)*

Product	**Description**	**Data Sources**
Community choice aggregation (CCA)	A CCA is a legal entity formed to procure power on behalf of a defined geographic area. Some CCAs retire RECs on behalf of their customers.	Survey, CalCCA (2024), EIA (2024b), Green Energy Consumers Alliance (GECA; 2024), Illinois Commerce Commission (ICC; 2024), Massachusetts Department of Public Utilities (MA DPU; 2024), New York Department of Public Service (NY DPS; 2024)
Power purchase agreements (PPAs)	Sales through direct contracts between renewable energy projects and buyers, which include both power and RECs. This category includes both physical PPAs and “virtual” PPAs where the buyer does not take physical possession of the power.	BNEF (2024)

* CRS provides a certification service known as Green-e that recognizes RECs that meet specific criteria. The data reflected in this report are not limited to certified RECs. CRS provides data on Green-e certified RECs, and NREL extrapolates a nationwide unbundled REC estimate based on historical Green-e certification rates.

Figure 3 illustrates how the composition of the voluntary renewable power market varies in terms of MWh sales and participation. Sales are driven by products marketed toward large, nonresidential customers, particularly unbundled RECs, power purchase agreements (PPAs), and utility renewable contracts. In contrast, participation is driven by products marketed toward residential and small commercial customers, especially community choice aggregations (CCAs), competitive suppliers, and utility green pricing programs.

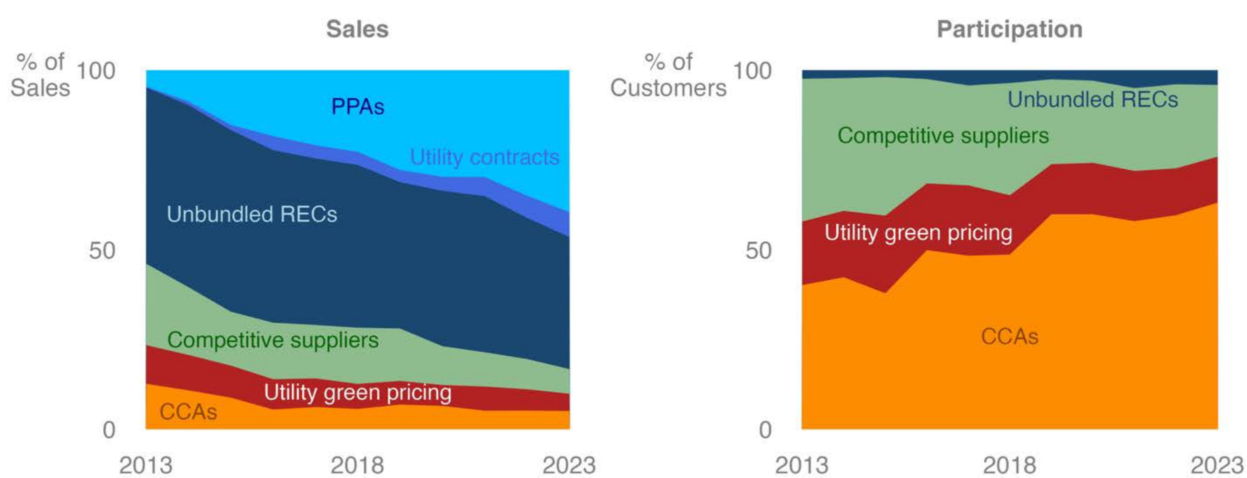

Figure 3. Shares of voluntary renewable power sales (left) and customers (right) over time by product.

PPAs and utility contracts collectively account for less than 1% of customers.

Figure 3 depicts how voluntary renewable power sales (MWh) have clearly shifted toward long-term contracts. In 2023, about 46% of all voluntary renewable power was procured through long-term contracts in the form of PPAs or utility contracts. In addition to those sales, California CCA renewable power sales are increasingly supported by long-term contracts.[4] By 2024, California CCAs had signed PPAs for over 14 GW of new renewable energy capacity, about one-third of which is operational (Dépit 2023). Further, survey data collected for this report indicate that around 7 million MWh or around 46% of utility green pricing sales are supported by REC contracts of at least 6 years. Finally, while precise estimates are unavailable, some corporate buyers procure unbundled RECs through long-term contracts. Collectively, these data indicate that voluntary renewable power sales procured through long-term contracts likely surpassed renewable power sales through near-term transactions in 2023.

Figure 4 further illustrates this trend by depicting the ranks of the different voluntary renewable power procurement mechanisms over the past decade. In 2013, unbundled RECs dominated the renewable power market in terms of sales, and the primary long-term contract strategies (PPAs and utility renewable contracts) generated fewer sales than all other renewable power mechanisms. That picture changed over the next decade, as long-term contract sales grew faster than sales through other procurement mechanisms. In 2023, PPAs surpassed unbundled RECs in terms of sales for the first time, and utility renewable contracts surpassed the other three mechanisms in terms of sales.

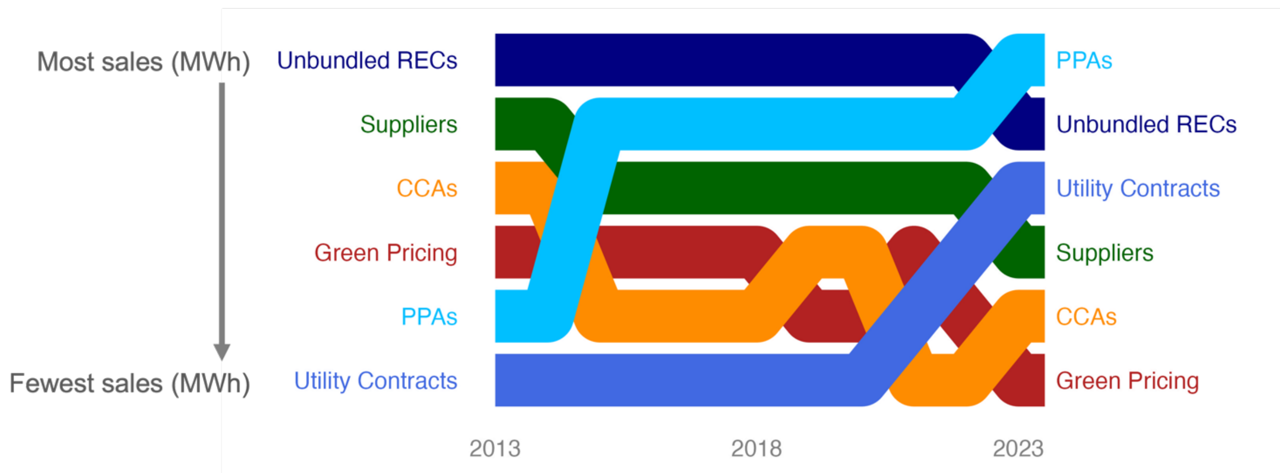

Figure 4. Sales rankings (in terms of MWh sold) of voluntary renewable power procurement mechanisms from 2013-2023

Figure 4 illustrates voluntary renewable power sales by product from 2013 to 2023, while Figure 5 illustrates renewable power participation by product from 2013 to 2023. Key factors driving these trends are discussed following the plots.

[4] For the purposes of this report, PPAs signed directly with end-use customer are tracked in a separate category, while PPAs signed by CCAs are tracked as part of CCA sales.

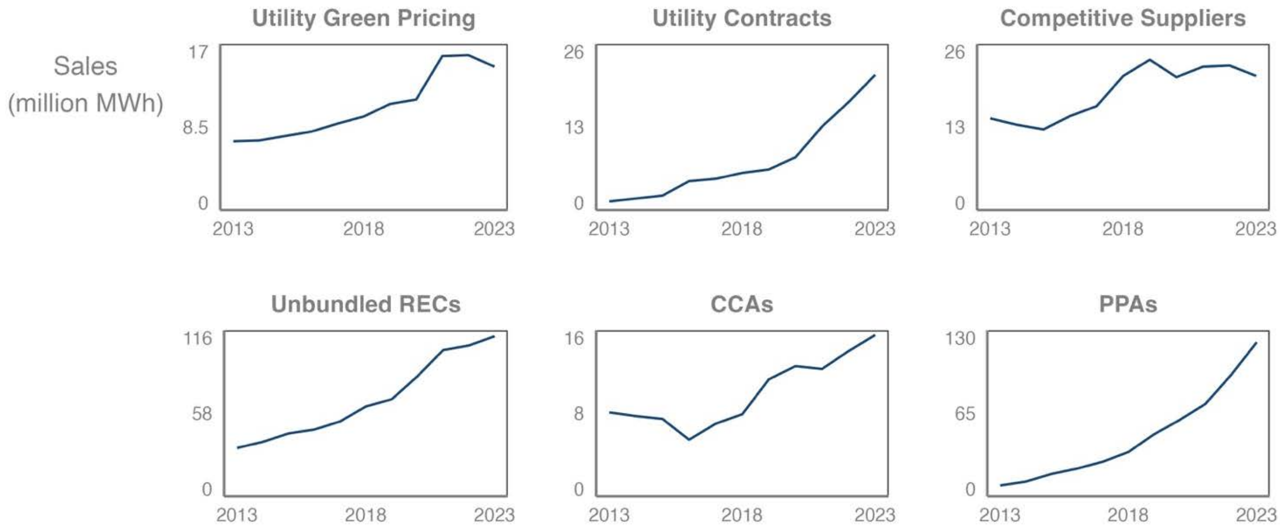

Figure 5. Voluntary renewable power sales by product, 2013–2023.

Plots are on different scales.

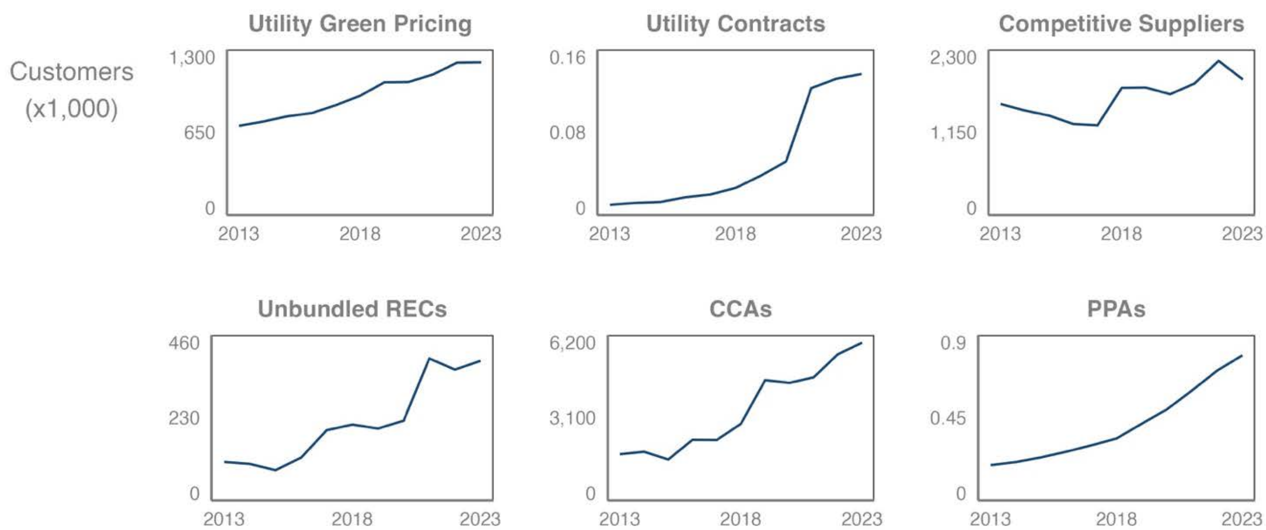

Figure 6. Voluntary renewable power participation by product, 2013–2023.

Plots are on different scales.

Utility green pricing participation remained relatively stable from 2022 to 2023, and our estimates suggest that utility green pricing sales declined from 2022 to 2023. In contrast, **utility renewable contracts** continue to expand, with an estimated 142 operational projects generating 22 million MWh of voluntary renewable power in 2023.[5] The utility renewable contract pipeline has also grown, with hundreds of megawatts in development to support utility renewable contract programs in states such as Arizona, Georgia, Michigan, and Utah.

Unbundled REC sales grew modestly from 2022 to 2023. One possible explanation for plateauing demand for unbundled RECs is the ongoing shift of non-residential customers toward PPAs and utility renewable contracts.

CCA sales and participation continued to grow in 2023. Among seven states with available data to estimate CCA voluntary renewable power sales (Table 2), California and Ohio together accounted for over 90% of renewable power sales in 2023.[6] In both states the growth of CCA renewable power sales in recent years has been driven by CCA adoption in large cities such as San Diego in California and Columbus in Ohio. CCAs in those two states have used distinct strategies to procure and deliver renewable power. In California, most CCAs offer a standard electricity package with more renewable energy content than required by RPS (e.g., 50%) and provide opt-in 100% renewable power products.[7] The renewable energy procured by California CCAs is mostly in-state or from bordering states, and California CCAs are increasingly procuring renewable energy through long-term contracts. In contrast, Ohio CCA renewable power sales are primarily driven by a few large CCAs that offer default 100% renewable power products. Ohio CCAs support these 100% renewable power products primarily through procurement of out-of-state unbundled RECs. The two states therefore achieved their high renewable power sales through different pathways, with California prioritizing procuring smaller volumes of local renewable power and Ohio prioritizing procuring larger volumes of more cost-effective out-of-state renewable power.

[5] Note that utility renewable contract customer estimates reflect the number of projects, which has typically equaled the number of customers. However, some utilities are evolving green tariff programs in ways that may allow multiple customers to contract for power from the same projects. Our methodology may be adjusted in future years to reflect these changes.
[6] In 2022, the City of Hoboken, New Jersey formed a CCA with an optional voluntary renewable power product. Data for sales in this program were unavailable at the time of this report.
[7] Our voluntary renewable power estimates for California CCAs are based on renewable energy procurement above RPS. However, some California CCAs may retire RECs above RPS obligations toward the California RPS (Baltar et al. 2024). Under state rules, RECs retired for RPS compliance may not be used for any other purposes, and RECs retired toward RPS above obligations in one year may be used toward compliance in a subsequent year (Baltar et al. 2024). Such procurement would therefore not be considered voluntary and would need to be factored out from our estimates of CCA voluntary renewable power sales. NREL will monitor this situation in future years and may adjust the reporting of California CCA renewable power sales as further clarity on CCA REC reporting is obtained.

Table 2. 2023 CCA Voluntary Renewable Power Sales and Customers by State

State	Renewable Power Sales (MWh)	Renewable Power Customers
California	12,440,000	5,099,000
Illinois	70,000	8,000
Massachusetts	587,000	276,000
New Hampshire	5,000	7,000
New York	430,000	234,000
Ohio	2,858,000	360,000
Rhode Island	38,000	119,000
Total	**16,427,000**	**6,103,000**

PPA sales continue to grow as more nonresidential customers—especially corporations—sign long-term contracts. Note that PPAs refer to two types of contract structures. “Physical” PPAs are contracts in which the buyer procures power and RECs so that the power is delivered to the buyer’s grid and “used” by the buyer. “Virtual” PPAs are contracts in which the power is sold into wholesale power markets and the arrangement between buyer and seller is strictly financial. Data from the EPA Green Power Partnership suggest that virtual PPAs account for around 60% of voluntary renewable power PPA sales.

3 Energy Storage and the Renewable Power Market

The U.S. electric grid's energy storage capacity is increasing due to a variety of factors. Increasing energy storage is expected to enable renewable energy deployment, generation, and use. Here, we explore potential interactions between increasing energy storage and the voluntary renewable power market and how the market could adapt. We begin by providing context around increasing energy storage.

3.1 Trends in Energy Storage

Most electricity is used at the moment that the electricity is generated. Less than 1% of generated electrical energy is typically stored on an annual basis. However, demand for energy storage is rapidly increasing, due in large part to the growing deployment of variable solar and wind power (Blair et al. 2022). Solar and wind power systems only generate electricity when the sun shines or the wind blows, respectively. As more solar and wind power comes online, solar and wind power intermittency can create grid stability challenges. Further, solar and wind output can exceed the grid's capacity to absorb more generation in certain hours, creating situations where solar and wind generators must be turned off or "curtailed." Marginal power can be more valuable outside of the hours of typical solar and wind profiles because such power displaces fossil fuel generation and reduces the associated fuel costs. Energy storage can resolve these challenges by temporally shifting solar and wind power dispatch to enhance grid stability, mitigate curtailment, and increase the grid value of solar and wind output.

The grid's primary existing storage technology is pumped hydropower, where generated electricity is used to pump water up a slope which can be released later to drive a turbine to generate electricity. Pumped hydro storage requires specific geological conditions only found in specific sites. As a result, pumped hydro storage is generally not considered a sufficient long-term solution to meet growing demand for the storage of solar and wind power. The primary alternative to pumped hydro storage is chemical storage in the form of batteries. Until very recently, the electric grid had trivial levels of battery storage capacity, but that is changing. Battery costs are falling rapidly, especially in the case of lithium-ion batteries. Falling battery costs and rising demand for storage are enabling a boom in battery deployment (Blair et al. 2022). Battery storage capacity is projected to exceed pumped hydro storage capacity for the first time in 2024 (Feldman et al. 2024). By some estimates, grid energy storage capacity could grow by more than a factor of five by 2050 (Blair et al. 2022).

For the purposes of the following discussion, it is important to distinguish two types of energy storage applications. Hybrid energy storage refers to a storage device that is co-located with and exclusively charged from a specific generator or generators. For instance, a battery can be installed on a wind farm and exclusively charged from the output of that wind farm. In contrast, we use the term "grid-tied" energy storage to refer to systems that can charge directly from the grid, possibly in addition to co-located generators. These two classes of energy storage systems could have unique interactions with the voluntary renewable power market.

3.2 Storage in Voluntary Renewable Power

Increasing energy storage could affect REC accounting frameworks, meaning the protocol implemented in REC tracking systems and market standards to verify the issuance (to generators) and use (by end-use customers) of RECs. Here, we focus on three potential impacts on REC accounting in terms of REC volumes, REC issuance, and REC temporal profiles:

- **Impacts on REC volumes:** Some useful energy is lost when fuels or natural flows (e.g., sunlight, wind) are used to generate electricity. Electricity generators can only typically convert around 30% to 50% of the energy in fossil fuels or natural flows into usable electricity, or as low as 20% in the case of solar photovoltaic panels. Additional useful energy is lost when electricity is passed through storage devices. These storage efficiency losses are typically on the order of 20%. That is, only around 80% of stored electricity is available to power end uses. Storage efficiency losses could affect voluntary renewable power accounting. RECs are currently issued based on the volume of electricity generated, which roughly equals the volume of electricity used (around 5% of electricity generated is lost during transmission and distribution). However, when renewable energy is stored and discharged, the volume of RECs from stored energy issued to generators is greater than the volume of renewable energy ultimately used by end-use customers. Increasing energy storage could create a growing gap between the volume of renewable energy generated on behalf of voluntary buyers versus the volume of that renewable energy that is delivered to end uses.

- **Impacts on REC issuance:** Under conventional REC accounting practices, each unit of renewable energy output is issued a single REC. The singular issuance of RECs ensures that each unit of renewable energy output supports one claim to the use of the same volume of renewable energy. Energy storage could create a need to revisit REC issuance frameworks to accurately allocate the flow of RECs through energy storage devices (Daly et al. 2024; EnergyTag 2024a). We explore potential adaptations in REC issuance in Section 3.3.2.

- **Impacts on REC temporal profiles:** A key benefit of energy storage is its ability to store energy output from intermittent sources (e.g., solar, wind) and dispatch that energy to the grid at some other time. Temporal shifting of generation could translate to temporal shifts in REC temporal profiles. The temporal shifting of renewable energy generation and RECs is largely irrelevant under conventional REC procurement strategies. Most REC buyers procure enough RECs each year to make claims to the use of the same volume of renewable energy within that year, a strategy known as annual matching. The timing of renewable energy generation and use does not affect annual matching claims. However, some buyers have begun to explore temporal matching strategies where buyers procure RECs during specific time periods (e.g., hours) to support claims to renewable energy use in those time periods. Energy storage could be an important resource for achieving temporal matching objectives by shifting intermittent solar and wind output to match buyer electricity use profiles (Holt 2025).

3.3 Potential Adaptations

Here, we explore potential adaptations to the energy storage trend, particularly those suggested in public comments related to proposed rules for REC accounting in clean hydrogen tax credits.[8]

[8] The proposed rule is a new section 45V of the Internal Revenue Code added by the Inflation Reduction Act. The rule would require temporal matching of RECs for the purposes of qualifying for clean hydrogen production tax credits. The 45V rule is a unique context that cannot be directly compared to the voluntary renewable power market. However, discussions around how energy storage could be integrated into that rule could provide a useful template for how energy storage could be integrated into the voluntary renewable power market. Several stakeholders commented on the role of energy storage in 45V during the public comment period (see, for instance, comments submitted by EnergyTag, RMI, and Verse). Public comments are available at https://www.regulations.gov/document/IRS-2023-0066-0001/comment.

3.3.1 Status quo

Maintaining the status quo in REC accounting frameworks may be a defensible approach, at least in the near term. REC accounting largely operates on the premise that units of renewable energy are indistinguishable components of the grid (Harvard Law 2024). Energy storage could be considered a background grid function—like transmission and distribution—that roughly equally affects all electricity. As such, there would be no need to assign storage efficiency losses to specific RECs. Further, insofar as annual matching remains the primary matching strategy, there may be no near-term need to adapt to the effects of energy storage on the timing of renewable energy generation and use.

3.3.2 Adaptations to storage efficiency losses

In the case of hybrid energy storage systems co-located with renewable energy generators, storage efficiency losses reduce renewable energy output that is ultimately available to meet the demand of end users. Further, the charging profiles of grid-tied energy storage devices tend to correlate with temporal patterns in electricity prices. All else equal, that correlation results in grid-tied energy storage devices charging during times of abundant intermittent solar or wind output. Storage efficiency losses therefore tend to disproportionately affect the renewable electricity underlying RECs, in contrast to other background grid functions such as transmission and distribution.

Public comments on proposed hydrogen rules (Daly et al. 2024) and guidance developed by EnergyTag (2024a) offer two potential pathways for accounting for storage efficiency losses in REC accounting (Figure 7). We summarize these two proposals here for discussion purposes, but we emphasize that other pathways may be explored in the future:

- **Storage, retirement, reissuance:** Stored RECs would be retired in REC tracking systems. Tracking systems would “reissue” RECs to electricity discharged from energy storage devices. These reissued RECs would be sold to and retired on behalf of voluntary renewable power customers. The metered output of storage devices would determine the volume of reissued RECs, meaning that the volume of reissued RECs would automatically deduct storage efficiency losses.

- **Updated attributes:** REC tracking systems would retire some portion of stored RECs to reflect storage efficiency losses. For the remaining RECs, tracking systems would issue new time “stamps” (i.e., attributes describing the time at which RECs are used) at the point that the electricity is discharged from storage devices. The discharged RECs would be sold with the updated time stamps and retired on behalf of voluntary renewable power customers.

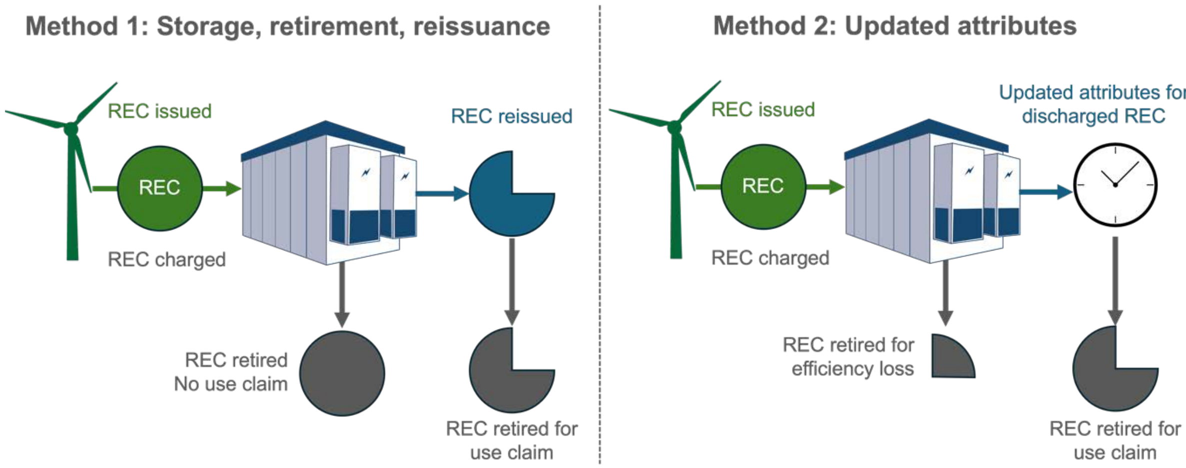

Figure 7. Two possible REC accounting frameworks for energy storage efficiency losses

Conceptually, both approaches yield the same outcome: generators would be issued and compensated for the same REC volumes, buyers could claim the same volumes of renewable energy use, and REC tracking systems would retire the same REC volumes. Neither approach has precedent in conventional REC accounting practices (Holt 2025). REC market stakeholders would need to ensure that any adaptations in REC accounting frameworks address potential challenges such as new double-counting risks and inconsistent attributes (e.g., time stamps).

In principle, both proposed approaches outlined above would require a way to distinguish renewable energy that is stored. That distinction would be relatively simple in the case of hybrid storage systems, where metered data could be used to quantify energy flows from specific generators into and out of specific storage devices. However, tracking stored renewable energy is a complex task for grid-tied energy storage systems. Identifying stored renewable energy in grid-tied energy storage systems would require a system of allocating RECs to stored energy, akin to the system of allocating RECs to grid energy flows more broadly.

3.3.3 Adaptations for temporal matching

As already noted, energy storage could be a critical tool for buyers seeking to temporally match renewable power output with electricity use on a temporally granular basis (e.g., hourly). In temporal matching frameworks, REC accounting practices would need to ensure that REC time stamps reflect the time that electricity is used, meaning the time that renewable energy is discharged from energy storage devices rather than the time that energy is generated. Both proposed approaches described in Section 3.3.2 make this adjustment. Any other adaptation would need to make a similar temporal adjustment to serve as a viable framework for temporal matching.

These temporal adaptations would be relatively straightforward in the case of hybrid energy storage systems with a single buyer of the system's RECs. However, more complex protocols would be required for cases where multiple buyers procure the RECs of a hybrid energy storage system and for grid-tied energy storage systems. To illustrate the issue in the context of hybrid systems, suppose a hybrid storage device charges exclusively from a solar system and a wind system with separate buyers for the RECs of the two systems. Suppose the system charges 5 MWh over the course of a day and discharges 4 MWh in the evening (accounting for efficiency losses). This context poses two questions: 1) how should the

RECs of the solar and wind systems be allocated to the stored energy and 2) how should the time stamps of discharged energy be allocated to the RECs of the solar and wind systems? To illustrate the issue in the context of grid-tied energy storage systems, suppose an energy storage device charges from a grid primarily during hours with significant solar output. Suppose a buyer has a contract to buy RECs from a solar project on that grid and wants to make a temporal claim to use solar output that was stored and discharged in the evening. Again, this context poses two questions: 1) how should RECs be allocated to stored renewable energy and 2) how should the time stamps of discharged energy be allocated to RECs?

To our knowledge, Daly et al. (2024) and EnergyTag (2024b) are the only resources that begin to explore these questions. Both resources suggest developing standards for separately tracking charging and discharging records and allocating RECs to those records. However, many open questions remain, and EnergyTag (2024b) acknowledges that "storage tracking is complex and is still in an early stage of development and implementation." Like other open questions explored in this section, REC market stakeholders will likely continue to explore practical solutions to integrate increasing energy storage into the development of temporal matching frameworks.

References

Baltar, M., R. Brown, L. Coe-Jull, H. Corral, C. Knierim, J. Melendez, L. Stiles, E. Sullivan, W. Wai-hone Yu. 2024. *2024 California Renewables Portfolio Standard*. California Public Utilities Commission.

Barbose, G. 2024. *RPS and CES Demand Projections*. Berkeley, CA: Lawrence Berkeley National Laboratory.

Bistline, J., G. Blanford, M. Brown, D. Burtraw, M. Domeshek, J. Farbes, A. Fawcett, A. Hamilton, J. Jenkins, R. Jones, B. King, H. Kolus, J. Larsen, A. Levin, M. Mahajan, C. Marcy, E. Mayfield, J. McFarland, H. McJeon, R. Orvis, N. Patankar, K. Rennert, C. Roney, N. Roy, G. Schivley, D. Steinberg, N. Victor, S. Wenzel, J. Weyant, R. Wiser, M. Yuan, and A. Zhao. 2023. "Emissions and energy impacts of the Inflation Reduction Act." *Science* 380(6652): 1324–1327.

Blair, N., C. Augustine, W. Cole, P. Denholm, W. Frazier, M. Geocaris, J. Jorgenson, K. McCabe, K. Podkaminer, A. Prasanna, B. Sigrin. 2022. *Storage Futures Study: Key Learnings for the Coming Decades*. Golden, CO: NREL. NREL/TP-7A40-81779.

BNEF. 2024. *US Corporate PPA Project Database*. Bloomberg New Energy Finance.

BPC. 2022. *Inflation Reduction Act Summary: Energy and Climate Provisions*. Washington, D.C.: Bipartisan Policy Center.

CalCCA. 2024. *CCA Programs*. Accessed 8/27/24. https://cal-cca.org/cca-programs/.

Cook, D. 2024. *Estimating the Potential Size of the Transferable Tax Credit Market*. Reunion.

CRS. 2024. Personal correspondence with Alex Pennock on 9/10/2023. Center for Resource Solutions.

Crux. 2023. *Transferable tax credit market intelligence report*. New York, NY: Crux Climate.

Daly, K., R. Fakhry, M. Rote, B.L. Gerber, M. Sloan. 2024. *RE: Section 45V Credit for Production of Clean Hydrogen; Section 48(a)(15) Election to Treat Clean Hydrogen Production Facilities as Energy Property.*

Dépit, C. 2023. *Community Choice Aggregation*. Truckee, CA: LEAN Energy U.S.

EIA. 2024a. *Electricity Data Browser*. U.S. Energy Information Administration. https://www.eia.gov/electricity/data/browser/.

EIA. 2024b. *Annual Electric Power Industry Report, Form EIA-861*. U.S. Energy Information Administration.

EnergyTag. 2024a. *Granular Certificate Matching Standard*. London, UK: EnergyTag.

EnergyTag. 2024b. *Granular Certificate Scheme Standard*. London, UK: EnergyTag.

EPA. 2018. *Guide to Purchasing Green Power.* Washington, D.C.: Green Power Partnership, U.S. Environmental Protection Agency.

Feldman, D., J. Zuboy, K. Dummit, D. Stright, M. Heine, S. Grossman, R. Margolis. 2024. *Summer 2024 Solar Industry Update*. Golden, CO: NREL. NREL/PR-7A40-91209.

GECA. 2024. Personal correspondence, Green Energy Consumers Alliance.

Good, A. 2024. *Renewables project finance to keep pace in 2024, but tax equity rule looms*. S&P Global.

Harvard Law. 2024. "Renewable energy credits as property." *Harvard Law Review* 137(3):936-957.

Holt, E. 2025. *Status and Trends Report on U.S. Energy Attribute Tracking Systems*. Washington, DC: EPA Green Power Partnership.

Hunter, L., M. Vliet. 2023. *The Risk Profile of Renewable Energy Tax Equity Investments*. Washington, DC: American Council on Renewable Energy.

ICC. 2024. *Electric Switching Statistics*. Illinois Commerce Commission. https://www.icc.illinois.gov/industry-reports/electric-switching-statistics.

Jiang, B. et al. 2022. *US Inflation Reduction Act – A tipping point in climate action*. Credit Suisse.

Jones, T. 2023. *The Legal Basis for Renewable Energy Certificates*. San Francisco, CA: Center for Resource Solutions.

King, B., J. Larsen, H. Kolus, A. van Brummen. 2024. *Tech-Neutral Tax Credits: The Foundation of US Electric Power Decarbonization*. New York, NY: Rhodium Group.

Lenoir, T., A. Wilson. 2024. *Voluntary renewable energy certificates set to double state targets past 2030*. S&P Global.

LevelTen. 2024. *Guide to Buying Transferable Tax Credits*. Seattle, WA: LevelTen Energy.

MA DPU. 2024. *Municipal Aggregation Annual Reports*. Massachusetts Department of Public Utilities. https://www.mass.gov/info-details/municipal-aggregation-annual-reports.

NY DPS. 2024. *In the Matter of Financial Reports for Community Choice Aggregation Programs*. New York Department of Public Service. https://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterSeq=53495.

O'Shaughnessy, E., S. Jena, J. Sumner. 2024. *Status and Trends in the U.S. Voluntary Green Power Market: 2022 Data.* Golden, CO: NREL. NREL/TP-7A40-88219.

SEPA. 2023. *Utilities' path to a carbon-free energy system*. Smart Electric Power Alliance. https://sepapower.org/utility-transformation-challenge/utility-carbon-reduction-tracker/.

St. John, J. 2023. *New tax-credit transfer rules could unlock $1T in cleantech investment*. Canary Media.

Sumner, J., E. O'Shaughnessy, S. Jena, and J. Carey. 2023. *Status and Trends in the U.S. Voluntary Green Power Market (2021 Data)*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-86162.

White House. 2023. *Clean Energy Economy: A Guidebook to the Inflation Reduction Act's Investments in Clean Energy and Climate Action*. January 2023, Version 2.