Status and Trends in the U.S. Voluntary Green Power Market (2021 Data)

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1 National Renewable Energy Laboratory
2 Clean Kilowatts, LLC

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List of Abbreviations and Acronyms

CCA	community choice aggregation
LMI	low- and moderate-income
PPA	power purchase agreement
RECs	renewable energy certificates
RPS	renewable portfolio standard

Executive Summary

Voluntary green power, for the purposes of this report, refers to renewable energy procurement above state renewable energy mandates by retail electricity customers. In this report, which the National Renewable Energy Laboratory publishes annually, we present data and key trends for voluntary green power market, except for a small portion of voluntary purchasing where no data are available.

In 2021, about 8 million retail electricity customers procured about 244 million megawatt-hours (MWh) of voluntary green power (Figure ES-1), which represents about 27% of all U.S. renewable energy sales, about 39% of non-hydropower renewable energy sales, and about 6% of all U.S. retail electricity sales. 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, also known as compliance-based procurement.

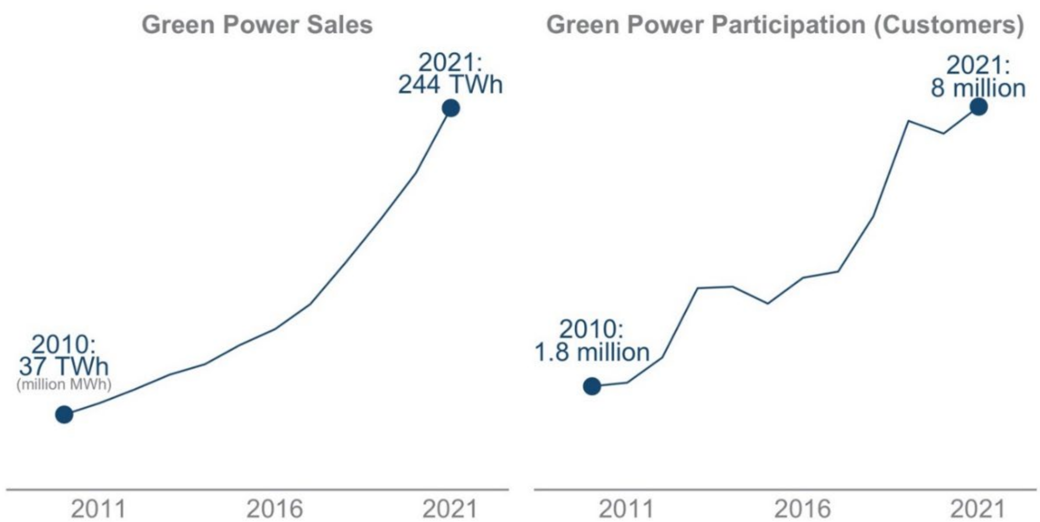

Figure ES-1. Voluntary green power sales (left) and participation (right), 2010–2021

In this year's report, we explore two emerging issues in the U.S. voluntary green power market. First, we explore emerging issues that could constrain the expansion of voluntary green power products. We explore how the increasing complexity of the voluntary green power market could help buyers implement green power procurement more impactfully but also pose some unique challenges for certain buyers, especially smaller buyers. Our second exploration focuses on the evolving role of voluntary green power market as grids decarbonize. We discuss how the voluntary green power market has already begun to evolve to changing grid realities by developing new products intended to maximize impacts.

Here are the key takeaways, from this year's report:

- *Green power demand continues to grow across all products.* Growth is particularly strong for the products that offer direct procurement from specific projects: utility contracts and PPAs.

- *Expanding green power access to smaller buyers is a soluble challenge.* Leading utilities and other green power suppliers have already developed innovative new products that expand green power market access, including LMI customers.

- *The green power market has adapted to the evolving needs of customers and grids.* There has been a marked shift toward products that directly connect buyers with power and RECs from specific projects through PPAs and utility renewable contracts, including 24/7, real-time products that ensure green power is delivered to grids when renewable energy is scarcer.

- *The green power market can play a role in deep decarbonization.* Buyers and sellers may develop new products catered to the specific needs of grids with higher levels of baseload renewable energy, such as products that support firm clean energy and battery storage.

In the future, green power buyers and sellers will likely continue to adapt to the changing needs of a decarbonizing U.S. grid.

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1 Introduction

Many states require retail electricity suppliers to buy specified amounts of renewable energy through mandates typically known as renewable portfolio standards (RPS). Retail electricity suppliers comply with RPS by buying and "retiring" renewable energy certificates (RECs), accounting mechanisms that represent the clean energy attributes of renewable energy generation.[1] Retail electricity customers can increase the renewable energy content of their electricity consumption by buying and retiring additional RECs. Voluntary green power, for the purposes of this report, refers to renewable energy procurement (i.e., RECs) above RPS mandates by retail electricity customers.

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 green power. The report focuses on voluntary green power sales and participation in calendar year 2021.[2] Note that, though the green power products vary substantially, all green power products ultimately serve as a conduit through which RECs are bought and retired on behalf of customers. Including RECs in all green power products ensures the associated renewable energy use cannot be double-counted and claimed by a retail electricity supplier for RPS compliance.

For the purposes of this report, the term green power refers exclusively to renewable energy procurement above RPS obligations. In some cases, retail electricity suppliers sell voluntary green power in a single product with standard electricity. In these cases, we factor out the portion of renewable electricity supply that was required to meet RPS obligations.

This report does not include green 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. Data from the U.S. Environmental Protection Agency's Green Power Partnership suggest on-site green power consumption by nonresidential customers may amount to about 2% of the green power market summarized in the report (EPA 2023), or about 5 million megawatt-hours (MWh) annually. Additional on-site green power, not accounted for in this report, occurs through residential installations and organizations that are not part of the Green Power Partnership.

We present voluntary green power market data and trends in Section 2. In Section 3, we discuss two emerging issues that, if addressed, could expand access to the voluntary green power market. In Section 4, we discuss the future of the voluntary green power market as grids approach higher levels of renewable energy penetration.

[1] For more information on RECs, see EPA (2018).
[2] For reports on previous years, see "Voluntary Green Power Procurement," NREL> https://www.nrel.gov/analysis/green-power.html.

2 Voluntary Green Power Market Sales and Participation

In this section, we summarize trends in the voluntary green power market through various visualizations. Numeric values for all figures in this section are available in a workbook format.[3]

The U.S. voluntary green power market has grown consistently and substantially over the past decade. We estimate that about 8 million customers procured about 244 million MWh of voluntary green power in 2021, up from 1.8 million customers and 37 million MWh in 2010 (Figure 1).

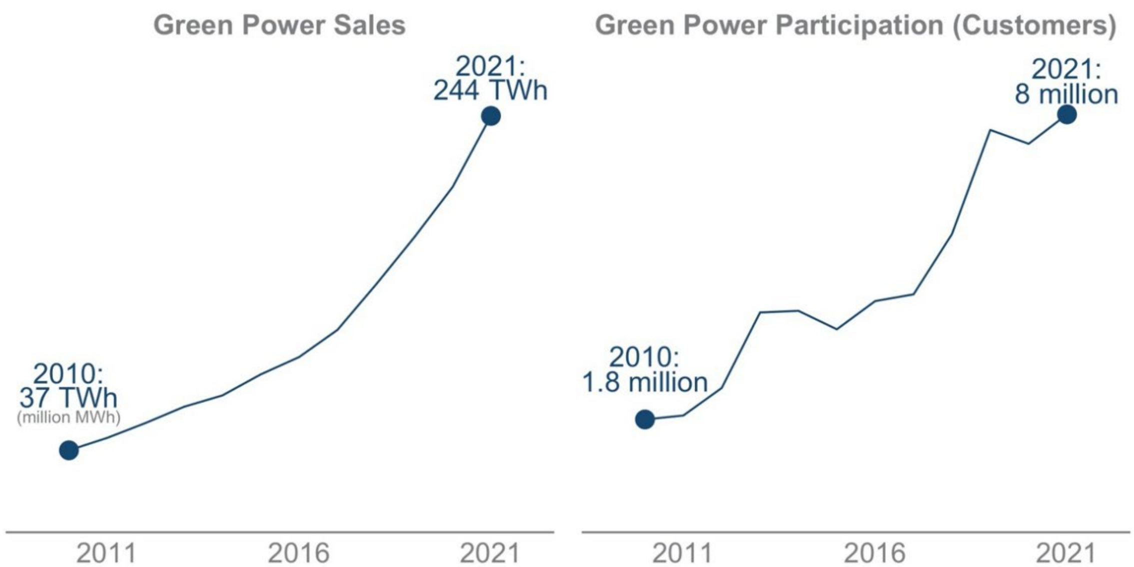

Figure 1. Voluntary green power sales (left) and participation (right), 2010–2021

By 2021, voluntary green power sales accounted for about 27% of all renewable energy sales in the United States and about 39% of renewable energy sales excluding large hydropower, based on data from EIA (n.d.). Further, voluntary sales accounted for about 38% of the total green power market (i.e., all REC-based procurement including voluntary and RPS-based or "compliance" procurement) (Figure 2).

[3] "Status and Trends in the U.S. Voluntary Green Power Market (2021 Data)," NREL, https://data.nrel.gov/submissions/196.

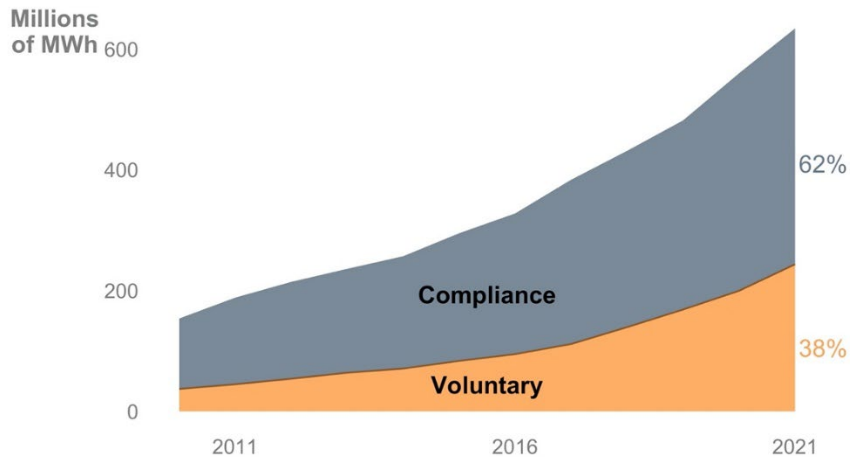

Figure 2. Renewable energy sales in voluntary and compliance markets, 2011–2021

Compliance estimates are based on data from Barbose (2019); 2021 compliance estimate is based on projected value.

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

Table 1. Voluntary Green 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 (2022)
Utility renewable contracts	A program wherein utilities procure power and retire RECs from specific renewable energy projects on behalf of customers who participate on a contractual basis	BNEF (2022)
Competitive suppliers	Non-utility retail electricity suppliers in restructured electricity markets that retire RECs on behalf of their customers	EIA (2022)
Unbundled RECs	Sales of RECs separated or "unbundled" from the underlying power	CRS (2022)
Community choice aggregation (CCA)	A CCA is a legal entity formed to procure power on behalf of a defined geographic area. Some CCAs procure green power on behalf of their customers.	Survey, CalCCA (n.d.), EIA (2022), GECA (2022), ICC (n.d.), MA DPU (n.d.), NY DPS (2022)
Power purchase agreements (PPA)	Sales through direct contracts between renewable energy projects and buyers which include both power and RECs	BNEF (2022)

Figure 3 illustrates how the composition of the voluntary green power market varies in terms of sales and participation (MWh). Sales are driven by products marketed toward large, nonresidential customers, particularly unbundled RECs and increasingly power purchase agreements (PPAs). 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.

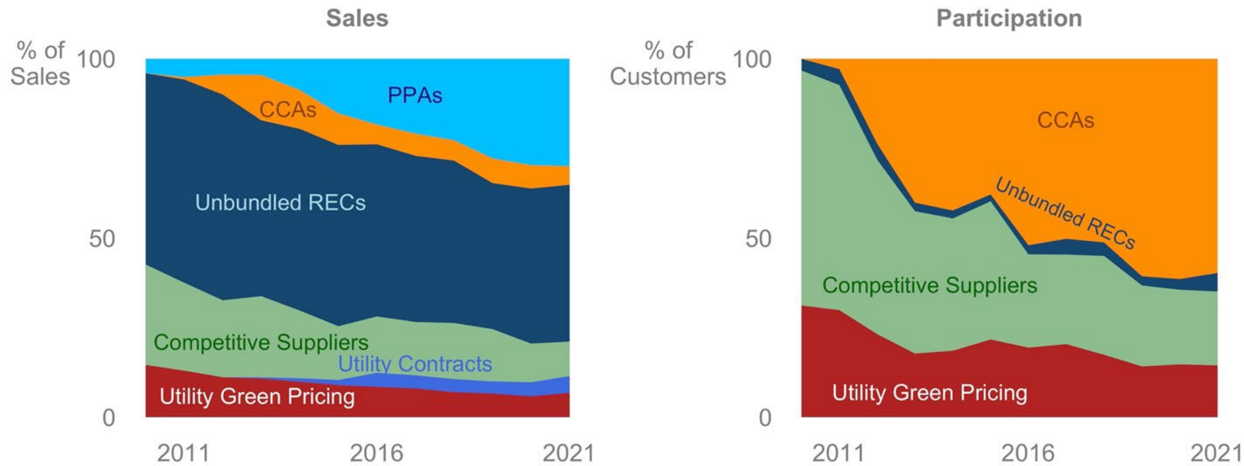

Figure 3. Shares of green power sales (left) and customers (right) over time by product

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

Figure 4 illustrates green power sales by product from 2011 to 2021, and Figure 5 illustrates green power participation by product from 2011 to 2021. Key factors driving these trends are discussed below the figures.

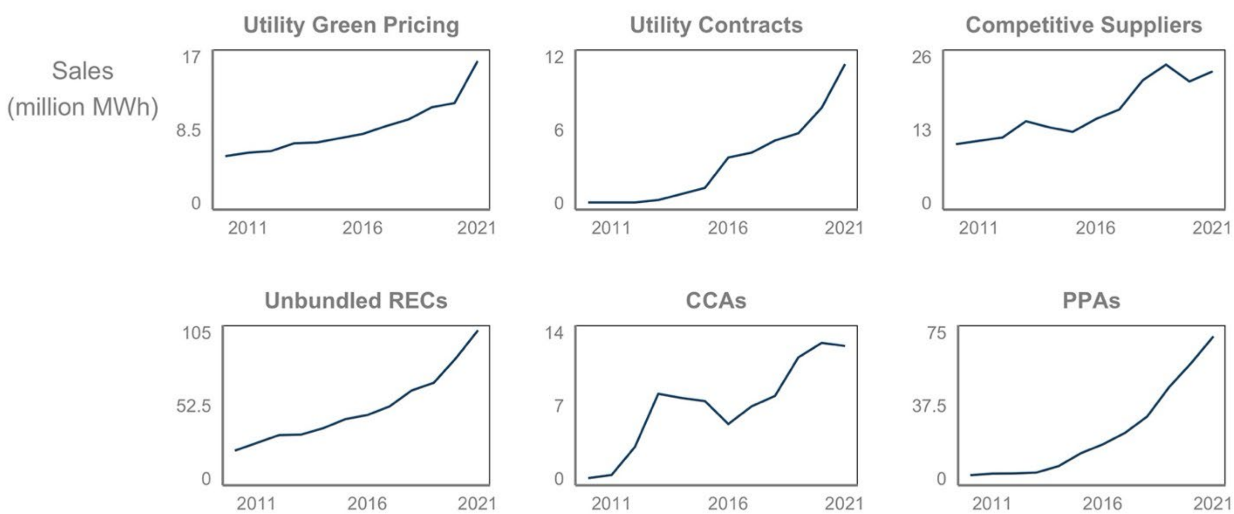

Figure 4. Green power sales by product, 2011–2021

Plots are on different scales.

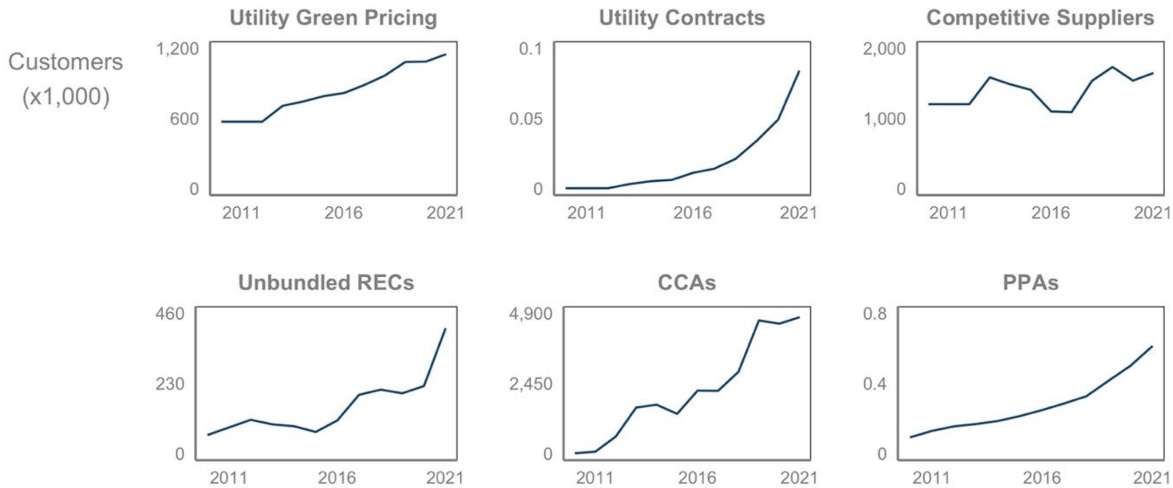

Figure 5. Green power participation by product, 2011-2021

Plots are on different scales.

2.1 Utility Green Pricing

Utility green pricing participation and sales continued to rise steadily in most programs. The relatively sharp increase in utility green pricing sales in 2021 is mostly attributable to significant year-over-year growth in California's community solar program, the largest community solar program in the country that retires RECs on behalf of subscribers. Overall, about 1.1 million customers procured about 16.5 million MWh of voluntary green power through utility green pricing programs in 2021.

Oregon, Washington, Colorado, Minnesota, and Michigan were the top five states with the highest number of customers; Michigan, Washington, Texas, California, and Minnesota were the top five states with highest generation (MWh). The top five states by number of customers wer3e 70% of the total number of customers procuring renewable energy through utility green pricing, and top five states by sales (MWh) form 61% of the total generation (MWh) procured through utility green pricing.

The market recovered after a relatively flat year in 2021, increasing sales by 42% (2020–2021) compared to only 5% (2019–2020). Though sales increased 42% (2020–2021), customers only increased by 6%, indicating larger per-customer volumes are driving sales growth. Admittedly, the utilities were facing uncertainties in the wake of the pandemic in 2020. Utilities that responded to our recent survey reported slight reductions in sales and participation from expected levels, typically around a 5% decrease.

As per the survey participants, the reduction in sales could be due to the reduced ability of utilities to actively market their programs, particularly through in-person marketing (e.g., door-to-door or via in-person events). Some utilities noted that other extreme events such as wildfires have caused similar disruptions to program marketing in recent years. At the same time, some utilities reported increased interest from proactive customers, perhaps because more time at home led to more interest in residential green power.

2.2 Utility Renewable Contracts

Utility renewable contracts continue to expand from a smaller base. Though utility renewable contract sales remained a small portion of the 2021 green power market, contracts in the pipeline suggest strong growth in utility renewable contracts for the foreseeable future (Figure 7). In 2021, utility contracts served 11.4 million MWh, which is nearly the size of the utility green pricing market. Sales increased 46% from 2020 and a substantial share of projects were in the pipeline. Utility contracts are usually used by large commercial buyers, and this number of customers increased by 71% over 2020 to a total of 84 customers. There is about twice as much capacity in the utility contract pipeline as there is current operational capacity. Utility renewable contracts are poised for significant growth, especially in Arizona, Michigan, Virginia, Tennessee, and Utah.

The Clean Energy Buyers Association's Deal Tracker,[4] which collects publicly announced contracted capacity of corporate deals shows utility-scale solar projects represented 76% of new contracted capacity in 2021. Information technology companies, especially companies with large data centers, represent the most procured clean energy by volume.

There is also interest from customers to use battery storage, partly due to corporate interest in the 24/7 procurement, an approach where buyers match renewable energy procurement to demand on an hourly basis (we discuss 24/7 procurement in depth in Section 4). Keeping in line with interest from potential buyers, it is possible that utilities will integrate battery storage into their green power products.

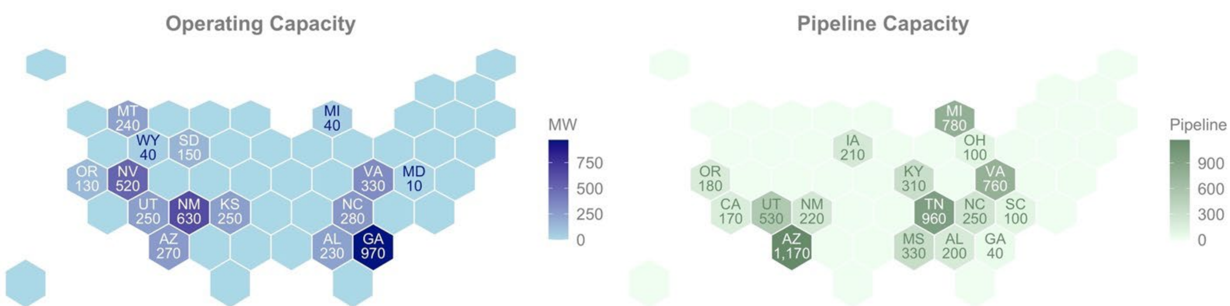

Figure 6. Utility renewable contract operating capacity (left) and pipeline capacity (right) by state.

2.3 Competitive Suppliers

We estimate green power sales from competitive suppliers grew slightly in 2021, mostly due to increased sales from a few suppliers with default 100% green power products. For example, CleanChoice Energy only offers 100% green power products. The sales (MWh) increased by 8 % and the total customers increased by 7 %. About 1.6 million customers procured about 23.4 million MWh of voluntary green power through competitive suppliers in 2021.

Some suppliers have begun to offer long-term green power contracts like utility green tariffs. With this [product], the supplier procures green power from a specific resource (e.g., through a PPA) on behalf of their customers, minimizing expenses and time the customers would need to

[4] "CEBA Deal Tracker ," Clean Energy Buyers Association, https://cebuyers.org/deal-tracker/.

spend to make their own power purchases. For instance, NRG created the Renewable Select plan, a retail contract that make it easier for business customers to obtain off-site green power from specific resources. Currently, the program includes 36 large commercial and industrial customers and provides renewable electricity to more than 345 offices, financial centers, and ATMs in Texas. The program has an output of 3 terawatts (TWh) annually and a collective 600-MW peak load. NRG plans to expand the program to also include smaller customers.

Competitive suppliers have also begun to offer community solar with RECs retired on behalf of subscribers. For instance, MP2 Energy has a community solar program partnership with Local Sun, a 1.5-MW solar project, which will power 300 homes and eliminate the need for long-term contracts. If customers will need more power than can be supplied by the array, MP2 will buy 100% renewable energy from other Texas sustainability projects.

2.4 Unbundled RECs

Unbundled RECs remain the most common source of green power supply (MWh), accounting for about 44% of green power sales in 2021. From December 2020 to August 2021, REC prices (nationally sourced, Green-e Eligible) increased from $1.50/MWh to $6.60/MWh. In response to increasing REC prices, some organizations are turning to direct procurement (e.g., PPAs), on-site renewables, and carbon offsets. Nonetheless, the market grew 23% from 2020 to 2021, which is comparable to growth trends in previous years. Unbundled REC customers increased sharply in 2021, to more than 400,000.

2.5 Community Choice Aggregation

Community choice aggregation (CCA) remains a growing way for communities to take charge of their energy choices. About *4.8 million customers* procured about *12.7 million MWh* of voluntary green power through CCAs in 2021. CCA participation and sales growth has plateaued in recent years, and the plateau reflects several trends in the five states where CCAs offer green power.

California has grown to dominate CCA green power sales and participation; it accounted for about 70% of all CCA green power customers in 2021 (Figure 6). Due to its large size, trends in California now dictate broader trends in CCA green power sales and participation. Although CCAs have continued to expand in California, participation and sales have leveled off since around 2019. CCA green participation grew by more than 50% from 2016 to 2021 in Massachusetts, New York, and Ohio, though the smaller absolute sizes of these markets mean this growth has a muted impact on CCA trends overall.

Table 2. Green Power Sales via CCA

State	Green Power Sales (MWh)	Green Power Customers
California	9,050,000	3,798,000
Illinois	178,000	32,000
Massachusetts	1,599,000	449,000
New York	910,000	184,000
Ohio	974,000	301,000
Total	**12,711,000**	**4,764,000**

In 2014, Westchester County formed New York's first CCA. Since then, three other aggregators have emerged to form CCAs in the state. Many New York communities have chosen to provide 100% renewable energy by default (i.e., opt out), and all aggregators offer opt-in green power products. New York CCAs are also innovating. Several CCAs offer their own community solar programs, and one aggregator (Joule Assets) offers a unique opt-out community solar product to eligible CCA customers. Finally, Illinois CCA green power demand has declined substantially from its peak in the mid-2010s, partly offsetting the CCA growth in the other states.

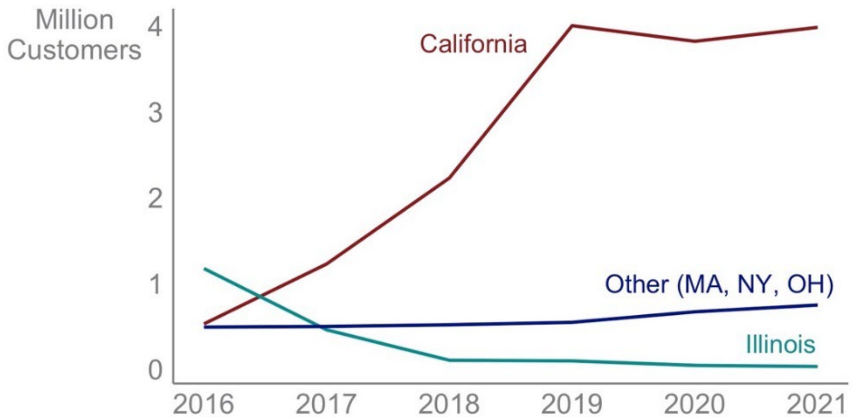

Figure 7. CCA green power participation by state, 2016–2021

2.6 Power Purchase Agreements

Power purchase agreement (PPA) green power sales grew by around 23% from 2020 to 2021. PPA green power sales continue to be concentrated in wind-heavy states with weak or no RPS. In 2021, around 62% of PPA sales came from Texas, Oklahoma, Ohio, and Kansas. The green power PPA market continues to be driven largely by corporate buyers (CEBA 2022). About 613 offtakers procured about 73 million MWh of voluntary green power through PPAs in 2021. These figures include only PPA sales where we estimate that the purchaser has retained the RECs.

3 Emerging Issues in the Voluntary Green Power Market

The future of voluntary green power markets depends on the ongoing expansion and adoption of green power products. In this section, we explore two emerging challenges that could constrain the increased adoption of green power: unequal market access (Section 3.1) and increasing green power product and claim complexity (Section 3.2).

3.1 Challenges to Market Access

In 2021, about 8 million retail electricity customers bought voluntary green power. These customers represent a wide variety of individuals, institutions, and companies with different capabilities, budgets, interests, and goals. The voluntary green power market has frequently adapted to this heterogeneity by developing and offering a diversity of products. Still, not all customers have equal access to green power. Unequal green power access is partly due to differences in the availability of green power products in different regions. Unequal green power access also reflects differences in the procurement ability of customers. For instance, low- and moderate-income (LMI) residential customers may face budgetary constraints that restrict their ability to procure premium products such as utility green pricing. Unequal access could pose challenges to the ongoing expansion of the green power market.

To unpack this challenge, it is helpful to organize green power customers into three classes. The hierarchy below is not a market standard; we developed the hierarchy solely for the purposes of this discussion:

- **Small-Scale Buyers:** residential customers and small businesses.
- **Mid-tier Buyers:** commercial, institutional (e.g., cities, governments), and corporate buyers who have limited staff and resources available to plan and implement green power procurement.
- **Top-Tier Buyers:** large, mostly corporate buyers who dedicate staff and resources toward green power procurement.

Note that we define the customer classes according to two dimensions of scale and capabilities. Mid- and top-tier buyers are primarily distinguished by the resources dedicated to green power procurement, not necessarily customer size. Broadly speaking, small-scale buyers account for most green power customers and top-tier buyers account for most sales (i.e., MWh). As we shall discuss, mid-tier buyers are likely underrepresented in the green power market in both categories.

In the remainder of this section, we explore market access issues in each customer class. We discuss historical and current market activity and specific challenges to maintaining and expanding participation in each class. Then, in Section 3.1.4, we explore challenges across the three customer classes.

3.1.1 Small-Scale Buyers

Small-scale buyers primarily buy green power through utility green pricing, competitive suppliers, and CCAs (where available). In recent years, the small-scale segment has been defined by two different trends illustrated in Figure 9. From 2016 to 2021, small-scale customer participation in utility green pricing programs and CCAs grew substantially, but most of that growth was confined to a few states. Rising participation in states such as California (3.4 million new customers), Massachusetts (140,000 new customers), and New York (50,000 new customers) is primarily attributable to the expansion of CCAs, and growth in states such as Oregon (190,000 new customers), Washington (80,000 new customers), and Michigan (60,000 new customers) is attributable to innovations in utility green pricing programs. At the same time, small-scale customer participation has been stagnant or declining in most other states.

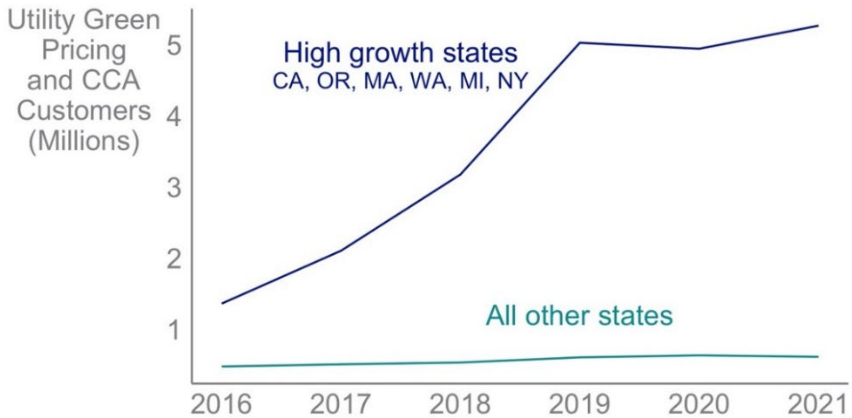

Figure 8. Small-scale green power participation across states

The figure excludes Illinois, an extreme outlier in terms of declining participation due to a contraction of CCAs.

The green power options of most small-scale customers have not substantially evolved in the past decade. Most utility green pricing programs continue to offer the same products and—despite rapidly falling renewable energy prices—at roughly the same cost premiums. Further, while we have limited insights into competitive supplier market activity, there is no evidence that competitive supplier green power products have evolved in the past decade. There are numerous exceptions to this stagnation in small-scale product offerings, but most innovation has concentrated in the few states depicted in Figure 8.

Though further research is required to identify specific challenges for small-scale customer green power products, available evidence from rooftop solar research suggests customer acquisition costs could be a key barrier to market expansion. Customer acquisition refers to costs for finding and recruiting new customers (e.g., advertising and door-to-door marketing). For rooftop solar, customer acquisition is the only installation cost that has generally increased rather than declined over time. Acquisition costs have increased as relatively easy-to-recruit early adopters already have solar and marketers exert more effort to convince more-skeptical, later adopters. A similar dynamic likely exists for small-scale green power programs. Many or most of the easy-to-recruit customers likely already procure green power, meaning program managers must exert more effort per customer to recruit new customers.

Another challenge to broadening small-scale green power participation is the availability of competing products. Small-scale buyer electricity use is often small enough to be fully met through an on-site solar system. One challenge with on-site solar as a substitute for green power is that many on-site solar buyers do not own the RECs generated by their systems. Similarly, many small-scale customers choose to buy community solar. Again, a challenge is that many community solar products do not retire RECs on behalf of subscribers. In both cases, the risk is that on-site or community solar products displace green power demand without adding the same quantity of REC demand, thus reducing overall demand for renewable energy.

A final challenge is finding ways to make small-scale buyer access more equitable. Although green power equity has not been directly studied, to our knowledge, the cost premiums associated with small-scale products (e.g., utility green pricing and opt-up CCA products) likely pose barriers to participation for LMI households. Developing LMI green power programs may be challenging because program providers must find ways to recoup REC costs without significantly increasing LMI customer electricity costs. Pacific Gas & Electric in California, for instance, uses state funds to subsidize LMI customer enrollment in the utility's Green Saver program.

3.1.2 Mid-Tier Buyers

Few green power products cater specifically to the needs of mid-tier buyers (Brasington 2020). Utility green pricing and competitive supplier products typically entail price premiums that are manageable for smaller customers with less demand but can be cost-prohibitive for mid-tier buyers with larger demand. Mid-tier buyers, who typically do not have as many dedicated procurement staff and resources as top-tier buyers, may struggle to navigate more-complex products such as utility renewable contracts and PPAs. Like the broader renewables market (Tian et al. 2016), mid-tier buyers are thus caught in a gap between products largely catered to small-scale and top-tier buyers.

Though we do not track specific data on mid-tier participation and sales, available evidence suggests mid-tier participation is growing slower than top-tier participation. For instance, direct procurement by local governments has lagged direct procurement by top-tier buyers. In 2021, local governments signed 119 off-site renewable energy deals, up from 52 in 2015 (Gonçalves et al. 2022). The growing number of deals reflects a clear market expansion: three of every four local government deals in 2021 were signed by first-time buyers (Gonçalves et al. 2022).[5] However, deals by top-tier buyers grew more substantially over the same period. Local government deals grew by about a factor of 2 from 2015 to 2021, and corporate deals increased by about a factor of 5 from 2016 to 2021 (CEBA 2022) (Figure 10).

[5] The number of local government on-site deals have grown more substantially, from 40 in 2015 to 171 in 2021. Consistent with the rest of this report, we exclude on-site procurement from this discussion.

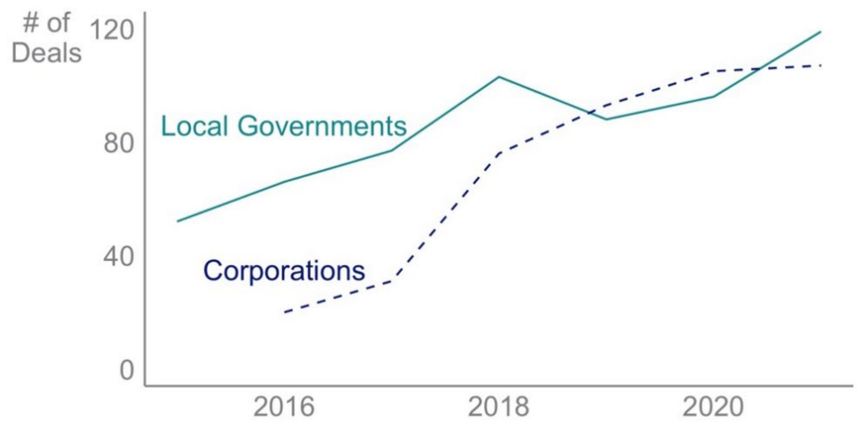

Figure 9. Number of off-site local government and corporate renewable energy deals, 2015–2021

Local government deals are based on off-site deal data from Gonçalves et al. (2022). Corporate deals are based on CEBA (2022). The comparison is provided for illustrative purposes; some of the difference may be attributable to methodological differences across the two sources. A 2015 estimate for corporate deals is unavailable.

Recent years have seen the development of some market innovations that could more effectively address the needs of mid-tier buyers. One emerging model is buyer aggregation, wherein multiple mid-tier buyers work together to buy green power under a single aggregated contract (Brasington 2020; Liu and Reback 2021). Through aggregation, mid-tier buyers can pool staff, resources, and expertise in ways that replicate the more substantial procurement resources of large-tier buyers (Liu and Reback 2021). Further, aggregation allows mid-tier buyers to access the lower costs associated with larger projects (Liu and Reback 2021). Another potential model is for mid-tier buyers to collaborate with top-tier buyers. For instance, in 2021, 14 cities in Georgia partnered with Walmart to sign a renewable energy customer agreement sharing the output of 80 MW of solar capacity (Gonçalves et al. 2022). The deal allowed the cities to leverage Walmart's green power procurement expertise while also accessing lower costs through economies of scale.

3.1.3 Top-Tier Buyers

The top-tier customer class has exhibited the most substantial green power market growth in recent years. Using data and methods from O'Shaughnessy et al. (2021), Figure 11 depicts how much of the recent growth in the U.S. voluntary green power market has accrued to corporate buyers, the primary group of top-tier buyers under our definition. In 2021, corporations alone signed about 11,000 MW in renewable energy contracts (CEBA 2022)—though not necessarily all of these corporation are "top-tier" buyers as we have defined the term.

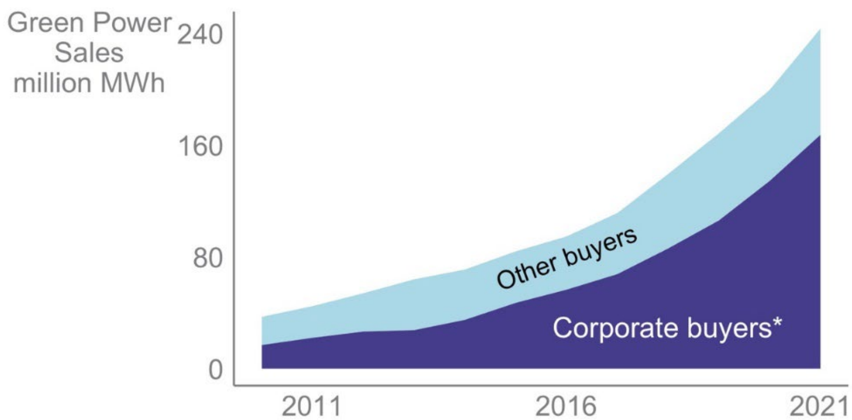

Figure 10. Green power sales among corporate and other buyers, 2010–2021

* Corporate buyer data are based on data and methods described by O'Shaughnessy et al. (2021). The corporate share provides a rough estimate of corporate demand based on available procurement data.

Top-tier buyers can use their size and procurement expertise to shape the green power market to suit their needs (O'Shaughnessy et al. 2021). As a result, the green power market has evolved to meet growing demand from top-tier buyers. This evolution includes the development of new products (e.g., financial PPAs), working with new partners (e.g., utility renewable contracts), and exploring entirely new ways of procuring green power. Arguably the most salient example of the third category is 24/7 procurement. We discuss 24/7 and related topics in Section 4 (page 18).

The top-tier customer class is arguably the healthiest segment of the green power market. Top-tier customer demand is projected to continue to grow at current levels for the foreseeable future (Shreve 2019; O'Shaughnessy et al. 2021). The challenges facing this customer class largely represent the broader challenges of the green power market as grids decarbonize, a topic we explore in Section 4.

3.1.4 Market Access Challenges Across Customer Classes

In the preceding three sections, we discuss how market growth in the small-scale and mid-tier customer classes is stagnant compared to growth among top-tier customers. This difference in market growth is partly attributable to factors within each customer class. For instance, products catered to small-scale customers have evolved little over the past 10 years (with notable exceptions for some utility programs) and the top-tier segment has seen a burst of market innovation that has yielded new products. In this section, we explore two potential challenges *across* the customer classes that could further stymy growth in small-scale and mid-tier market segments.

3.1.4.1 Market Crowding

One potential challenge is that top-tier customer demand could crowd out opportunities for green power participation by small-scale and mid-tier buyers. To unpack this challenge, it is important to recognize that green power supply is fundamentally constrained in the near term. As grids decarbonize, most deployed renewable energy output is procured in the compliance market, leaving a residual of output for voluntary buyers. Top-tier buyers can directly influence the size of that residual market, such as by contracting for new projects through PPAs. However, due to the broad challenges of siting and developing new renewable energy projects, top-tier buyers have limited influence over the near-term size of the residual renewable energy supply. As a result, all buyers compete to buy green power from the same limited pool of residual renewable energy supply. Some evidence of this market crowding is evident in the increasing market share of corporate buyers depicted in Figure 10.

Top-tier buyers could use their size and procurement expertise to effectively outcompete small-scale and mid-tier buyers. Top-tier buyers can typically procure green power at lower cost and can directly influence suppliers. A tangible example of this phenomenon is utility renewable contracts. Utility renewable contracts are effectively a response to top-tier buyer demands for improved access to renewable energy in states without retail electricity competition (O'Shaughnessy et al. 2021). Utility renewable contracts could divert utility resources from programs to deploy renewables on behalf of small-scale and mid-tier buyers toward programs to deploy renewables on behalf of specific top-tier buyers. The net result could be accelerated renewable energy deployment but with fewer opportunities for small-scale and mid-tier buyer participation.

3.1.4.2 Claims Competition

A second challenge is that friendly competition among green power buyers could undermine the green power claims of small-scale and mid-tier buyers. As discussed in Section 3.2, top-tier buyers are pursuing increasingly complex claims about their renewable energy procurement. These claims are often motivated by friendly competition; top-tier green power buyers aim to differentiate their own procurement practices from those of their peers. In top-tier buyer efforts to distinguish their own procurement, top-tier buyer claims may imply small-scale and mid-tier procurement is less impactful. The risk is certain claims made by top-tier buyers could undermine confidence in the green power products relied on by small-scale and mid-tier buyers.

3.2 Managing Increasing Product and Claim Complexity

Voluntary green power products effectively exist to validate *claims* that electricity customers make about renewable energy usage. Over time, both green power products and claims have become increasingly complex. Increasing product and claim complexity poses challenges to the implicit and explicit frameworks that underpin the voluntary green power market. Importantly, increasing claim complexity creates challenges for the market and legal frameworks that validate renewable energy use claims.

3.2.1 Voluntary Green Power Market Claims Frameworks

The voluntary green power market is largely self-regulated and supported by a legal basis governing green power products and claims. Market conventions dictate that all renewable energy use claims must be substantiated by RECs, and the details of those claims must be consistent with the specific characteristics of RECs used to support those claims. RECs are formally recognized as a valid basis for making renewable energy use claims by the Federal Trade Commission, the U.S. Environmental Protection Agency, the U.S. Federal Energy Regulatory Commission, the U.S. Federal Energy Management Program, the American Bar Association, and at least 35 U.S. states and territories (Jones, Quarrier, and Kelty 2015). RECs are used as accounting mechanisms to comply with power disclosure requirements (Braslawsky, Jones, and Sotos 2016). RECs are also recognized for Scope 2 emissions reduction claims for greenhouse gas accounting purposes (Sotos 2015; CDP 2016; 3Degrees 2018). Third-party certification and verification services such as Green-e provide further validation for renewable energy use claims. Language from a Federal Trade Commission act (15 USC §45) establishes the fundamental and necessary role of RECs in substantiating renewable energy use claims:

> The [REC] represents a property right in the technological and environmental attributes of renewable energy… Generally, one REC represents the right to describe one megawatt [sic] of electricity as "renewable,"[6] (16 CFR 260 Vol. 72 No. 227)

RECs convey all the clean energy attributes of renewable electricity, including the location and types of generation (e.g., solar and wind). Market best practices dictate that claims should include language about *what* the buyer did (e.g., how many MWh were purchased) and *how* the buyer procured renewables (e.g., the buyer's financial role in the renewable energy project) (Tawney, Sotos, and Holt 2018).

3.2.2 Increasing Complexity in Claims

Green power products and claims have become increasingly complex as the voluntary green power market has evolved. These two trends are related: increasingly complex products help buyers make increasingly complex claims. For instance, buyers who contractually commit to buying RECs from projects that have yet to be built can make more-complex claims about their roles in project development. The trend toward increasing claim complexity is also driven by a desire for differentiation, especially among corporate buyers. As more corporations made renewable energy use claims, leading buyers began to make efforts to distinguish the impacts of their own procurement practices (Tawney, Sotos, and Holt 2018). The push for differentiation was accelerated by reports such as *Clicking Clean: Who is Winning the Race to Build a Greener Internet?* (Cook et al. 2017) in which the authors analyzed and compared the renewable energy procurement efforts of corporate buyers.

To illustrate this trend toward more-complex claims, we compare public statements about renewable energy use made in corporate social responsibility statements. Note that all the examples we report represent small quotes of text from larger statements on renewable energy use. Our selection of these examples is meant to be illustrative rather than critical.

An example of a basic claim is the following from Starbucks:

> Starbucks has invested in renewable energy and achieved a milestone last year by purchasing the equivalent of 100 percent of global company-operated stores' electricity consumption.—Starbucks

The Starbucks claim simply states that the company has purchased enough RECs to match global company-operated stores' electricity use. We can contrast this basic claim with two more precise claims:

> We have purchased renewable electricity primarily… by buying RECs and entering into green power contracts with various electricity suppliers.—Cisco

[6] The actual Federal Register language refers to one megawatt, while a REC is a unit of electricity representing one megawatt-hour.

> Today we take great pride in becoming the first Fortune 500 company and first bank to sign a long-term agreement to buy as much solar power as we use in a year.—Fifth Third

Like the Starbucks in its claim, Cisco states the company has bought renewable energy without specifying location or technology, but it adds details about precisely how they bought renewables (e.g., RECs and green power contracts). Fifth Third further clarifies that they have bought solar power, specifically. The extended Fifth Third claim includes details about the specific solar project.

These three examples are firmly within market and legal frameworks for renewable energy use claims. However, increasing product complexity has yielded claims that begin to push the boundaries of existing frameworks. Specifically, buyers increasingly try to differentiate their procurement by making claims about procurement *impact*. Consider the following example from Microsoft:

> At Microsoft, we have a policy of additionality. We will only purchase a PPA if it adds renewable energy to the grid.—Microsoft

Here, Microsoft—like other buyers—emphasizes the importance of "additionality," a concept implying a renewable energy purchase results in new capacity that would not otherwise have been installed. While the statement above is not a claim on a specific purchase, implicit in the statement is that all Microsoft PPAs are "additional."

Consider another statement made by Google related to their procurement goals (emphasis theirs):

> We're carving a path forward to fully decarbonize our electricity supply and operate on carbon-free energy *entirely*. Clean energy every hour, every day, everywhere.—Google

This statement is not a renewable energy use claim, but it could provide a framework for future claims. The line "clean energy every hour, every day, everywhere" refers to the fact that Google plans to implement an emerging type of procurement often known as 24/7: buying green power that geographically and temporally matches the buyer's load at every hour of the year. There is an implicit claim that 24/7 procurement is more impactful than other procurement approaches. Google states that 24/7 allows buyers to "entirely" decarbonize their supplies, implying that other procurement approaches incompletely decarbonize supplies.

Finally, consider a claim made by Apple:

> Over 80 percent of the renewable energy that Apple sources for its facilities are now from Apple-created projects, benefitting communities and other businesses.—Apple

The Apple claim makes a statement on the broader social impact of its green power procurement. Again, the Apple claim goes beyond a simple statement of renewable energy use and offers an analysis of the environmental and social impacts of their procurement.

3.2.3 Challenges

Increasing green power product complexity and claims have enabled buyers to explore new ways to maximize the impact of their procurement. However, increasing claim complexity poses several challenges under existing market and legal frameworks for regulating green power claims. Existing frameworks require quantitative and qualitative claims of renewable energy use to be substantiated by the quantitative and qualitative characteristics of RECs. Increasingly, complex claims push the boundaries of existing frameworks by making qualitative claims beyond those that can be clearly substantiated by RECs.

In the case of impact-based claims such as additionality, it is often unclear how buyers can substantiate specific impacts (Tawney, Sotos, and Holt 2018). For instance, the Microsoft statement asserts that the company will only sign PPAs that "[add] renewable energy to the grid." However, there is no single accepted methodology for determining when a project is additional. Even in the case of PPAs, an offtaker cannot clearly claim to have added renewable energy to the grid if the project could have sold the power to another offtaker (Sallee 2022). In the absence of a single unifying framework for adjudicating valid claims to additionality, individual buyers may develop their own criteria for additionality claims. Inconsistencies in these criteria could undermine overall confidence in green power claims.

Time-differentiated claims such as 24/7 pose challenges to existing frameworks. There is currently no single definition for 24/7 procurement or set of standards for validating 24/7 claims (LDES Council 2022). RECs could conceivably certify generation on an hourly basis, but there is no existing market or legal basis to validate that a megawatt our generated in a specific hour has been matched to a megawatt-hour used by a specific customer in the same hour. The lack of standards could cause market confusion and undermine confidence in 24/7 claims. Though 24/7 claims remain a challenge under existing claims frameworks, it is worth noting that several efforts are underway to develop systems for 24/7 validation. A prominent effort to develop 24/7 standards is the EnergyTag initiative (an independent, non-profit initiative), which aims to verify the purchase of renewable energy at an hourly level. Just as RECs eventually formed a widely accepted basis for green power claims, the widespread adoption of a certification standard such as EnergyTag could eventually lead to a broadly accepted basis for 24/7 claims.

Finally, a third challenge of increasing complexity is claims that go beyond the scope of the REC framework. As recognized by the Federal Trade Commission, RECs convey the "technological and environmental attributes" of renewable electricity. Some buyers use renewable energy procurement to make claims that are not directly related to these technological and environmental attributes, such as Apple's claim that their procurement benefits communities and other businesses. Though they might be less common today, claims of social benefits may become more common as corporations and other buyers integrate social equity goals into their procurement strategies (Bird, O'Shaughnessy, and Hutchinson 2021). Green power buyers and sellers might need to develop new frameworks and legal bases to validate green power procurement claims that go beyond the technological and environmental attributes of renewable electricity.

4 Voluntary Green Power in a Decarbonizing Grid

The U.S. voluntary green power market emerged in the context of grids with little renewable energy. In 2005, for instance, green power (excluding large hydropower) accounted for just around 2% of U.S. retail electricity sales (EIA n.d.). The voluntary green power market has contributed to the ongoing expansion of renewables, with non-hydropower green power reaching about 23% of U.S. electricity demand in 2021 (EIA n.d.). Under conservative assumptions, DOE (2021) estimates non-hydro renewables will account for around 38% of the grid mix by 2035 and 56% by 2050 (Figure 12). Under scenarios assuming the implementation of ambitious decarbonization policies, DOE (2021) projects non-hydro renewables could account for as much as 75% of the U.S. grid by 2035 and 90% by 2050; actual renewable shares will likely fall somewhere between these two cases.

The progression of renewable energy penetration depicted in Figure 11 reflects an evolving context for the U.S. voluntary green power market. As grids decarbonize, the voluntary green power market might need to adapt to ensure green power products continue to achieve the extent of impacts expected by green power buyers.

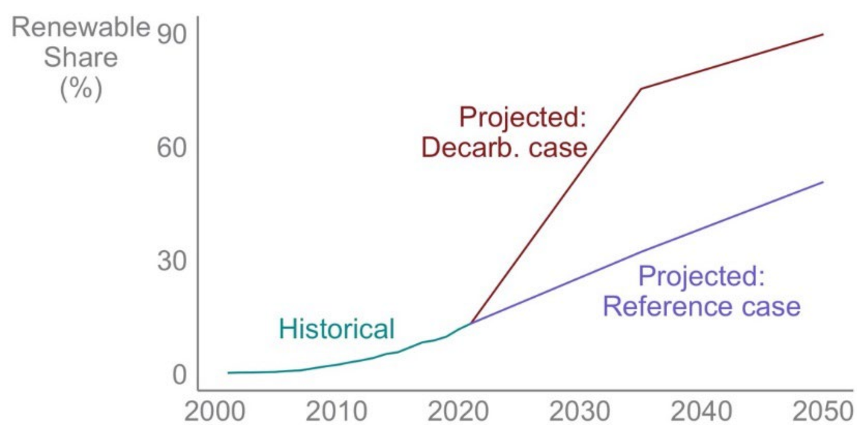

Figure 11. Historical and projected renewable energy shares of the U.S. grid (excluding large hydropower)

Historical estimates are based on EIA (n.d.)/ Projected estimates are based on reference and decarbonization scenarios from DOE (2021).

In this section, we explore the implications of ongoing grid decarbonization for the voluntary green power market. And we explore how increasingly renewable grid mixes could change the role of the voluntary green power market and how the market could adapt.

Before proceeding, it is important to establish four considerations for our discussion in this section. First, grid decarbonization is a decades-long process. Even after accounting for increased renewable energy deployment enabled by the Inflation Reduction Act of 2022, the U.S. grid will not likely approach 100% decarbonization even by 2050 (Jenkins et al. 2022). Further, most state-level mandates for 100% renewable or zero-carbon energy do not require 100% decarbonization until 2040 or later (CESA n.d.). Thus, the challenges and trends discussed in this section will play out over decades not years. Second, the following discussion is exclusively prospective and long-term. None of our prospective discussion should be construed as commentary on historical, current, or near-term aspects of the voluntary green power market. Third, for the sake of simplicity, we use the term "conventional" procurement to refer to broadly accepted prevailing practices for voluntary procurement; however, there is no single definition of conventional procurement. Further, our use of the term "conventional" should not be construed as critical; we simply seek to contrast prevailing practices today with the types of adaptations the market could implement to respond to changing grid needs. Fourth, we restrict our discussion to the potential adaptations and role of the voluntary market on changing grids. Policy and regulatory adaptations will also be required, including policy and regulatory adaptations that could affect the voluntary market (e.g., wholesale electricity market reforms). These policy and regulatory adaptations are outside the scope of our discussion.

4.1 Impacts of Grid Decarbonization on Green Power Market

Grid mixes have become increasingly renewable over time. The renewable share of the national grid mix (including large hydropower) grew from about 14% in 2011 to about 23% in 2021 (EIA n.d.). These shares belie important regional differences. States with strong hydropower resources such as Vermont and Pacific Northwest states already source well over 30% of electricity from renewables (EIA 2020). Further, as of June 2022, 12 states had mandates for 100% clean energy supplies, 2 states, Washington, DC, and Puerto Rico had mandates for 100% renewable energy, and 7 states had carbon neutrality targets (Figure 13) (CESA n.d.). These mandates will most likely be met largely by renewables, primarily solar and wind (DOE 2021), though some mandates allow for nonrenewable, zero-carbon resources such as nuclear.

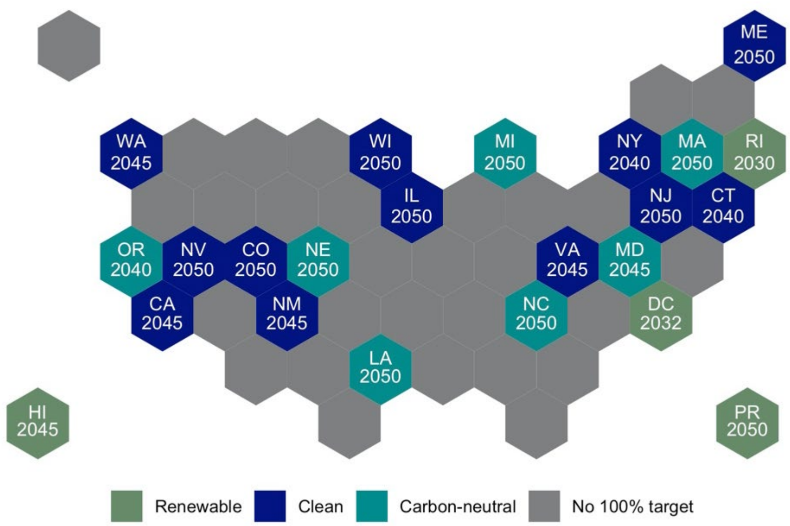

Figure 12. States with 100% renewable, 100% clean energy, or carbon neutrality targets

The figure is based on data from CESA (n.d.).

Increasingly, renewable grid mixes could affect green power demand in at least two ways:

- *Increasingly, renewable grid mixes could undermine the rationale for green power participation*. As grids decarbonize, customers can buy increasingly clean energy without investing the time and money required to buy voluntary green power. For instance, if a state RPS increases over time from 20% to 80%, the surplus demand (i.e., demand above RPS) of customers demanding 100% renewable energy falls from 80% to 20%. Increasingly, renewable grid mixes could therefore drive some customers to stay with or return to the grid mix.

- *RPS increases could suppress voluntary demand by increasing voluntary REC prices*. Electricity suppliers and green power buyers compete to buy RECs from a common pool such that increased RPS-driven demand can increase prices in the voluntary green power market and vice versa. Competition between the compliance and voluntary markets has been mild to date because renewable energy supplies have generally kept pace with demand in both markets. However, as grids approach 100% clean energy, RECs may become increasingly scarce. In a future of increasing REC scarcity, voluntary REC prices could correlate more strongly with compliance REC prices, with the most likely outcome being an increase in voluntary REC prices. These higher prices will, all else being equal, suppress green power demand among price-sensitive buyers.

4.2 Evolving Grid Needs

Voluntary green power market have driven grid decarbonization to date by enabling the deployment of renewable energy capacity. As grids decarbonize, the needs of grids evolve in ways that affect the potential role of voluntary markets in future decarbonization. To understand this assertion, it is useful to think of grid decarbonization as an evolving process that can be roughly broken down into three phases:

- **Phase 1: Low (e.g., <50%) Renewable Energy Shares:** The first phase is characterized by grids with relatively low (e.g., <50%) shares of renewable energy. Most grids are currently in this first phase. In this first phase, he decarbonization strategy is relatively straightforward: deploy low-cost renewables—mostly wind and solar—to displace fossil fuel output.
- **Phase 2: Increasing (e.g., 50%–90%) Renewable Energy Shares:** As wind and solar comprise greater shares of the grid, wind and solar supply variability begin to generate more significant issues for grid reliability (Denholm et al. 2021). At higher renewable energy penetration levels (e.g., >50%), grids may need to reinforce certain types of grid infrastructure (e.g., transmission), increase operating reserves to balance fluctuations in variable renewable energy supply, and deploy more energy storage. A few U.S. grids—such as those in California and Hawaii—have begun to make these types of investments in response to increasing renewable energy shares.
- **Phase 3: Deep Decarbonization (>90% Renewable Energy):** The challenges of renewable energy penetration increase manifold as grids approach high renewable energy penetration levels (Figure 14) (DOE 2021), a stage often referred to as “deep decarbonization.” Deep decarbonization will require investments in technologies and infrastructure that were not required during earlier phases of decarbonization, including firm clean energy (e.g., nuclear, biomass, geothermal, and hydrogen), long-term energy storage, and more substantial investments in transmission (Denholm et al. 2021).

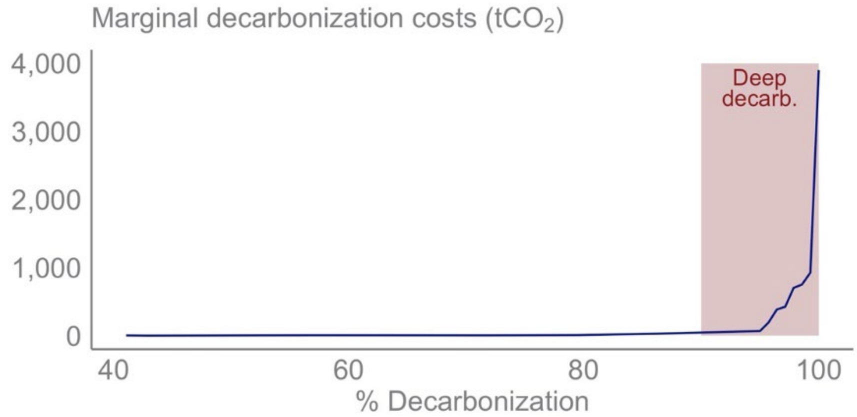

Figure 13. Exponentially increasing decarbonization costs

The figure is based on data from DOE (2021).

Voluntary markets have largely evolved to meet the needs of grids in the first phase, by developing ways to help customers procure enough green power to meet their demand, primarily solar and wind. As grids decarbonize, the potential role and impacts of voluntary procurement in subsequent decarbonization phases changes for several reasons:

- **Impact Crowding:** Conventional green power procurement practices tend to favor resources that allow customers to match renewable energy demand at the lowest possible cost, which typically means solar and wind. Over time, demand for low-cost solar and wind causes projects to cluster in areas with strong solar and wind resources. Project clustering causes the marginal impacts of projects to decline as more solar and wind projects come online. For instance, the first wind farm in a region will displace more fossil fuel output than the tenth wind farm in that region, all else being equal. *Conventional procurement practices do not account for these diminishing marginal impacts*.
- **Non-Generation Service Requirements:** As renewable energy penetration increases, non-generation services (e.g., reserve capacity, frequency regulation, and voltage control) become increasingly important for balancing variable supply and variable demand (Denholm et al. 2021). Given that non-generation services do not count toward matching customer renewable energy demand, *conventional green power procurement practices provide no incentives for non-generation services*.
- **Need for Firm Clean Energy Capacity:** Firm clean energy resources are clean energy generators whose output is available on call to respond to grid needs. Examples of firm clean energy resources include geothermal, low-impact hydropower, concentrating solar power, biofuels, nuclear (under certain definitions), and emerging technologies such as hydrogen combustion turbines. Firm clean energy will become increasingly important for deep decarbonization as these resources can be ramped up or down to balance supply and demand (Denholm et al. 2021; DOE 2021). Firm clean energy resources generally come at a cost premium to variable resources (e.g., solar and wind) in terms of energy costs ($/MWh). *Conventional procurement practices that prioritize low-cost renewables are unlikely to make a significant contribution to firm clean energy capacity*.
- **Need for Energy Storage:** Energy storage will become increasingly vital on decarbonizing grids (Denholm et al. 2021; DOE 2021). Energy storage can store and shift variable

renewable energy, essentially converting variable resources like solar and wind into firm clean energy capacity. *Conventional procurement practices provide no incentives for battery storage*, given that buyers use RECs at the point of generation and glean no additional value from storing and shifting the underlying electricity.

These limitations of conventional green power procurement largely reflect the limited role of retail electricity customers in grid decarbonization. Green power buyers—like all retail electricity customers—are not directly responsible for ensuring their electricity use aligns with grid needs, which are the purview of regulated utilities, system operators, and policymakers. Still, buyers could adapt their procurement practices in ways that meet the evolving needs of utilities and system operators. These potential adaptations are the topic of the next section.

4.3 How the Green Power Market Could Adapt

In this section, we explore how the voluntary market might adapt to the changing needs of decarbonizing grids. Before proceeding, it is worth noting that the discussion in this section is strictly prospective: *it should not be interpreted as analysis of historical or current voluntary green power market practices*. Further, some proposed adaptations conflict with existing voluntary market practices and definitions. The discussion here should be interpreted as a menu of ideas that are not yet broadly accepted by all market stakeholders. Finally, much of the literature discussed in this section focuses on market adaptations for larger buyers and especially large corporate buyers. As we discussed in Section 3.1.1 (page 9) and Section 3.1.2 (page 11), a key challenge for the market will be finding ways to engage smaller and mid-sized buyers as the market adapts.

Voluntary green power buyers and suppliers have frequently adapted to changing market conditions and could similarly adapt to changing grid needs. Adapting to changing grid needs as grids approach 100% clean energy would require a reassessment of the objectives of green power procurement. Under conventional procurement practices, customers generally match RECs to their demand to make claims about their *own* renewable energy use. Bird, O'Shaughnessy, and Hutchinson (2021) argue procurement objectives will need to shift toward actions designed to transform and decarbonize the grid itself. They state that transformative procurement (1) maximizes emissions reductions, (2) accelerates clean energy deployment, (3) enables broader clean energy adoption, (4) supports new technologies and innovations, and (5) enables an equitable and just clean energy transition. Table 3 defines these impacts and describes how transformative procurement practices differ from conventional procurement practices. See Bird, O'Shaughnessy, and Hutchinson (2021) for detailed descriptions and examples of each of these impact categories.

Table 3. Comparison of Conventional and Transformative Procurement Impacts

Impact	Conventional Procurement Practices	Transformative Procurement
Emissions reductions	All procurement can reduce emissions, but conventional products are not designed to maximize emissions reductions.	Transformative procurement includes approaches that are explicitly designed to maximize emissions reductions, such as by prioritizing deployment on carbon-intensive grids or prioritizing technologies that generate more output during carbon-intensive times of the day or year.
Clean energy deployment	Many conventional products support existing projects.	Transformative procurement directly supports the deployment of new clean energy capacity at a faster pace than required by RPS.
Clean energy adoption	Conventional buyers procure green power to maximize the strength of their own claims.	Transformative buyers take actions that enable other customers to buy their own clean energy. For instance, procuring energy storage can make renewable energy projects more flexible, making it easier for other buyers to add more renewable energy onto the grid.
Enabling technologies and innovation	Conventional procurement is mostly based on RECs from solar and wind projects.	Transformative buyers support the broader suite of technologies required for deep decarbonization, including firm renewable energy (e.g., geothermal), energy storage, and grid infrastructure projects.
Enabling and equitable and just clean energy transition	Conventional buyers do not typically consider the broader societal impacts of green power procurement.	Transformative buyers seek opportunities for broader societal benefits, such as supporting minority-owned businesses and engaging with local communities to maximize the local benefits of project development.

Building on the transformative practices identified by Bird, O'Shaughnessy, and Hutchinson (2021), we identify three ways the voluntary green power market could adapt to grid decarbonization (Table 4). We explore each of these potential adaptations in depth in the remainder of this section. We begin our discussion with the adaptation closest to conventional procurement practices (customer-aligned procurement) and then move onto two adaptations entailing more-fundamental shifts from conventional procurement practices.

Table 4. Potential Green Power Procurement Adaptations

Approach	Description	Comparison with Conventional Procurement
Customer-aligned procurement (Section 4.3.1)	Practices that force buyers to procure resources that match the geographic and temporal profiles of customer electricity use	Conventional procurement matches green power supply to demand on a coarser basis, typically through annual matching without specific requirements for resource location.
Grid-aligned procurement Section 4.3.2)	Procurement practices designed to maximize the impacts of green power on the grid (e.g., MW deployed) or for the environment (e.g., tons of CO_2 abated)	Conventional procurement does not explicitly aim to maximize impacts on the grid or environment.
Socially motivated procurement (Section 4.3.3)	Procurement designed to achieve specific social benefits	Conventional frameworks do not incentivize socially motivated procurement.

4.3.1 Customer-Aligned Procurement

For the purposes of this report, customer-aligned procurement refers to green power that aligns with the location and timing of the electricity demand of individual customers. Customer-aligned procurement is essentially a sophisticated form of matching that forces buyers to match renewable energy supply to demand geographically and on an hourly or subhourly basis rather than an annual basis. In this regard, customer-aligned procurement is a relatively simple adaptation of conventional procurement.

Customer-aligned procurement can increase green power impacts by forcing buyers to procure more diverse resource portfolios than those driven by conventional procurement (Miller 2020; Xu et al. 2021).[7] To align procurement and demand profiles, buyers must ensure green power is available even when the sun is not shining or the wind is not blowing. Customer-aligned procurement could therefore drive investments in the types of resources required for deep decarbonization, such as firm clean energy and battery storage (Xu et al. 2021; LDES Council 2022).

Another way to achieve customer-aligned procurement is to reshape customer demand profiles according to solar and wind output (Miller 2020; Bird, O'Shaughnessy, and Hutchinson 2021). Customers can reschedule or shift certain loads to hours when more solar or wind is available, thus better aligning procurement and demand profiles without needing to procure costlier green power resources. There are many ways to reshape demand profiles, ranging from simple and manual—e.g., a household choosing to run a laundry machine during the day—to complex and automated—e.g., data centers shifting computing operations to optimize the use of clean energy at different points on the grid.

[7] Note that an enhanced impact is not inherent to customer-aligned procurement. For instance, a business that uses most power during the day could theoretically achieve 24/7 matching buying mostly solar power. In such cases, the impacts of 24/7 procurement would not be fundamentally different from the impacts of annual matching. The impacts of customer-aligned procurement should thus be evaluated on whether aligned procurement forces buyers to procure a more diverse portfolio of renewable resources.

Efforts to create a voluntary green power market based on customer-aligned procurement are at an early stage. Only large, sophisticated buyers such as Google, Microsoft, and the U.S. federal government are seriously pursuing customer-aligned procurement practices such as 24/7 procurement (Xu et al. 2021). The primary challenge to scaling customer-aligned procurement is developing a framework through which customers are credited for aligned hourly supply and demand (LDES Council 2022). Initiatives such as EnergyTag have begun to explore potential frameworks. Another key question is whether and how to account for temporal profiles of renewable supply on the grid mix. For instance, should customers somehow be credited for shifting demand to times of day when the grid mix is more renewable, such as midday hours in solar-heavy regions? Such questions will shape the future design of voluntary markets for customer-aligned procurement.

The key distinguishing feature of customer-aligned procurement is that its objectives are defined exclusively by customer needs. Customer-aligned procurement is designed to reduce *individual* emissions and maximize *individual* claims to renewable energy use in ways that benefit the grid. The remaining adaptations shift the focus toward metrics based on the grid or society at large.

4.3.2 Grid-Aligned Procurement

Grid-aligned procurement refers to strategies to achieve specific outcomes on the grid. Grid-aligned procurement actions include strategies that change where, when, and which types of clean energy technologies are deployed.

Buyers can align procurement with grid needs by adjusting *where* green power is procured. A clear example of the role of location in driving procurement impact is spatial differences in grid emissions intensity (tons of CO_2 emitted per MWh of electricity). The emissions intensity of the U.S. grid varies by nearly a factor of seven in the continental United States, from about 0.1 tons of CO_2 (tCO_2)/MWh in upstate New York to about 0.7 tCO_2/MWh in eastern Wisconsin. Buyers can leverage these differences by strategically siting green power on carbon-intensive points on the grid to maximize the impacts of green power procurement.

Buyers can also align procurement with grid needs by adjusting *when* green power is procured. Just as grid emissions vary at different points on the grid, emissions also vary over time. For instance, the emissions intensity of the California grid can vary by roughly a factor of two over the course of a single day due to the daytime availability and nighttime absence of solar power (Figure 15). Green power buyers can maximize the temporal impacts of their procurement by prioritizing technologies that generate during emissions-intensive periods. In some cases, this may mean complementing solar with wind or vice versa. A more effective approach would be to prioritize firm clean energy resources that can generate at any time or to add battery storage to solar or wind projects. Further, buyers can work with project developers to operate projects in ways that maximize the temporal impacts of green power. For instance, in the California example, a buyer could add storage to a solar project and shift some solar output to the late-afternoon peak.

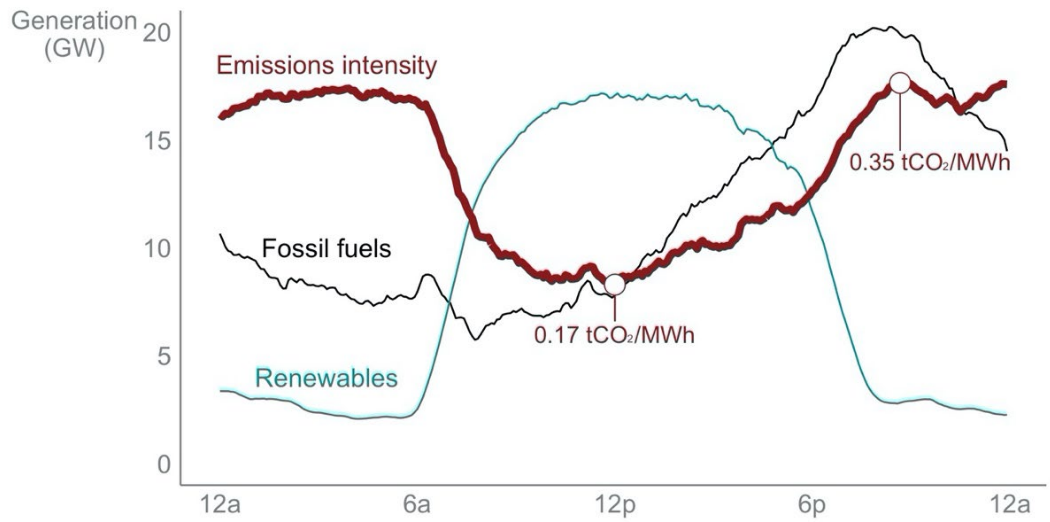

Figure 14. Generation profiles and grid emissions intensity in California on June 21, 2022

The figure is based on data from "Today's Outlook" from the California ISO.

A final form of grid-aligned procurement is actions to determine *which* types of technologies are deployed. As already noted, decarbonizing grids will require increasing resource diversity. One way buyers can support resource diversity is by enabling emerging clean energy technologies (Bird, O'Shaughnessy, and Hutchinson 2021). Green power buyers can enable new technologies in several ways:

- *Be early adopters of new technologies*. Most emerging technologies rely on early adopters who take risks on uncertain and unproven new products. Early adoption drives technological diffusion when costs are high, allowing industries to find ways to reduce costs through scale and innovation. Buyers can be early adopters of risky new technologies, some of which will scale and drive decarbonization.
- *Demonstrate new technologies*. Buyers could work directly with researchers or suppliers to demonstrate new and emerging technologies at small scales. For instance, some buyers are exploring small-scale demonstrations of carbon capture technologies (Bird, O'Shaughnessy, and Hutchinson 2021). Demonstrations may have negligible impacts on buyer emissions profiles but help emerging technologies to scale and make meaningful contributions to grid decarbonization.
- *Develop products that enable new technologies*. Buyers and suppliers can develop new products that enable emerging technologies. For instance, as already noted, conventional products provide no incentives for battery storage. Buyers and suppliers could develop products that credit buyers for the extra value generated from battery storage used in ways to benefit the grid or reduce emissions.

Grid-aligned procurement requires market products, practices, and protocols that incentivize buyers to take actions that meet grid needs. One example is the Greenhouse Gas Protocol, which allows buyers to use green power to reduce their emissions (for reporting purposes) based on grid emissions intensity at the point of green power generation (Sotos 2020). The Greenhouse Gas Protocol thus provides incentives for these buyers to procure green power that maximizes emissions. Some green power buyers are also exploring how to align procurement plans with grid needs by collaborating with utilities in long-term grid planning (Bonugli et al. 2021). Direct procurement products, such as PPAs, are inherently sensitive to grid needs given that products that better serve the grid can obtain higher market prices. Utilities and competitive suppliers could potentially explore ways to better align small buyer products (e.g., utility green pricing) with grid needs.

4.3.3 Socially Motivated Procurement

Grid decarbonization will yield enormous benefits as well as costs (DOE 2021). The benefits and costs of grid decarbonization will not necessarily be distributed equitably with respect to factors such as income and race (Carley and Konisky 2020). Governments are increasingly exploring and implementing measures to drive more equitable distributions of clean energy benefits and costs. Voluntary green power buyers could similarly factor social equity and justice into their procurement actions. Examples of socially motivated procurement include:

- **Equitable Siting:** Buyers can prioritize project sites that maximize equity benefits. In some cases, this means supporting projects deployed in disadvantaged communities that generate local benefits for those communities. For instance, solar projects in disadvantaged communities can provide additional tax revenues, lease revenues, and temporary local jobs. In other cases, this means avoiding procurement from projects associated with procedural injustices. For instance, buyers could avoid enabling projects that were opposed by Indigenous communities.
- **Equitable Project Development:** Buyers can maximize the equity benefits of project development. For example, beginning with their supply chain, buyers can prioritize product developers that source parts from manufacturers with sustainability statements or from minority-owned businesses. During development, green power buyers can promote local hiring, workforce diversity, and educational opportunities (Bird, O'Shaughnessy, and Hutchinson 2021).

Of the three adaptations discussed in this section, socially motivated procurement represents the most fundamental shift from conventional procurement practices. Socially motivated procurement would require new market and legal frameworks to validate social claims (see also Section 3.2, page 14). Some early efforts provide testing grounds for potential solutions. For instance, multiple organizations now offer RECs coupled with social attributes, such as social RECs for projects developed in disadvantaged communities and so-called peace RECs for projects in areas recovering from war. These or similar frameworks could be scaled to provide buyers a way to drive a more equitable clean energy transition through socially motivated procurement.

5 Conclusions and Observations

The U.S. voluntary green power market continues to grow. We estimate that in 2021 about 8 million customers procured around 244 million MWh of green power, a 22% increase from 2020. The market owes its continued growth partly to the ongoing adaptations of green power products to evolving customer and grid needs. We conclude with four observations from our report:

- *Green power demand continues to grow across all products*. Growth is particularly strong for the products that offer direct procurement from specific projects: utility contracts and PPAs. Utility contracts and PPAs both have substantial pipelines that ensure continued growth into the foreseeable future.
- *Expanding green power access to smaller buyers is a soluble challenge*. In Section 3 (page 9), we identified some emerging challenges to improving existing products and expanding green power market access, particularly to smaller buyers. These challenges are soluble. Some utilities and other green power suppliers have already developed innovative new products that expand green power market access. Innovative new green power products, where successful, could provide a template for other suppliers to implement. Expanded product access could provide a way to engage a more diverse customer base, including LMI customers.
- *The green power market has adapted to the evolving needs of customers and grids*. The U.S. voluntary green power market has consistently demonstrated an ability to adapt. In the past decade, buyers and sellers have worked together to spawn a variety of new products that meet unique buyer needs and, in some cases, might ensure more substantial grid and environmental impacts. There has been a marked shift toward products that directly connect buyers with power and RECs from specific projects through PPAs and utility renewable contracts. More recently, buyers and sellers have begun working together to develop products that meet the evolving needs of grids, such as designing 24/7 products that ensure green power is delivered to grids when renewable energy is scarcer.
- *The green power market can play a role in deep decarbonization*. In Section 4 (page 18), we discussed how deep grid decarbonization will pose new and unique challenges to the voluntary green power market. The ongoing ability of the green power market to adapt suggests the market will adapt to evolving grid needs and play a role in deep decarbonization. Buyers and sellers could develop new products catered to the specific needs of grids with higher levels of baseload renewable energy, such as products that support firm clean energy and battery storage. By continuing to adapt to the needs of an evolving grid, the voluntary green power market could continue to play a long-term role in grid decarbonization.

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