Hybrid Electricity Markets

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MIT
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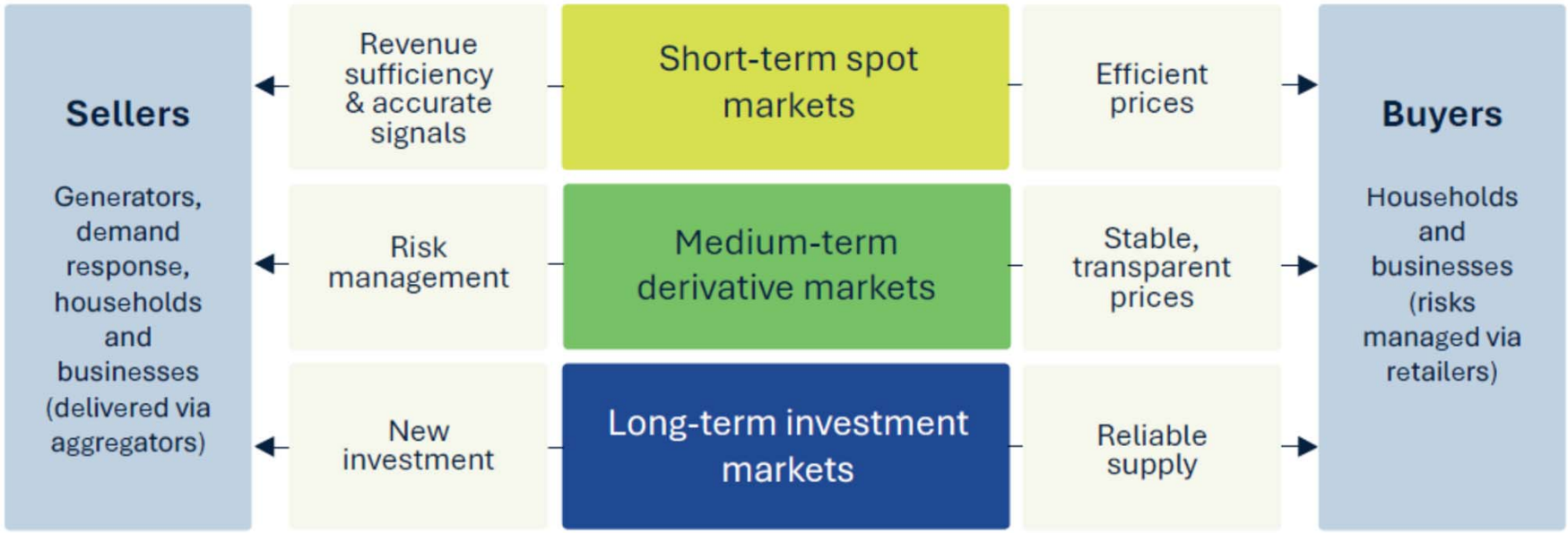
Figure 5 – Features of a successful electricity market for buyers and sellers



National Electricity Market Review, Australia, February 2025 (Draft), page 16

Hybrid Markets

U.S. academic research focuses on this

U.S. academic research largely ignores this

Short-term wholesale markets

- Market-based least-cost security constrained (LMP) economic dispatch through organized markets for energy and AS
- Efficient short-term wholesale prices for energy, congestion, ancillary services, and reliability given existing capital stock through competitive bidding and co-optimization
  - P ≥ SRMC
- Scarcity pricing contingencies to send reliability signals
- Manage curtailments efficiently
  - Transmission constraints
  - Overgeneration of wind and solar

Wholesale markets for LT PPAs/CfDs

- LT PPAs are 10 - 30 year "off-take" contracts between a generator(s) and a buyer
- Have various price and production provisions
- Should support meeting decarbonization targets if they exist with a least cost mix of wind, hydro, nuclear, hydro, batteries, etc.
- Should support meeting Resource Adequacy(RA/SoS) constraints
- Should minimize expected costs given the decarb and RA/SoS criteria
- **Contract design should be compatible with efficient short-term market operation, pricing, demand response, and incentives for efficient performance**
- Flexible LRP to guide portfolio construction at the aggregate market level

Competition in the market

Competition for the market

What is a LT PPA?

- A 10 – 30-year contract between an electricity supplier and a buyer or "off-taker"
- Who are the buyers?
  - utility LSE (default service, RPS, Resource Adequacy); alternative to building/owning generation and storage
  - competitive LSE with stable customer choice portfolios
  - large "institutional" customers (for profit, non-profit, government)
  - community aggregators
  - financial intermediaries
- Specifies a price for output
  - Fixed price per MWh
  - Indexed price per MWh
  - Seasonal price per MWh
  - Partially hedged price (sharing) per MWh
  - Capacity price per MW
  - Treatment of curtailments
  - Negative price contingencies
- Specifies quantities to be supplied
  - All output, specified output, "modelled" output
  - Location and delivery point (congestion/basis risk)

Southern California Edison Recently Approved PPAs (February 2026)

Developer / Project	Resource Type	Contract Type	Nameplate Capacity	Expected Generation (MWh/ year)	Contract Term	Location	Initial Delivery Date
174 Power Global, Bonanza Peak I	Single-Axis Solar PV	RPS-Eligible	400 MW	1,154,000	20	Inyo County, California	09/01/2029
174 Power Global, Bonanza Peak II	Single-Axis Solar PV	RPS-Eligible	100 MW	289,000	20	Inyo County, California	09/01/2029
174 Power Global, Bonanza Peak III	Single-Axis Solar PV	RPS-Eligible	100 MW	289,000	20	Nye County, Nevada	09/01/2029
Avantus, Aratina II PV	Single-Axis Solar PV	RPS-Eligible	150 MW	447,000	15	Kern County, California	12/01/2027
Avantus, Aratina II BESS	4-Hour Lithium Ion BESS	Resource Adequacy with Energy Settlement	113 MW	n/a	15	Kern County, California	12/01/2027
Intersect Power, Darden I PV	Single-Axis Solar PV	RPS-Eligible	287.5 MW	808,000	15	Fresno County, California	08/01/2028
Intersect Power, Darden II PV	Single-Axis Solar PV	RPS-Eligible	287.5 MW	807,000	15	Fresno County, California	08/01/2028

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Intersect Power, Darden II BESS	4-Hour Lithium Ion BESS	Resource Adequacy with Energy Settlement	287.5 MW	n/a	15	Fresno County, California	08/01/2028
Terra-Gen Power, Lockhart IV	Single-Axis Solar PV	RPS-Eligible	80 MW	n/a	20	San Bernardino County, California	02/01/2027

EDP Renewables and Meta ink PPA for 250-MW solar project

This is the third such deal between EDP Renewables and Meta, bringing the total procured energy between the two companies to 545 MW.

Published May 7, 2026

Diana DiGangi
Reporter

January 15, 2026

Clearway Signs Portfolio of Power Purchase Agreements with Google Totaling Nearly 1.2 GW Across Three States

SAN FRANCISCO –Clearway Energy Group (Clearway) announced the 2025 execution of three new long-term power purchase agreements (PPAs) with Google totaling 1.17 GW of carbon-free energy projects located in Missouri, Texas, and West Virginia.

Under the new agreements, Clearway will deliver carbon-free energy to local grids to support Google's data centers in SPP, ERCOT, and PJM for up to 20 years while driving economic growth across the local communities. Together, the three projects represent over $2.4 billion invested in reliable energy infrastructure.

Construction will begin this year on the projects totaling over 1 GW, with the first sites expected to come online in 2027 and 2028. The new agreements build on Google and Clearway's existing 71.5 MW PPA in operation in West Virginia, bringing the total partnership to 1.24 GW.

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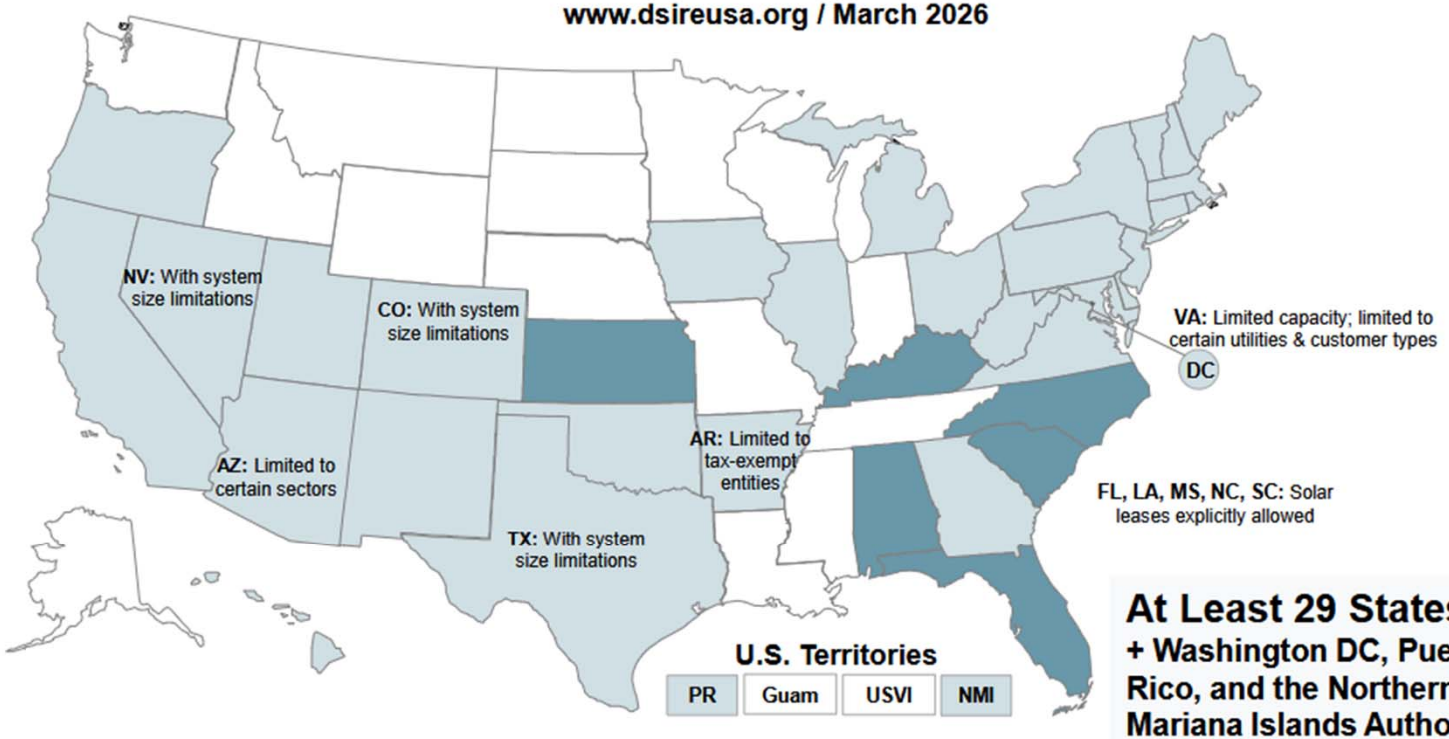
3rd Party Solar PV Power Purchase Agreement (PPA)

www.dsireusa.org / March 2026



Apparently disallowed by state or otherwise restricted by legal barriers

Authorized by state or otherwise currently in use, at least in certain jurisdictions

Status unclear or unknown

At Least 29 States
+ Washington DC, Puerto Rico, and the Northern Mariana Islands Authorize or Allow 3rd Party Power Purchase Agreements for Solar PV.

MIT "Virtual" PPAs

- Buying carbon credits by supporting investment in wind and solar
  - Not really buying electricity to serve MIT's demand
  - Effectively buying carbon credits
  - But LT PPA facilitates financing the projects
- Summit Farms Solar (North Carolina)
  - 60 MW
  - 25-year PPA
- Big Elm Solar (Texas)
  - 200 MW
  - 15-year PPA
- Bowman Wind (North Dakota)
  - 208 MW
  - 15-year PPA

Massachusetts PPA Procurements

- Hydro + Transmission
- Offshore Wind + Transmission
- Storage
- Managed by MA but the ultimate counterparties are the three T&D IOUs (per MA laws)
- Small scale solar procurement relies on de facto feed-in tariffs
- Other states managing LT PPA procurements: New York, Connecticut, Maine, New Jersey, Rhode Island, Maryland, California

Massachusetts selects 1.2GW of BESS through RFP

By April Bonner (https://www.energy-storage.news/author/april-bonner/)

December 31, 2025

UK secures 4.9 GW of solar capacity in CfD auction

The seventh allocation round (AR7) awarded contracts to 157 solar plants due online by 2029.

FEBRUARY 10, 2026 **MATTHEW LYNAS**

PV Magazine

Record breaking auction for offshore wind secured to take back control of Britain's energy

A record 8.4GW of offshore wind secured in Europe’s biggest ever offshore wind auction.

January 14, 2026, UK.GOV

Why Turn To LT PPAs?

- Reduce financing cost/risk to the developer by transferring risk to buyers with high credit ratings
  - Buyer counterparties typically have high credit ratings and relatively low cost of capital
  - By transferring most market risk to buyers or intermediaries, developers can finance new projects on relatively attractive terms (Newbery)
  - Sellers typically retain some market risk (e.g. output variability), performance risks (forced outages), curtailments, government policy changes (e.g. tariffs, subsidies), etc.
  - Buyers, especially "large loads" that seek stable supply of power at a specified price, want to avoid dealing with the "plumbing" of wholesale markets, ongoing market design changes, interconnection, transmission cost allocation, often while supporting voluntary decarbonization commitments
- Manage Reliability (Security of Supply) risks as system level
- "Push" the system to meet decarbonization obligations, commitments, and goals reflected in government procurement policies
  - Most of U.S. has no carbon prices and the prices in three regional carbon markets are too low to drive the system to meet decarbonization commitments (RGGI ~ $45)
  - Decentralized market mechanisms lead to too little investment in wind, solar and batteries compared to targets and commitments of buyers
  - Costs of renewables and storage will be too high if developers do not have access to low-cost financing --- follow the money
  - Decarbonization is falling behind goals!

The Walmart View

Driving scale through long-term power purchase agreements (PPAs). To date, we have found the Power Purchase Agreement (PPA) to be a highly effective model for Walmart to leverage our scale and buying power to accelerate renewables. Under these arrangements, Walmart agrees to buy renewable power from an energy provider over a long period of time – often 5, 10, 15 or more years. Long-term PPAs have unlocked enormous renewable potential, but have also required a new way of thinking. Prior to 2006, the renewable energy industry sought 20-25 year PPAs, while Walmart was accustomed to buying power in 1-year or less contracts.

PPAs are mutually beneficial for Walmart and the energy provider. Under PPAs, the energy provider also owns, installs, and operates the renewable energy systems, relieving Walmart of that operation and maintenance responsibility. For project developers, PPAs provide a predictable stream of income, which is what financiers and banks say is the key to the low cost of capital and preferred financing arrangements. When Walmart promises to buy the electricity, the project can be built with low-cost financing and deliver electricity at or below non-renewable power prices.

Source: Walmart

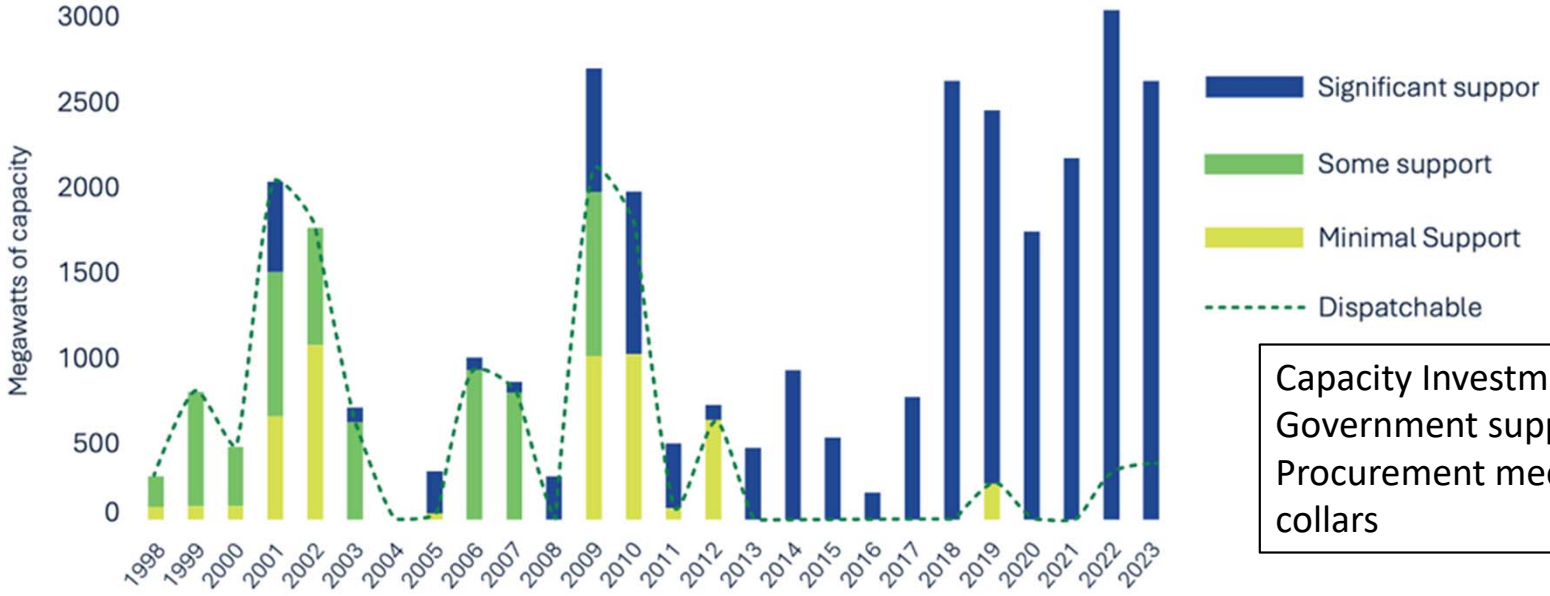
Australia

Although the design of the NEM aimed to let market forces drive investment decisions, government policy support has been a significant driver of investment in new generation since its inception. The Panel notes that this has been a feature of most deregulated electricity markets, irrespective of the market design adopted. Almost all investment in new generation capacity in the NEM has received some form of government support, and there are very few examples of pure, market-only investments that were made entirely on the basis of expectations about future spot market revenues and forward derivatives markets. Emerging research suggests NEM spot prices and derivative markets on their own have not driven recent investment decisions in the NEM, in contrast to the strong role of policy support[8].

NEM Review (Draft) February 2025, page 38

Australia

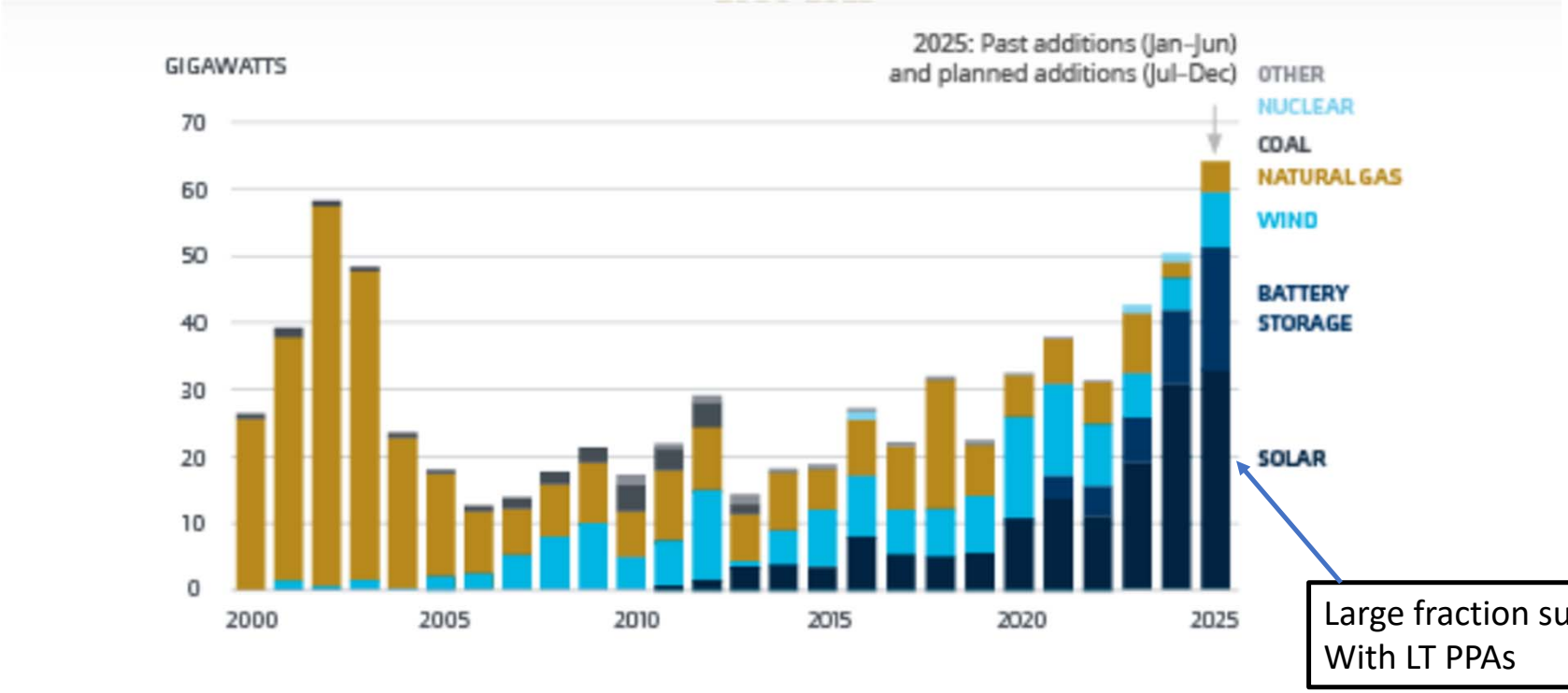
Figure 17 – Generation build by non-market support, 1998–2023



Capacity Investment Scheme (CIS)
Government supported PPA
Procurement mechanism with revenue collars

Sources: NEM review analysis drawing on AEMO Generation Information, Bloomberg New Energy Finance, and the work and expertise of a range of experts. Includes utility scale generation from coal, gas, solar, wind, hydro. Excludes batteries, pumped hydro, rooftop solar or other small-scale resources, and demand side participation.

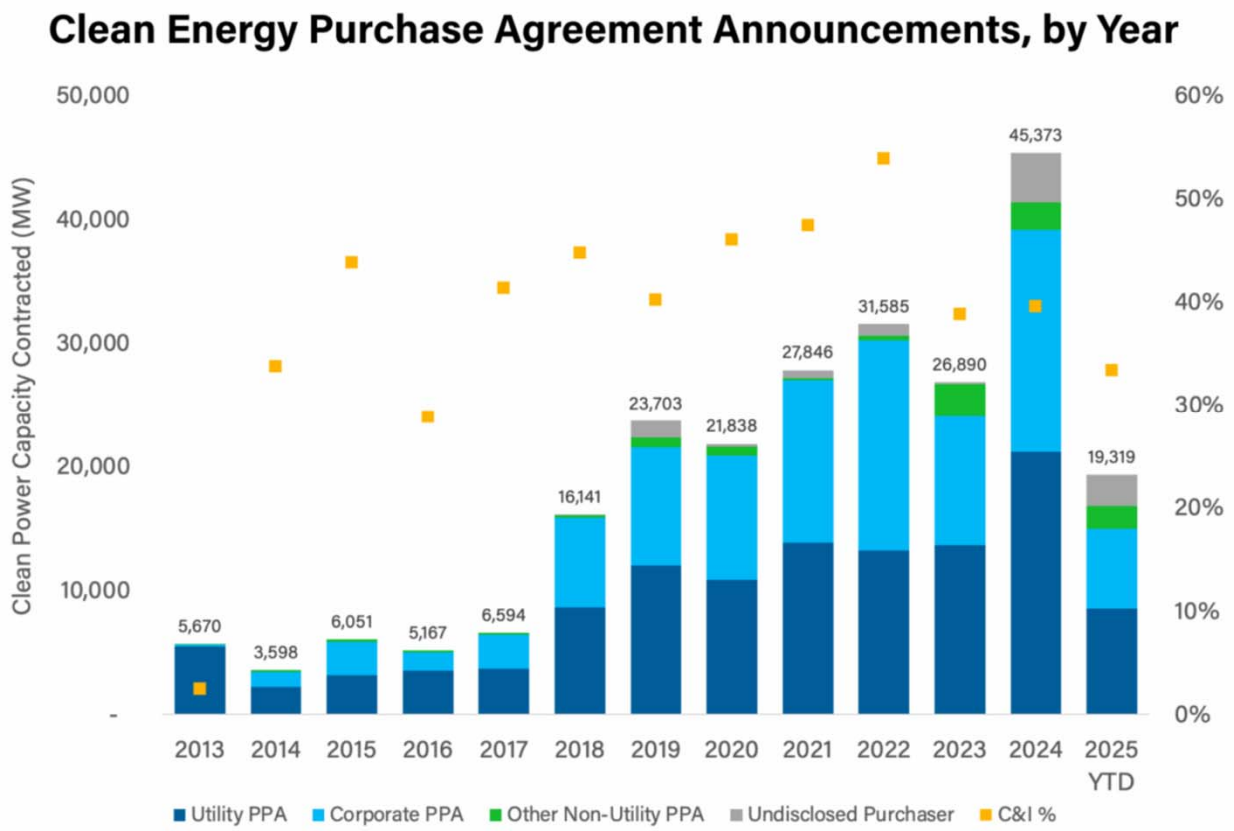
NEM Review (Draft) February 2025, page 39



Large fraction supported
With LT PPAs

Data Source: U.S. Energy Information Administration, Preliminary Monthly Electric Generator Inventory, June 2025

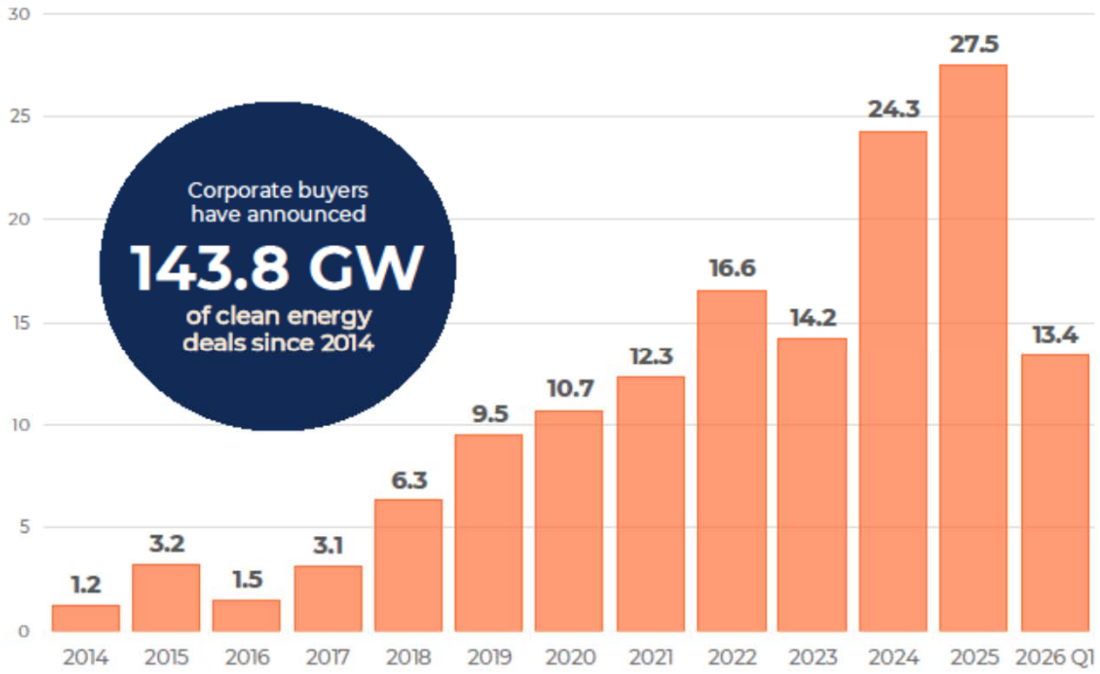
Source: U.S. developers report half of new electric generating capacity will come from solar. August 2025. U.S. Energy Information Administration[24]



American Clean Power Association

CEBA Corporate Energy Buyers Association

CEBA DEAL TRACKER

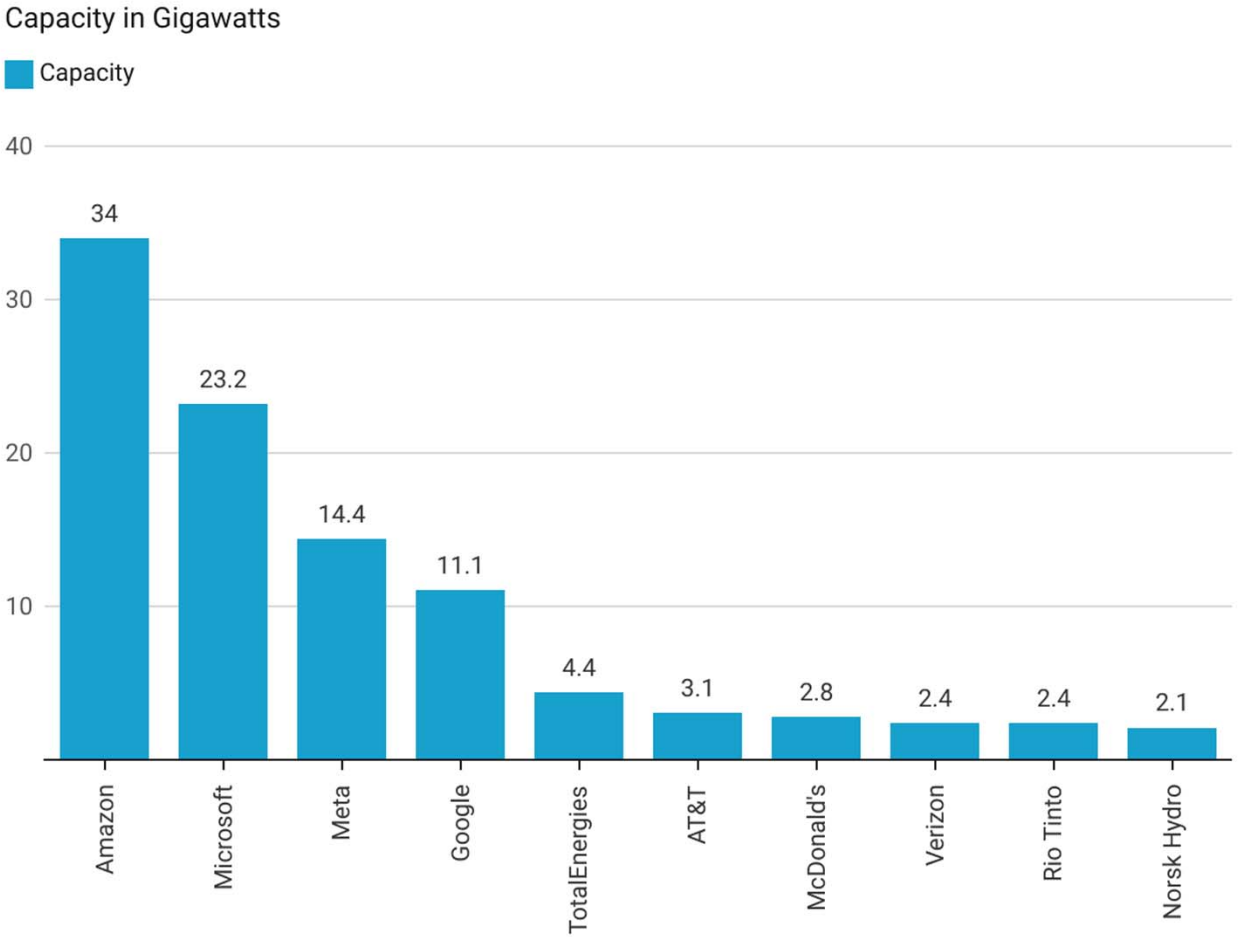


As of March 2026, includes publicly announced corporate clean energy procurement through power purchase agreements, green tariffs, tax equity investments, and direct and project ownership in the U.S. from 2014-March 2026. Excludes onsite generation <20 MW.

Source: CEBA Deal Tracker

CEBA

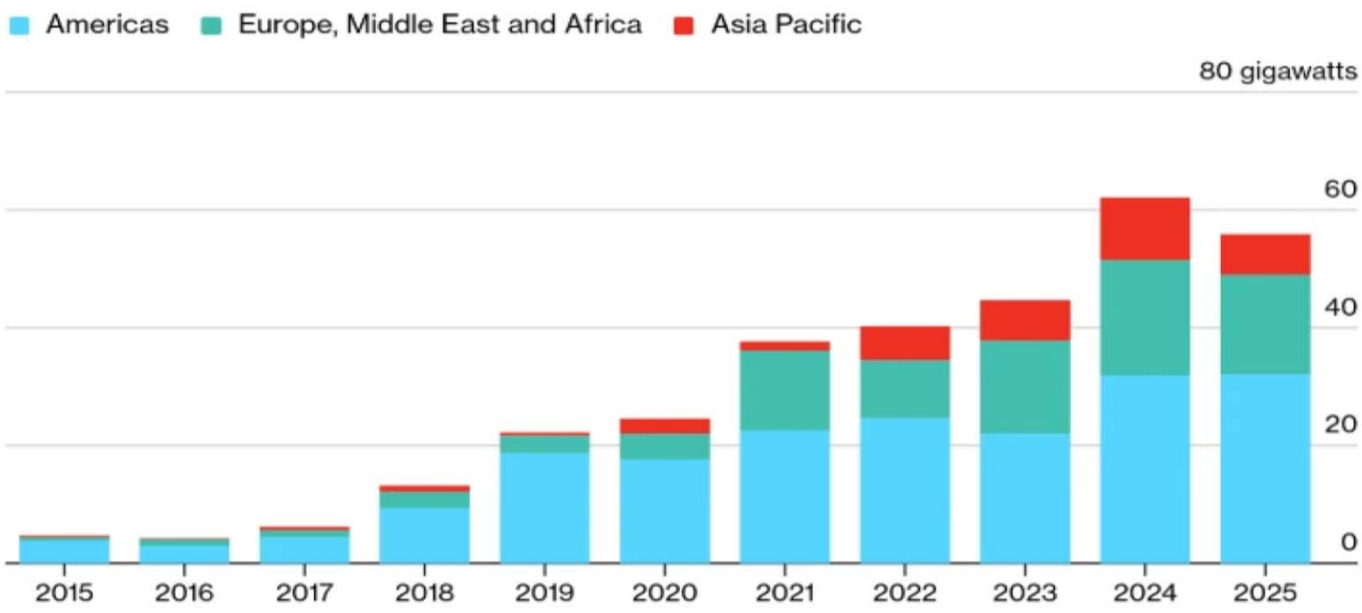
Global Cumulative Renewable PPA Capacity in 2024 - By Company



(Capacity in Gigawatts)

Source: Market.us Scoop

Corporate Clean Energy PPA Procurement



Source: BloombergNEF
Note: Chart shows only offsite corporate power purchase agreements (PPAs) that are publicly disclosed or submitted directly to BNEF by market participants and meet a set of minimum requirements. Only PPAs with contract durations greater than one year are included. Previously estimated deal volumes in Asia Pacific have been removed. Only reported Asia Pacific deals are included. Figures are subject to change as more information is made available. Data through December 2025.

BloombergNEF

Simple Fixed Price Contract
(or two-way CfD with fixed strike price)

Issues:

- Exogenous construction cost changes have become a significant risk especially as pressure on supply chains has led to much higher prices for equipment
- Completely insulated from short-market prices and incentives to respond
- No incentive to do maintenance when prices are low
- Contributes to negative prices when there is “excess” generation and curtailment
- May distort incentives to update inverter technology and power electronics to supply ancillary services
- May distort timing of maintenance
- May distort incentives to install on-site storage ex post
- Repowering incentives may be muted

Competitive Procurement Design

- Not a simple textbook uniform market clearing price auction
- Issue an RFP and Model PPA Contract (typically single source but sometimes “all-source” renewables)
  - All source procurement makes evaluation too complicated in practice
  - RFP specifies numerous qualification details
  - Model contracts often 50-60 pages
- Price, output, and non-price considerations
- Buyer or independent evaluator ranks the responses to the RFP using specified criteria for individual attributes
- Small number offers are chosen for further information and negotiation
- Winner (s) is selected after negotiations, the PPA is signed, and security is posted
- Backup offers may also be identified if the winner runs into problems

Non-price Considerations

- Financing capabilities
- Developer experience
- Site control and interconnection queue status
- Equipment acquisition status
- Maintenance scheduling
- Treatment of curtailments
- Repowering and other opportunities to increase value (e.g. provide operating reserves, frequency regulation, inertia)
- Wholesale market design and regulatory changes
- Dispute resolution and Force Majeure
- Portfolio integration

Aggregate Market Implications for RA (SoS) and System Cost

- Objective function has at least three targets: RA/SoS, decarbonization, least cost
- Procurement by Individual buyers may not lead to aggregate results that take all objective function "targets" into account
  - Get the prices right on all margins === HARD
  - Carbon price
  - ELCC (RA)
  - Cost
- Buyers may seek lowest cost carbon credits, lowest cost electricity, or both
- LSEs or RTO must play an indicative planning and RA crediting (ELCC) and enforcement role
- State by state? MA vs. ISO-NE

Conclusions

- PPAs are playing an important role in supporting investment in new generating capacity, especially to meet decarbonization goals in the absence of a goal-consistent carbon emissions price
- PPAs are increasing providing financial support for investments in wind, solar, batteries, nuclear, geothermal
  - RTO "missing money" calculations are increasingly irrelevant for investment decisions
- Much more attention needs to be played to efficient integration between PPAs with short-term wholesale markets, reliability, criteria and decarbonization goals
- Best practices for PPA design deserves more attention by policymakers and ISOs
- Policymakers need to be less insular and endeavor to learn from other countries