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Incorporating Battery Energy Storage (BESS) in Renewable Energy (RE) Auctions

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Climate Economic Analysis For Development, Investment, And Resilience (CEADIR) Activity

Photo Credit: Anesco

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Topics for this Presentation

- Rationale for battery energy storage systems (BESS)
- Case studies of technology-neutral renewable energy (TNRE) auctions that included BESS
- Challenges and opportunities for incorporating BESS in TNRE auctions
- Recommendations

— Rationale for Battery Energy Storage

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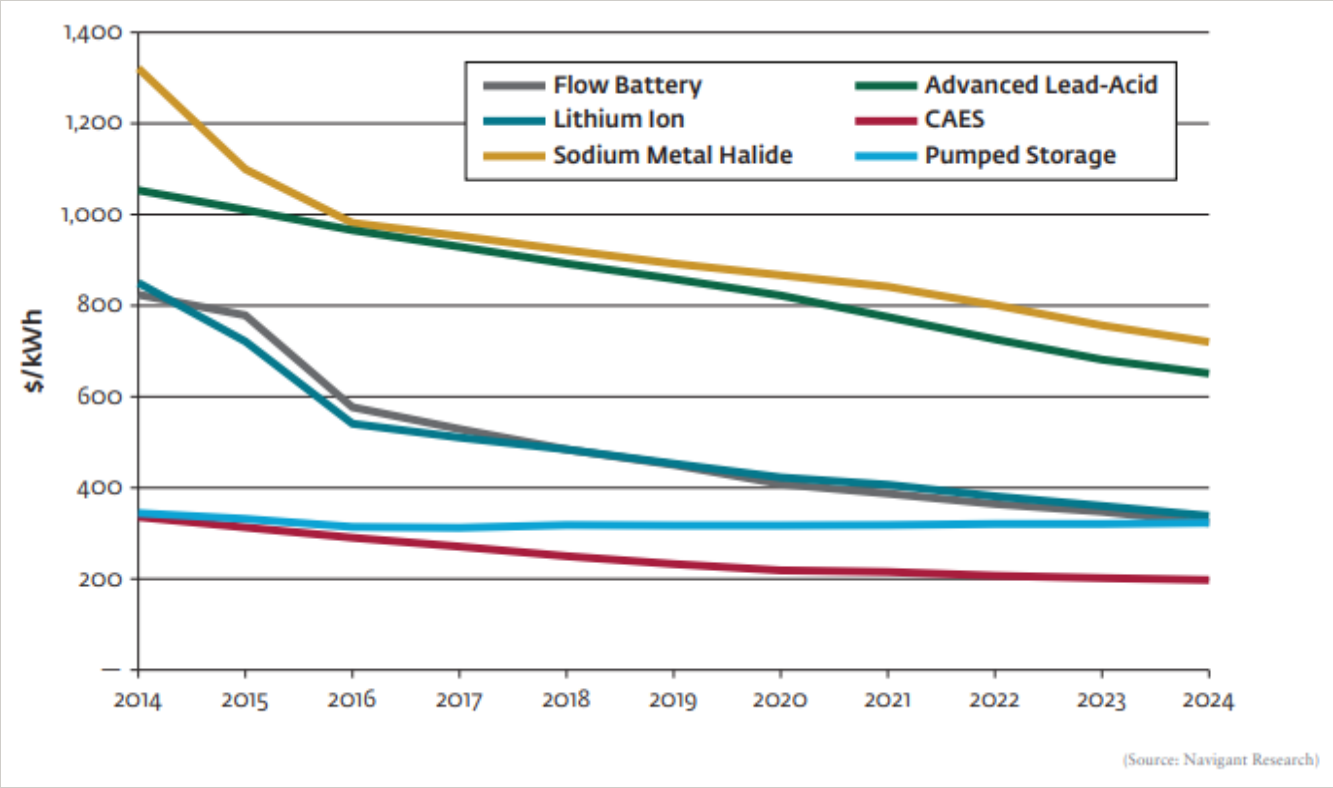
Low Power Prices from RE Auctions Need to Be Considered With Caution

- Product bid was usually electricity generated (MWh), but can be new installed capacity (MW)
- Electricity generated may not be available when needed or usable on the grid when available (*dispatchable*)
- Early RE auction contracts based on "pay as generated", without incentives to smooth production
- System operators had to add other resources to balance the system and maintain reliability
- Should grid operators or energy developers be responsible for smoothing out supply and demand volatility?
  - Costs incurred in either case and will need to be recovered
  - Which is more efficient?
  - How will battery energy storage systems affect this decision?

Declining Cost of BESS Can Contribute to RE Expansion

- Large systems with natural storage (hydropower) can manage production variability relatively easily and cheaply (in the absence of Transmission constraints)
- Utilities and system operators face growing difficulties managing intermittency as RE share increases:
  - Isolated systems with large share of RE capacity (Hawaii)
  - Old generation fleets, with limited flexibility for fast ramp up and down
  - Wind turbines and solar inverters not designed to produce ancillary services for managing intermittency and voltage fluctuations
- RE costs expected to continue decreasing, so more is likely to come on line

Pumped Storage Cheapest Now, BESS May Be Competitive by 2024



Source: Eller and Gantlett (2017)

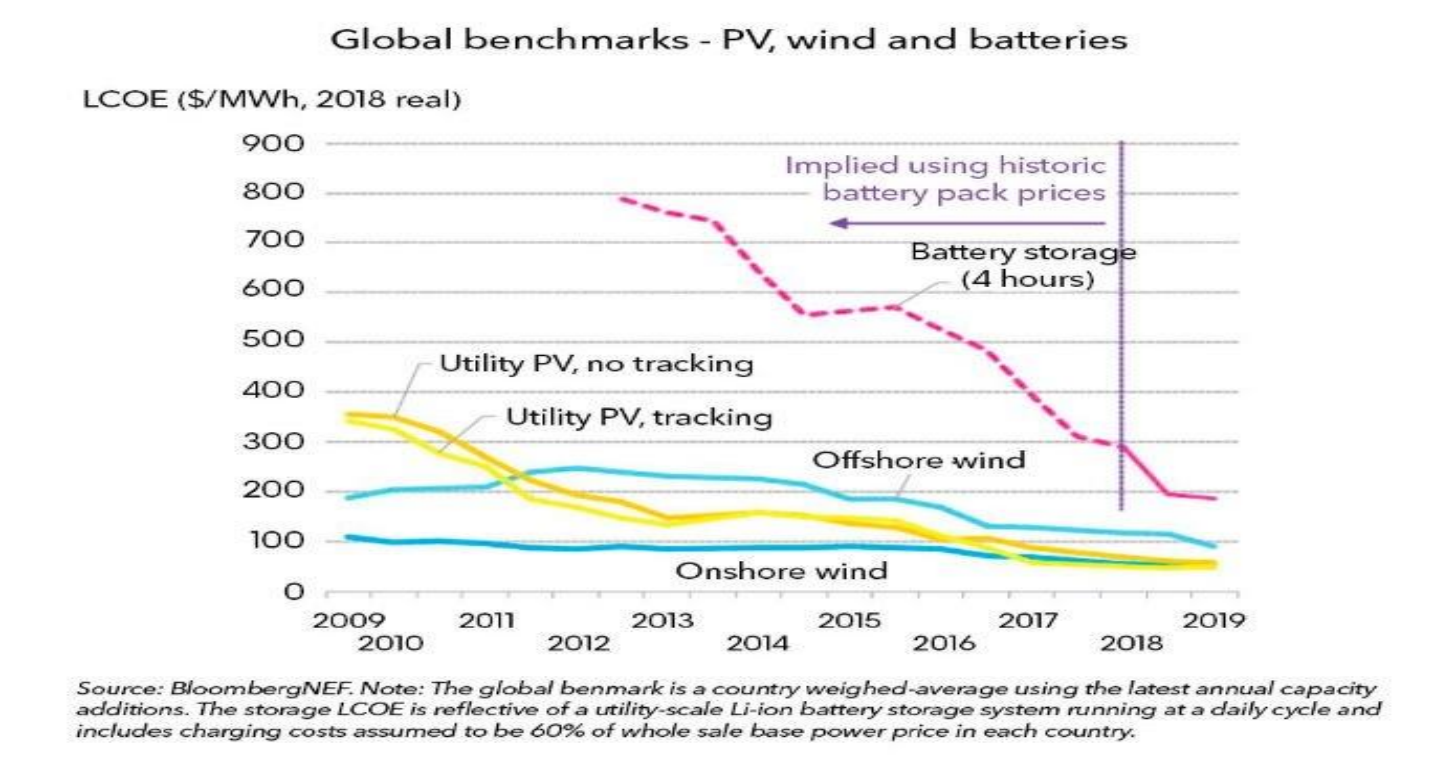
BESS Suitable for Wide Range of Applications

Application	Capacity Requirement	Classification	Discharge Cycles per Year	Applicable Technologies
Peak Pricing Arbitrage	4–6 hours	Bulk Storage	200–400	Advanced Batteries, Compressed Air Energy Storage (CAES), Pumped Storage
Generation Capacity	2–6 hours	Bulk Storage	200–600	Advanced Batteries, CAES, Pumped Storage
Transmission and distribution (T&D) Asset Capacity	2–4 hours	Bulk Storage	201–600	Advanced Batteries, CAES
Frequency Regulation	1–15 mins	Ancillary/Power Services	1,000–20,000	Advanced Batteries, Flywheels, Ultracapacitors
Volt/VAR Support	1–15 mins	Ancillary/Power Services	1,000–20,000	Li-ion, Advanced Lead-Acid, Flywheels, Ultracapacitors
Renewables Ramping/ Smoothing	1–15 mins	Ancillary/Power Services	500–10,000	Advanced Batteries, Flywheels, Ultracapacitors

(Source: Navigant Research)

Source: Eller and Gantlett (2017)

Li-Ion Batteries Mainly Adopted for Four-Hour Storage To Date



Source: BloombergNEF (2019).

RE Paired With BESS Can Replace Traditional Thermal Generation in Future

- Locations with announced goals to replace thermal generation with RE+BESS driven by economics, policy, and environmental goals
  - Australia – Abundant RE resources and an aging fleet of coal plants
  - Hawaii – Dependent on thermal generation, has a RPS of 100% by 2045
  - California – Retired San Onofre nuclear plant, relative competitiveness of RE + storage versus natural gas peaker plants

PV With Storage Key to Hawaii's Goal of 100 Percent RE By 2045

Project name	Island	Developer	Size	Storage
Waikoloa Solar	Hawaii	AES	30 MW	120 MWh
Hale Kuawehi	Hawaii	Innergex	30 MW	120 MWh
Kuihelani Solar	Maui	AES	60 MW	240 MWh
Hoohana Solar 1	Oahu	174 Power Global	52 MW	208 MWh
Mililani I Solar	Oahu	Clearway	39 MW	156 MWh
Waiawa Solar	Oahu	Clearway	36 MW	144 MWh

Source: Hawaiian Electric (2019)

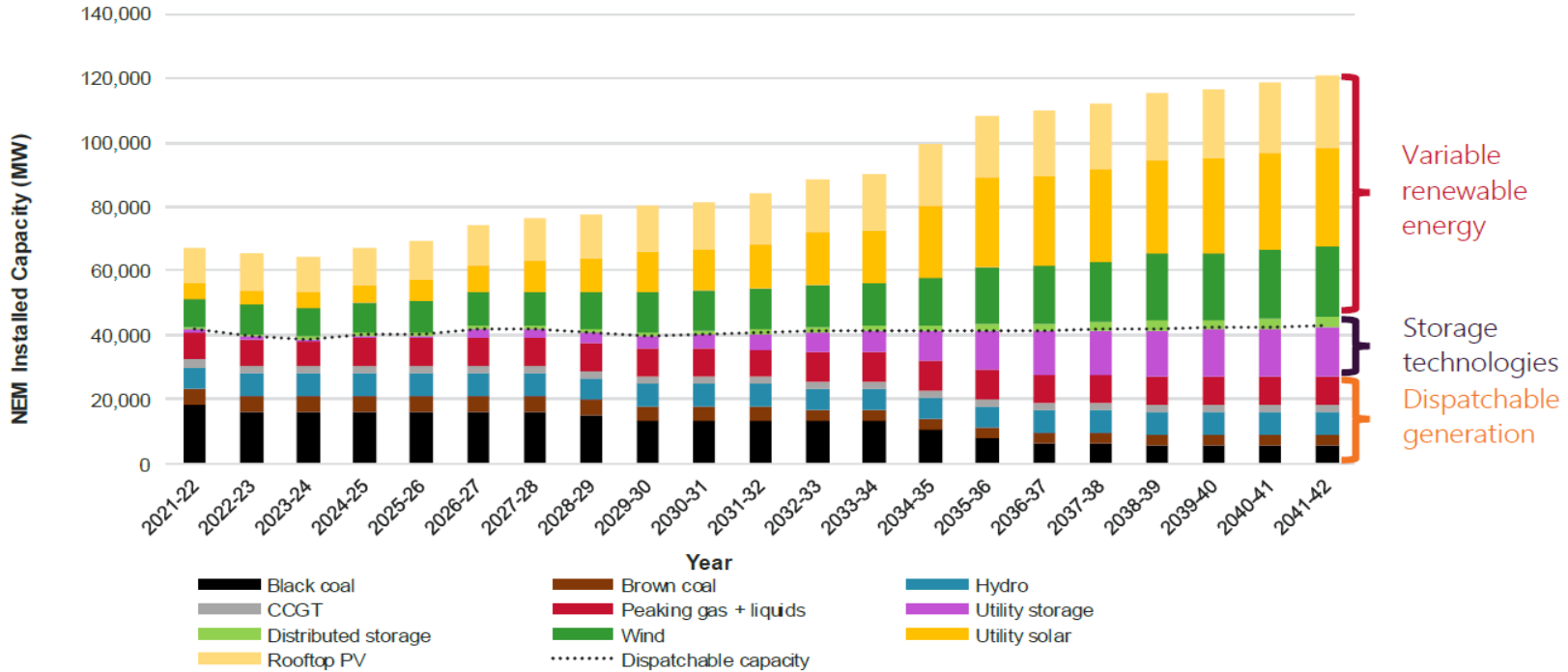
California Moving to RE + Storage Due To Economics, Environmental, and Community Concerns

- In 2014, Southern California Edison (SCE) competitively contracted for 2,200 MW of power from new resources, including 250 MW of storage
- Needed due to closure of San Onofre Nuclear Generating Station and anticipated retirement of older, natural gas generation plants
- SCE selected 7 projects with 195 MW of BESS instead of a natural gas peaker plant (Puente)

Source: Bloomberg NEF (2019)

Australia Could Replace Coal Generation With RE, Pumped Storage, and BESS

Figure 1 Forecast NEM generation capacity in the ISP Insights development plan, Neutral scenario



Source: AEMO (2019)

RE With BESS Competitively Procured in Several Australian States

- South Australia: Four projects -- 500 MW of wind, 780 MW of solar, 800 MW of storage
- Queensland: Eight projects, -- 400 MW of wind and solar, 100 MW of storage
- Australian Capital Territory: 250 MW of wind and solar, 20 MW of storage

Examples of Renewable Energy Auctions That Included BESS

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Auctions for RE Paired With BESS (I)

Location	Product Auctioned	Type of Contract	Award Criteria	Technology Neutral?	BESS?
Arizona (Tucson Electric Power)	PV and BESS	Blended PPA(*). Contract sets charge and discharge parameters for BESS	Lowest premium to a PV-only PPA	No, only PV and BESS	Yes
Australia	Wind and/or PV storage	Contract for differences	Lowest energy cost	Largely yes, combinations of wind, solar and storage	Yes
Brazil (Roraima)	Capacity and associated electricity	Capacity available 24x7 (lower during off-peak)	Lowest capacity payment	Yes	Yes, one bidder only
California	Capacity and ancillary serv.	Depends on market	Lowest price	Yes	Yes
Chile (Time-Variant)	MWh	Time-variant blocks	Lowest price bid per time block for optimized system	Yes	Possible
Colorado (Public Service of Colorado)	Non-dispatchable generation	Energy	Lowest price	Partially dispatchable generation competition	Yes

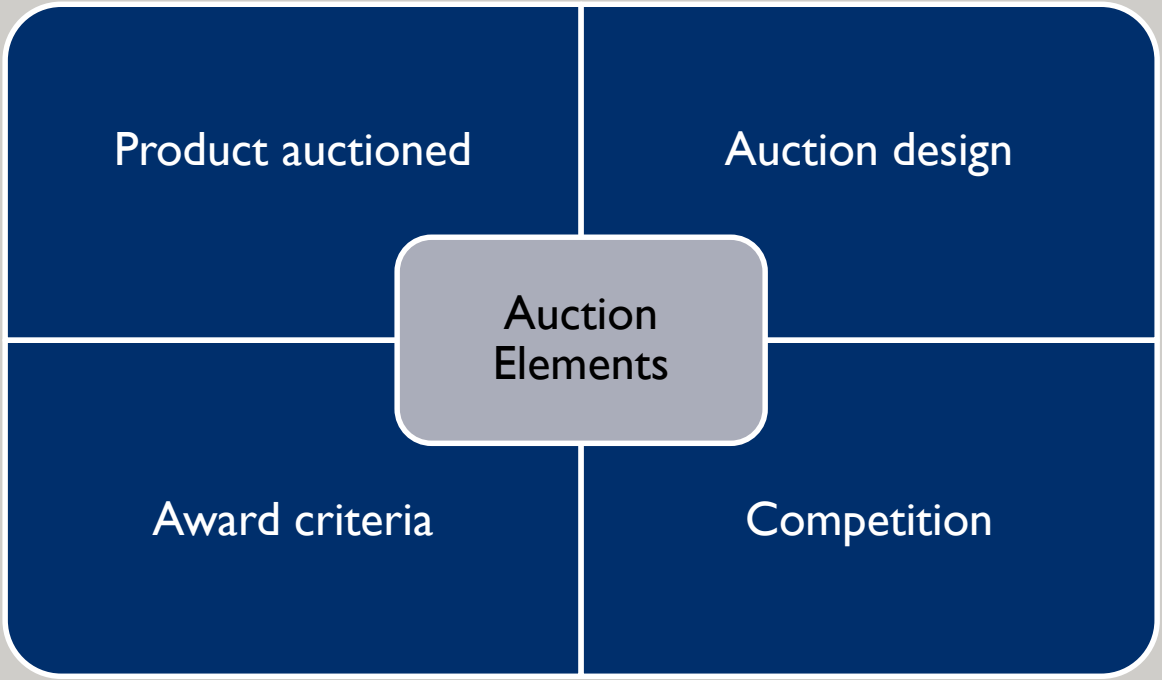
Source: Adapted from Maurer and Doyle, forthcoming (*) PPA = Power Purchase Agreement.

Auctions for RE Paired With BESS (II)

Location	Product Auctioned	Type of Contract	Award Criteria	Technology Neutral?	BESS Participate?
Hawaii (Various)	PV and BESS	Availability, with adjustments (fee based agreement, or "tolling")	Price and technical ranking, followed by best final offer	No, only PV and BESS	Yes
India	Peak and off-peak	Energy delivered (peak and off-peak)	Lowest price for peak energy and FiT for off-peak	Largely yes, combinations of wind, solar and storage	Yes, to be auctioned
ISO New England	Capacity during peak hours	Fixed capacity payment	Lowest price	Yes	Yes
Nevada (NV Energy)	PV and BESS	Set PPA price for PV, capacity payment for storage	Lowest energy and capacity payment	No, only PV and BESS	Yes
Thailand	Electric energy by zone	Peak and off-peak	Lowest cost per zone	Yes	Yes, one bidder only

Source: Adapted from Maurer and Doyle, forthcoming.

Many Types of RE Auctions, Technology-Neutral or Not



Product Auctioned

- Electricity, time profiled (i.e. allocated over time intervals)
- Peak power
- Availability of dispatchable RE + BESS
- Capacity and associated electric energy (MWh)
- Ancillary services (in different time horizons and smoothing voltage fluctuations
  - See slide, "BESS Suitable for Wide Range of Applications"
- Types of electricity generated
  - Dispatchable – Available 24x7 on operator's instruction
  - Semi-dispatchable – Available on operator's instruction during peak hours
  - Non-dispatchable – Not necessarily available when needed by operator

RE Auction Design

- Technical prequalification
- Mostly sealed bid reverse auctions (not dynamic auctions) (*)
- In some cases, price and non-price factors weighted (**)
- Combinatorial auctions for time-variant contracts (delivery obligations differentiated by hour, daily blocks, or peak and off-peak periods)

Award Criteria

- Lowest bid for electricity
- Lowest bid for electricity subject to optimization of power system (model run by regulator)
- Lowest capacity payment
- Highest price and nonprice weighted score
- All territory or zonal based

Competition

- Standalone BESS
- BESS paired with one specific RE source
- Multiple RE sources (hybrid) and any type of storage
- Multiple forms of RE and BESS storage
- All technologies, with BESS free to compete
- With or without demand response

Six Business Models for Auctions With BESS

Product	Ancillary services	Peaking	Time-differentiated supply blocks	Semi-dispatchable to firm up renewables	Dispatchable firm energy	Dispatchable capacity and firm energy
Competitors (addition to BESS)	All source and demand response	Comparison with natural gas peakers	All-sources or only RE	Non-BESS storage or hybrid	PV or other renewables	All sources
Geography	ISO-New England	Southern California Edison	Chile, Colombia	Australia, Colorado (USA) India, Mexico,	Thailand	Roraima State (Brazil)
TNRE or TNE?	TNE	TNE	TNE or TNRE	TNRE	TNRE	TNE

Source: Maurer and Doyle, Forthcoming.

— Recommendations for Incorporating BESS in TNRE Auctions

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Status and Enabling Environment for RE and BESS Auctions (I)

- Number of operating RE facilities with BESS still limited
  - Several RE auctions with storage being designed (Australia, California, India)
  - In many cases, BESS was selected storage option (Hawaii)
  - Projects tendered and under construction
- Technical and economic rationale for BESS paired with RE demonstrated in several projects under development
- Several business models and auction designs adopted
  - Lack of standardization of contracts, payments, and award criteria
  - Multiple combinations of products and services
  - Financial community prefers standard products for bankability

Status and Enabling Environment for RE and BESS Auctions (II)

- Learning curve for policymakers, regulators, and developers to improve enabling environment
  - Declining cost of BESS relatively recent and still being processed by planners
  - Many countries with RE auctions have not allowed developers to bid for portfolio of RE resources or BESS to smooth out intermittency
  - Mitigation of intermittency typically managed by system operator due to lack of incentives for developers
- Institutional, regulatory, and technical barriers need to be addressed
  - Establish grid codes for BESS
  - Market rules to monetize benefits of fast response

Incorporating BESS in Auction Design (1)

- Update least-cost expansion plans for power production to reflect, technology innovations and opportunities from BESS
- Design auctions that reward BESS developers for multiple services provided by storage at several time-intervals (*value stacking*) – for example:
  - Peak demand reduction (i.e. charge energy off-peak and discharge during peak hours)
  - Fast response reserve
  - Frequency regulation
- Design Power Purchase Agreements to give incentives for developers to reduce power generation volatility

Incorporating BESS in Auction Design (2)

- Enable participation of hybrid solutions in TNRE auctions (i.e. wind combined with solar)
  - Eliminate explicit or hidden barriers to a level playing field for BESS in TNRE auctions
    - Acknowledge the value "firmed up" energy in defining the auction product
    - The same for fast ramp-up response
  - Foster co-location of RE resources and BESS
- Learn from diverse experiences with BESS and RE auctions in other countries – an ongoing process
- Each region or market will have different system requirements – BESS auctions and BESS business models need to be customized

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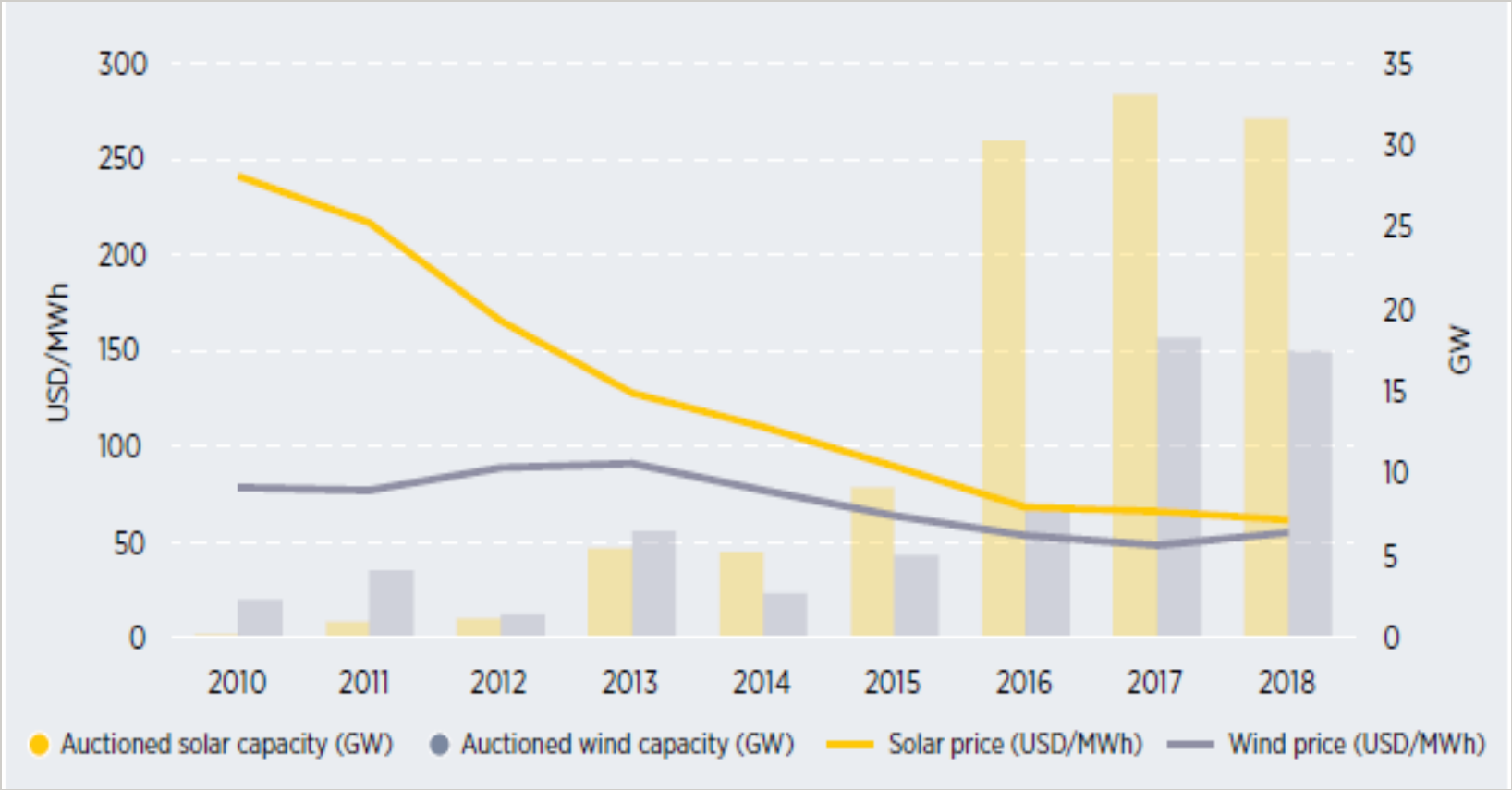
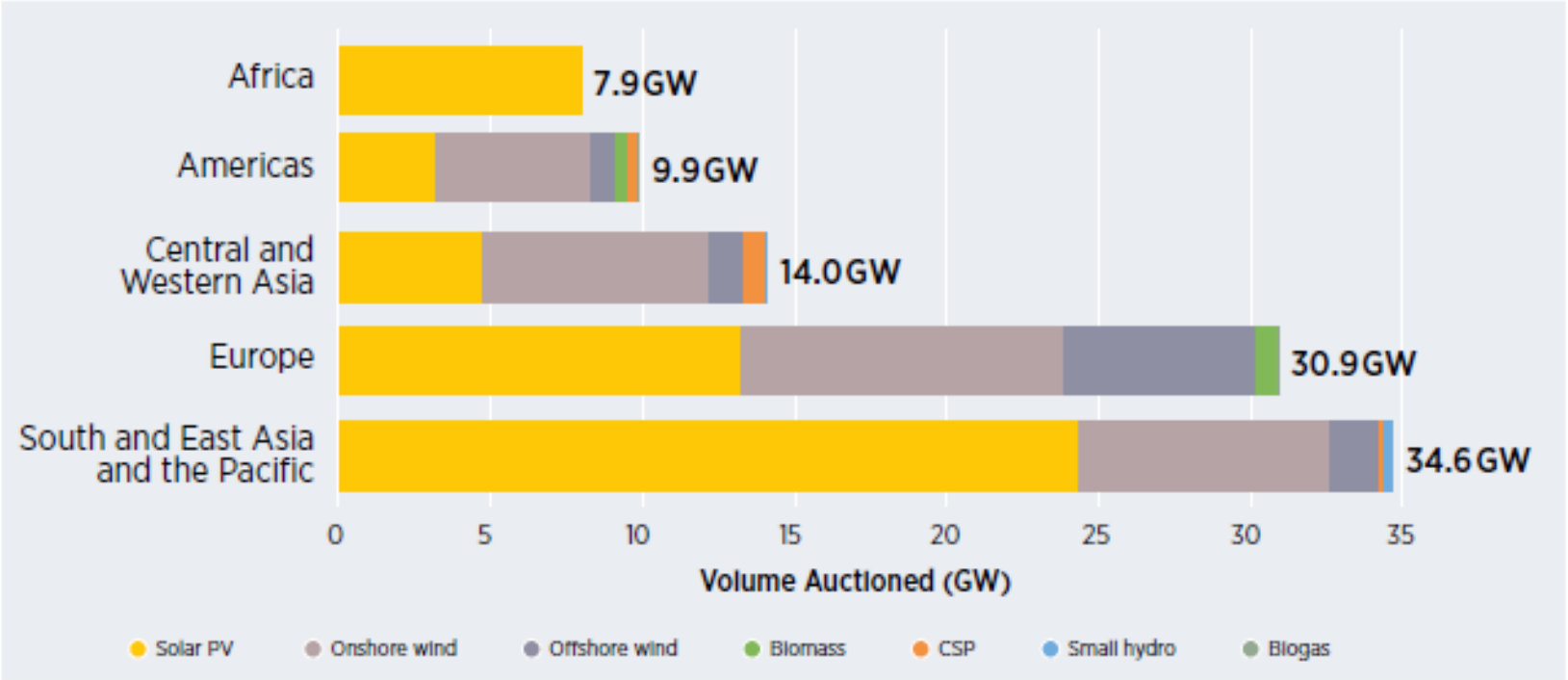
ANNEXES

RE Auction Volumes Increased as Prices Decreased



Source: IRENA (2019)

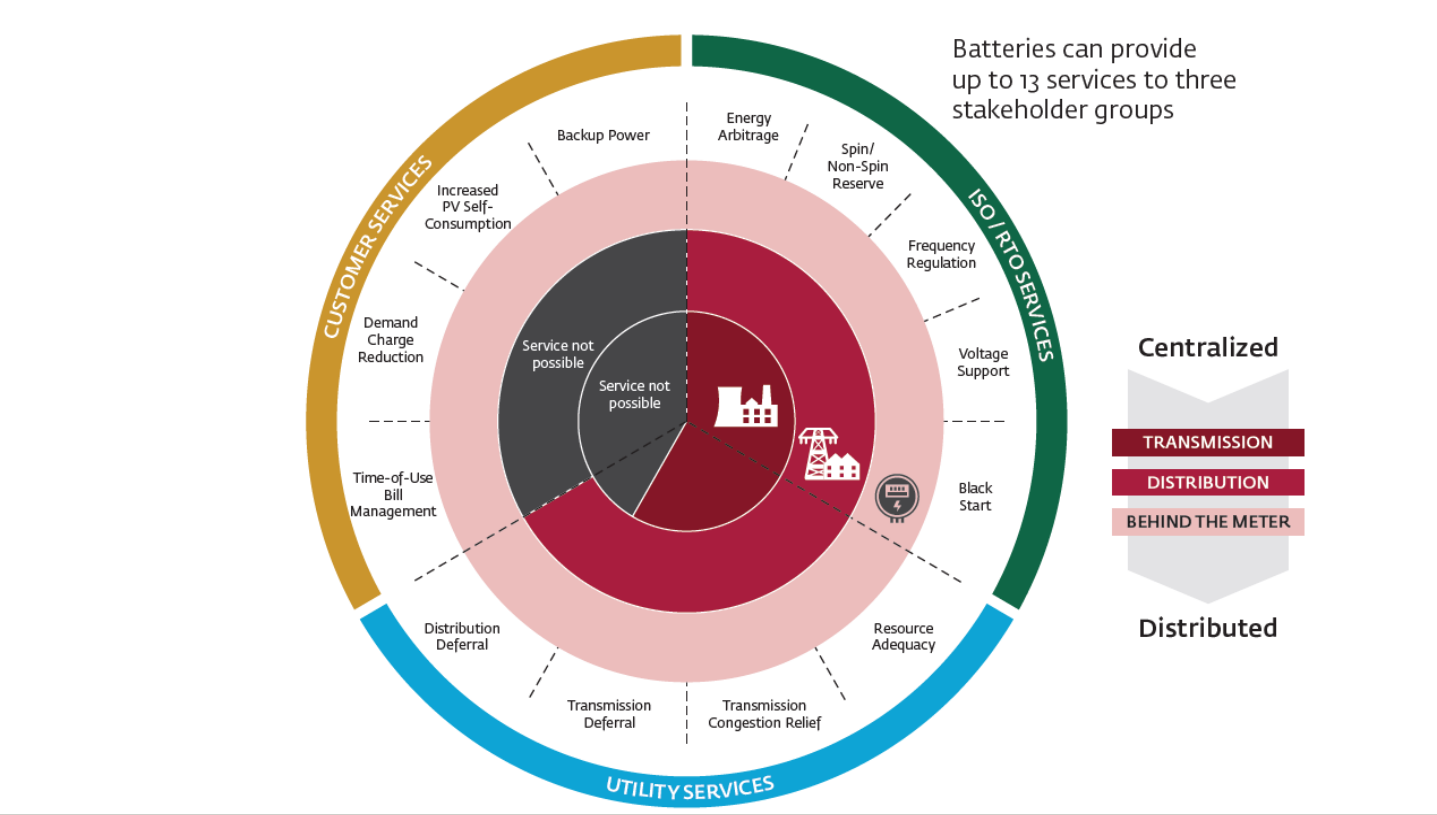
Almost 100 GW of RE Auctioned from 2017-2018



Note: PV = photovoltaic, CSP = concentrated solar power

Source: IRENA (2019)

Battery Solutions for Utilities and Electricity Customers



Source: Rocky Mountain Institute (2015)

What Are Competitive Procurements and Reverse Auctions?

- Methods for purchasing a product or service through an open and competitive process with multiple bidders
- Purchase of an energy or capacity product (typically a contract)
- A competitive framework is central to the development of a low-cost and high-RE electricity sector.
- Provide a vehicle for tendering projects transparently, as opposed to on a bilateral or negotiated basis
- Regulator conducts a pre-qualification process prior to the auction to select preferred bidders.
- Reverse auction—lowest priced bids win

Sources: Lawson (2017) and Maurer and Barroso (2011)

USAID Approach to Auctions for Renewable Electric Power

- Promotes competitive procurement of renewable energy (RE) to rapidly scale clean energy at low prices
- Helps meet economic development and climate change goals
- Provides reverse auctions support through bilateral energy programs
- May fund activities believed to have the most development impact

Source: Lawson (2017)

Examples of USAID Support for Renewable Electric Power Auctions

- Provided targeted support in Mexico to enhance the quality of auctions and leverage billions of private sector investment
- Attracted the first independent power project (IPP) in Afghanistan Power Africa through the U.S. Energy Association (USEA)
- Conducted a workshop in Tanzania to assess and discuss their readiness for auctions
- Ongoing support to USEA to organize an auction workshop in Kazakhstan
- Supported Colombia in the design of an auction IT platform and in reviewing the auction rules

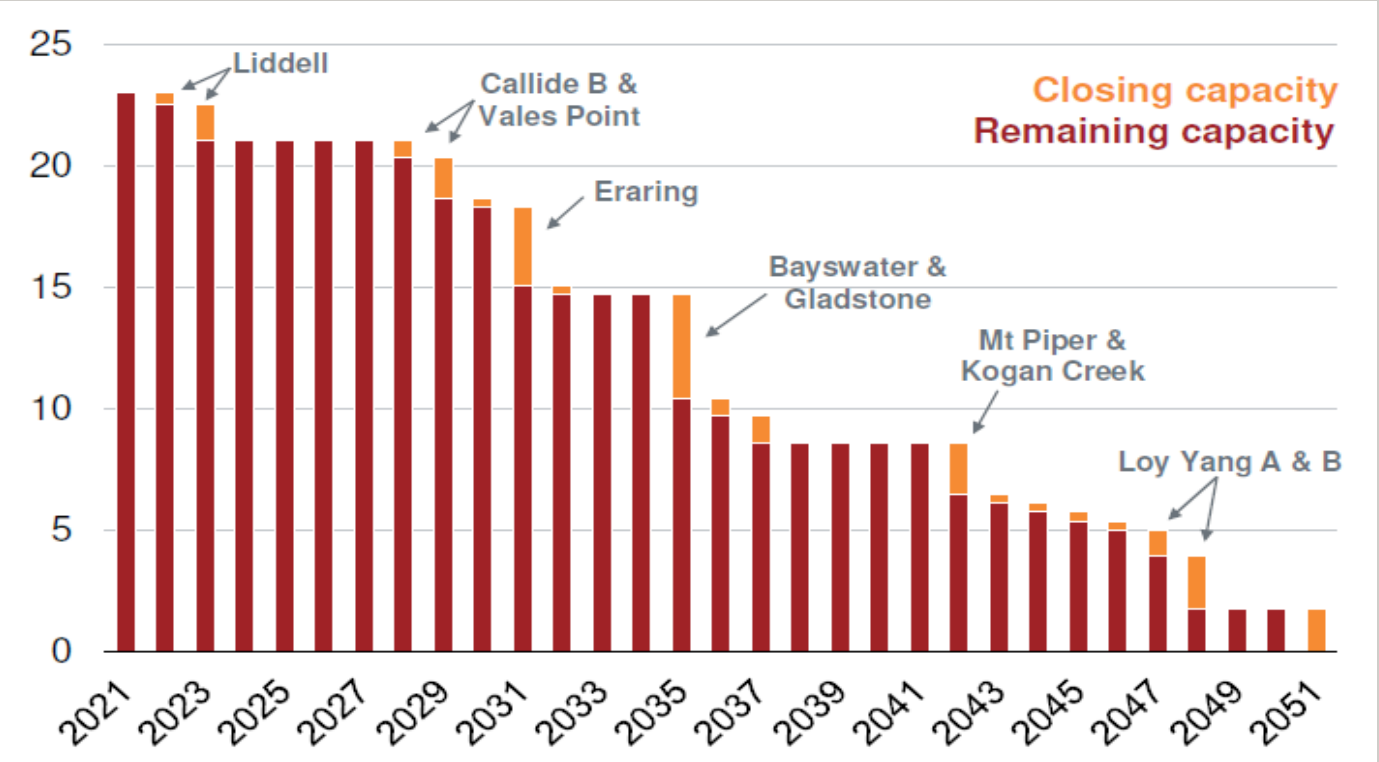
Sources: Lawson (2017) and USAID (2019)

Auctions in Eight Countries With PV Prices Below $25/MWh

Jordan	China's Jinko Power	24.89	Jordan's Round III Auction
Tunisia	Scatec Solar	24.40	200 MW project in Tataouine
United Arab Emirates	Abu Dhabi Power Corporation, China's JinkoSolar and Japan's Marubeni Corp	24.20	Sweihan, 1.2 GW
Saudi Arabia	ACWA Power	23.42	Sakaka Project, 300 MW
Chile	Enel	21.48	Antofagasta, 116 MW
Mexico	Neoen	18.93	Pachamama
Brazil (*)		16.95	163 MW, Milagres
Portugal (*)		16.48	

Source: Maurer and Doyle, forthcoming.

Australian Coal Plants Nearing End of Useful Life



Source: Wood *et al.* (2019)

Examples of RE Auctions With and Without BESS Participation (I)

Locations	Nature of Contract	Description	Technology Neutral	Storage Participation	Level Playing Field for Storage	Type of Award and Payment
Brazil (from 2008-2018), Argentina, Chile (until 2016)	Electricity only (non-firm)	Settlement over long-time interval (> 1 month) Energy profiling based on actual generation RE given priority for grid dispatch	No, only RE	No	No	Two-stage reverse auction. Based on lowest bid for power ($/MWh)
Brazil (2019)	Electricity only (non-firm)	Settlement over long-time interval (> 1 month) Electricity profiling based on load curve, creating mismatches between actual production and contractual obligations	Yes	No	Incentives for hybrid solutions exist, hybrid solutions not allowed to bid	Reverse auction. Based on lowest bid for power ($/MWh)

Examples of RE Auctions With and Without BESS Participation (2)

Locations	Nature of Contract	Description	Technology Neutral	Storage Participation	Level Playing Field for Storage	Type of Award and Payment
Mexico	Electricity only (non-firm)	Contracts for difference. Price granularity in time and space (*locational marginal pricing*)	Yes	Yes, in areas with transmission constraints	Yes, possibility of locating storage where locational prices are higher	Reverse auction. Based on lowest bid for power (first auction provided extra points for priority locations). Revenue for generator included "green certificates"
Colombia (since 2006)	Electricity only (during critical periods)	Reliability payment auction with call for power during government-declared critical period (demand peak or supply shortfall from drought)	Yes	No	Yes, but system was chronically short of electricity in dry periods. BESS not suitable for this deep storage	Reverse auction. Award for lowest electricity strike price bidder for option to be dispatched
Chile (since 2017)	Electricity only (firm)	Settlement three times a day (energy blocks) and seasonally. Bids included contract volume obligations for each block	Yes	Yes	YES, but some e benefits of BESS not monetized (e.g., rapid ramp-up rate)	Combinatorial auction. Based on lowest bid for power per time block ($/MWh) minimizing costs to power system (based on optimization model)

Examples of RE Auctions With and Without BESS Participation (3)

Locations	Nature of Contract	Short Description	Technology Neutral	Storage Participated	Level Playing Field for Storage	Type of Award and Payment
Thailand (2017)	Capacity and associated (firm) electricity	Contractual obligation to meet load curve requirements for peak and off-peak	Yes	Yes, one bidder (PV+BESS)	Incentive for storage to provide firm electricity in peak hours	Nine simultaneous auctions per zone. Based on largest discount from FiT per zone ($/MWh), adjusted for inflation.
Brazil (Roraima State) (2019)	Capacity and associated (firm) electricity	Contractual obligation to meet load curve requirements 24x7	Yes	Yes, one bidder (biofuel + PV + BESS)	Incentive for BESS for integration of biofuel generation and PV	Reverse auction. Based on lowest bid for capacity ($/MW)
India (2018)	Electricity only (non-firm)	Renewables no longer had priority dispatch with transmission constraints	No, only renewables	Yes, any form of storage, but prior preference for pumped-storage	Incentives for intra-day storage to shift supply when grid constraints relieved	Reverse auction. Based on lowest bid for peak power. Payment for off-peak power based on FiT.

Examples of RE Auctions With and Without BESS Participation (4)

Locations	Nature of Contract	Short Description	Technology Neutral?	Storage Participated?	Level Playing Field for Storage?	Type of Award and Payment
Public Service of Colorado (Xcel) (2018)	Energy and capacity (peak)	Joint renewable and storage auctions	NO, only renewables allowed to participate in the non-dispatchable category	YES, but only in non-dispatchable category	Partially, storage + RE not allowed for dispatchable resources	Reverse auction. Based on lowest bid for power
Australia (several states)	Firm energy and capacity	Concern over intermittency of RE supply	Yes, but storage mainly participated in RE auctions (pumped storage and BESS)	Yes, in some cases	Trend for co-located hybrid renewables and storage. Contracts for difference offer incentives for BESS and pumped hydro	Reverse auction. Based on lowest bid for power (US/MWh). Can also participate in ancillary services market.
USA (Most RTOs and ISOs)	Capacity and other ancillary services	Ancillary services for reliable system operation (supply and demand)	No, since technology-specific (including BESS). Exception: New England Power Pool allowed storage with other technologies	Yes, in most cases	FERC Order 841/2018 directed all grid operators to propose models for the participation of storage as a wholesale generation asset	Typically, capacity (US/MW). Revenues may include ICAP and other ancillary services provided

Source: Maurer and Doyle, forthcoming.