Multi-Objective Auctions for Utility-Scale Solar Battery Systems: Lessons for ASEAN and East Asia

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Changing Context for Electricity Markets in Many Countries

Objective of market: Provide the right price signals for the right investment at the right time to deliver reliable electricity to the consumers at affordable price.

	1990s - early 2000s	Current 2023
Policy	• Competition, Privatization, Deregulation and Unbundling • Targeted Subsidy	• Climate and other Environmental, Social and Governance (ESG) • Competitive Subsidies for Renewable Energy - Auctions rather than the earlier fixed feed-in-tariff
Market	Wholesale markets • Thermal technology with dominance of variable costs • Highest marginal cost clear the price	Wholesale markets • Renewable energy with high capital costs and low variable costs • Volatile prices due to variable renewable energy
Climate and ESG	Gas (e.g., dash for gas) and 24/7 power: • No subsides Large hydro: ESG impacts	Variable renewable energy and hardly 24/7 power with storage • Subsides – high capital cots • ESG impacts in remote locations and critical minerals
Investor	• Climate and ESG outside the profit maximization, e.g., Corporate Social Responsibility (CSR)	• Morality in competitive markets increasingly important • Profit and welfare (climate and ESG) maximization • Corporate Renewable Energy Power Purchase 24/7 Tracking
Consumer	Passive	Active participation

Challenges for ASEAN and East Asia to the Changing Context of Electricity Market

- Increasingly export oriented firms are subject to voluntary or involuntary climate and other ESG regulations.
- Nearly 80 percent of power generation are from fossil fuel with over 40 percent is from coal in Southeast Asia in 2020 (IEA 2022).
- Average age of coal-fired power plants in East and Southeast Asia is 10-15 years (World Bank 2022).

Multi-Objective Auctions for Utility-Scale Solar Battery Energy Storage Systems (BESS) for ASEAN and East Asia

- Competition in the Market

wholesale electricity markets, e.g., Japan, Korea and Singapore

- State-owned single buyer

e.g., Vietnam, Cambodia, Indonesia and Lao PDR

- Competition for the markets

Actions for bidders to compete for specific market segments under the power purchase agreements (PPAs)

- Renewable energy PPAs' challenges in delivering 24/7 renewable power

Energy storage addition to renewable energy in auctions will improve the transparency in climate and ESG compliance by enabling investments in clean, dispatchable capacity

Example: The United Kingdom government Call for Evidence on introducing non-price factors into the Contracts for Difference Scheme April – May 2023 (e.g., employment, innovation, industry, ESG, etc.)

Key Summary of the Study in this Presentation

- Theoretical and conceptual framework of auction markets where demand and supply have their own ESG objectives
- Auction risks
- Role of Auctions among other Policy Instruments
- Business models
- ESG risk mitigation and management costs vs. avoided ESG costs and achieved benefits
- Conclusion

Theoretical and Conceptual Framework: Static

Building on Tirole (2017, 2021) , Dewatripont and Tirole (2022),

$\widehat{p_i} \equiv p_i + \phi_i(a_i)$ ---- (1) the net price perceived by the buyer

$U_i \equiv [p_i - c_i(a_i)]D_i(\hat{p}) + \alpha_i W_i(\hat{p}, a)$ --- (2) Seller's utility function

$\mathbb{E}\,[u(p_i(v_i), v)] = [p_i(v_i) - v_i]Pr(Win|p_i(v_i))$ ---- (3) Seller's expected utility

By the envelope theorem, $\frac{du}{dv} = \frac{\partial u}{\partial p_i(v_i)}\frac{\partial p_i(v_i)}{\partial v} + \frac{\partial u}{\partial v} = \frac{\partial u}{\partial v}$, then, $\frac{du}{dv} = \Pr(Win|p_i(v_i)) = \Pr(lowest\ bid) = \Pr(lowest\ value) = F(v)^{n-1}$. Utility is rewritten as $u(v) = u(0) + \int_0^v F(v)^{n-1}dv = \int_0^v F(v)^{n-1}dv$, which substituted into equation (3) results in: $p_i(v_i) = \frac{u(p_i(v_i),v)}{\Pr\left(Win|p_i(v_i)\right)} + v_i = F(v)^{-(n-1)}\int_0^v F(v)^{n-1}dv + v$.

For example, where $v \sim U$ on $[0,1]$, then $F(v) = v$, and $p(v) = \frac{v}{n} + v = \frac{v(1+n)}{n}$.

Higher the number of participants, the higher the competition, the higher the ESG.

Rearranging equations (1) and (2) results in:
$p_i \equiv \widehat{p_i} - \phi_i(a_i) \equiv [U_i - \alpha_i W_i(\hat{p}, a)] * \frac{1}{D_i(\hat{p})} + c_i(a_i)$

ESG irresponsible bidder will result in higher costs

Theoretical and Conceptual Framework: Dynamic

Bidders who does not participate in the first auction to see the outcome and decide to participate in the next auction is disadvantaged in the next auction.

Participation in the auction give the bidder experience and more information for the bidder's advantage in the next auction.

According to Bergemann and Juuso (2010) and Bergemann and Välimäki (2019),

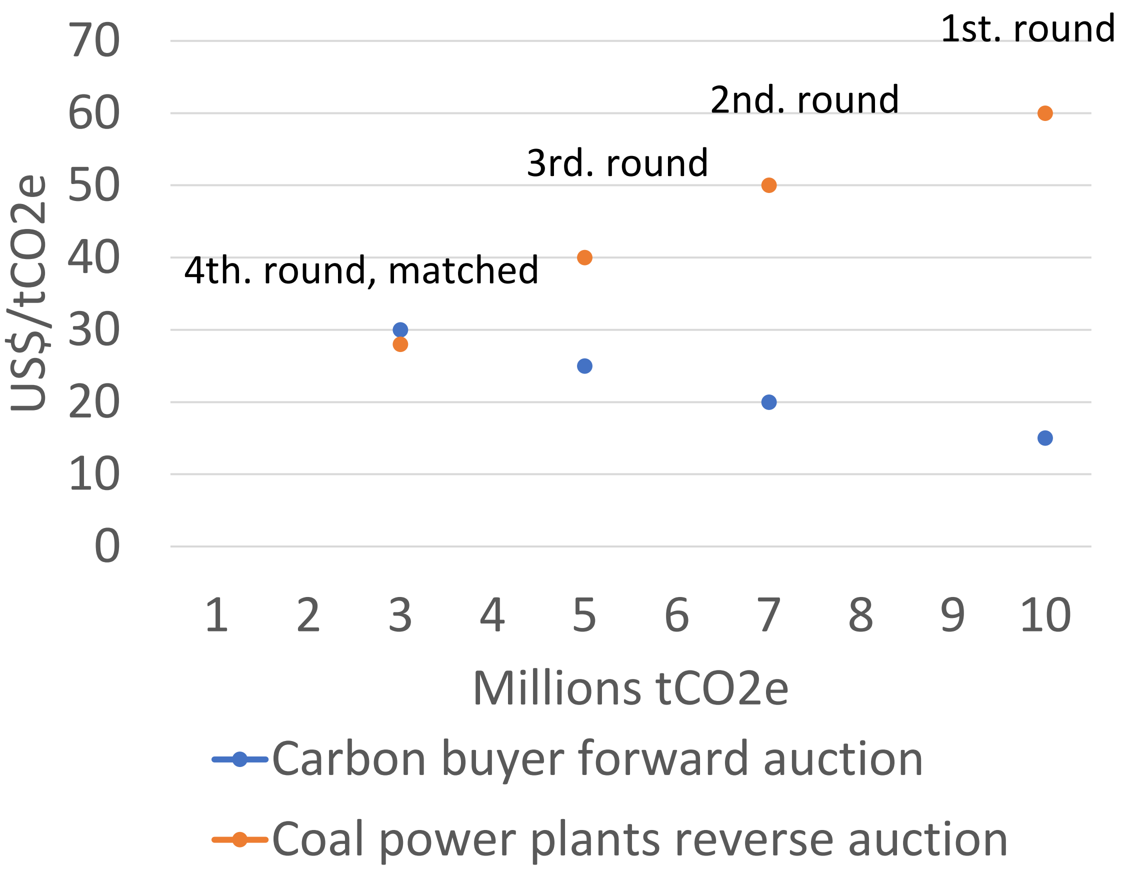
$m_i(\theta_t) = M_i(\theta_t) - \delta M_i(\theta_t, h_t^*)$ --- (4) flow marginal contribution to welfare of seller i
$a_t^*: H_t \rightarrow [0,1]'$ ---- (5) socially efficient allocation rule

Expanding the flow term with respect to time gives: $m_i(\theta_t) = \big(W(\theta_t) - W_{-1}(\theta_t)\big) - \delta\big(W(\theta_{t+1}|h_t^*) - W_{-1}(\theta_{t+1}|h_t^*)\big)_i$, where the first bracket M_i starting at t and the second bracket M_i starting at $t+1$ and h_t^*. Rearranging, $m_i(\theta_t) = (W(\theta_t) - \delta\big(W(\theta_{t+1}|h_t^*)) - (W_{-1}(\theta_t) - \delta W_{-1}(\theta_{t+1}|h_t^*)\big)$, where the first bracket current value with bidder i and the second bracket current value without bidder i but with h_t^* .

Given the marginal contribution to welfare is $M_i = v_i - p_i$, rearranging, price bidder i : $p_i = v_i - M_i$ --- (6)

By adjusting equation (6) into an intertemporal setting, the socially efficient allocation rule (5) satisfies ex post incentive and ex post participation constraint with payment p: $p_{i,t}\left(h^*(\theta_t), \theta_{-i,t}\right) = v_i\left(h^*(\theta_t), \theta_{-i,t}\right) - m_i(\theta_t)$

Theoretical and Conceptual Framework: Incentive



Staged product-matching auctions

(i) a reverse auction to determine a price at which coal-fired power producers voluntarily relinquish their capacity with carbon dioxide equivalent (CO2e) emissions avoided

(ii) a forward auction for avoided CO2e emissions

(iii) a forward auction of solar PV and BESS (maybe with backup generator) to take the freed-up capacity

Source: Author

Risks

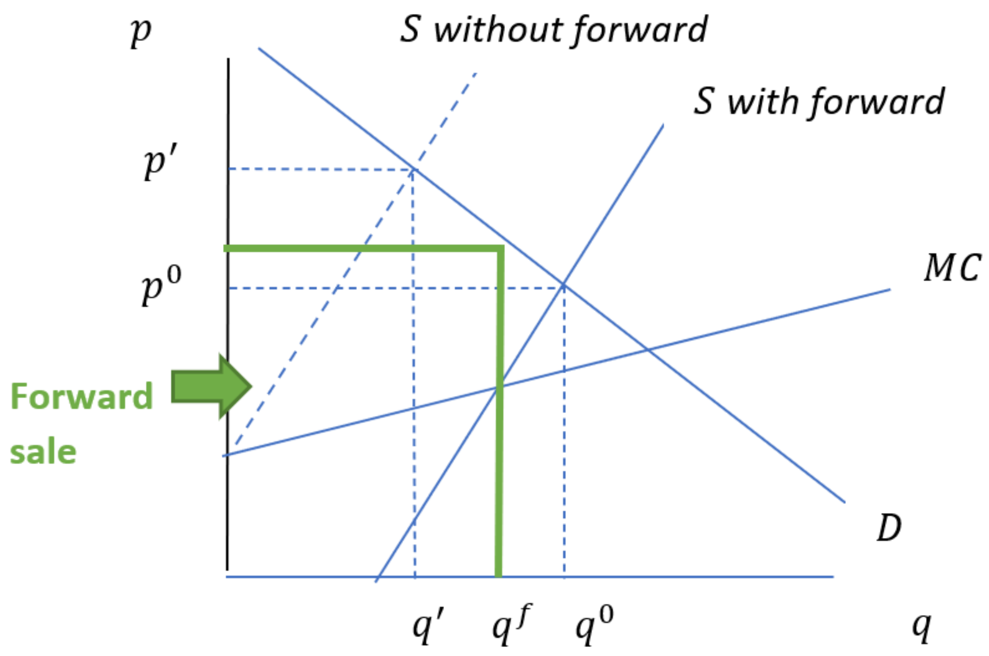
- Allocation risk
- Underbidding risk
- Under-contracting risk
- Nonrealization risk

	India	Malaysia	Brazil	United Kingdom	The Netherlands	France	Ireland	California, US	China
Auction years	1997-2022	2016-2022	2009-2010	1990-2001	2011	2011	1995-2003	2011-2015	2003-2004
Technology	Wind	Solar PV	Biomass, wind, small hydro	Technology neutral	Technology neutral	Solar PV	Wind, hydro, biomass, and CHP	Technology neutral	Wind
Realization rate	25% by 2022	47% by 2022	~30% by 2014	~30%	68% by 2015	<50%	~30% by 2005	>75%	100% by 2007

CHP: Combined Heat and Power

Source: Wigand et al. (2016), Kreiss et al. (2017), REN21 (2022), and Santos (2022a).

Role of Auctions among other Policy Instruments



Source: Cramton 2020

- Solar PV and BESS: the ability of BESS to complement or substitute for other power system elements – Revenue stacking from multiple markets (e.g., Australia wind+BESS, Chile solar PV+BESS)
- South Korea's policy mix of auctions, feed-in tariffs (FiT) for small solar PV producers, and renewable portfolio standards (RPS) (Kwon 2020)
- Forward auction markets to mitigate potential prices significantly above marginal costs in wholesale spot markets (Cramton 2020)

Solar PV and BESS Business Model

Circumstance or Objective	Suitable Business Model
Provide peak load Fill in the gap under system contingencies	PV/BESS for Peak Load or Capacity Markets
Reduce total generation-transmission-distribution costs Provide BESS investment incentives	PV/BESS for Time-Differentiated Supply Blocks
Provide semi-dispatchable (partial-firm) power to specified periods despite variable renewable energy intermittency	Solar PV/BESS for Semi-Dispatchable Firm Power
Support greater renewables penetration toward 24/7 clean energy Cost-wise suitable only for small systems given technological advances and costs as of 2022	PV/BESS for Firm Dispatchable 24/7 Power
Provide ancillary services to an electricity grid either to a distribution company or to an ancillary market	BESS for Ancillary Services
Complement or substitute for generation, ancillary services, transmission, distribution, demand response, and other system elements	BESS as Stacked Services

Key ESG risk mitigation and management costs vs. avoided ESG costs and achieved benefits

ESG Risk Mitigation and Management Costs	Avoided ESG Costs and Achieved Benefits
Environmental and social impact assessments and stakeholder engagement Benefit sharing Local employment, content, industry, and participation 24/7 clean power arrangements	Higher financing costs due to project delays Increased capital and operations and management costs Penalties Bid bonds (securities) and sunk costs due to project cancelation Greenwashing or non-compliance Local development benefits

Case Study: Thai Partial-firm Renewables Auction 2017

The first country in Asia to:

- require developers to supply partial-firm power generation
- allow bids based on either a single technology, or a hybrid combining two or more technologies for consistent feed-in to the grid.

PPAs: 100$\pm$ 2 percent of specified capacity during peak periods (9AM-10PM on weekdays), and limit output at other times to 65$\pm$ 2 percent of capacity.

42 of 85 bids passed the pre-qualification stage, resulted in 17 winners:

- 14 for biomass and the other three solar PV+BESS
- 15.6 to 99.99 percent of the ceiling price, with net prices of B1.85–3.38/kWh (US$0.06–0.11/kWh) (IRENA, 2019a; O'Mealy et al., 2020).

Conclusion

1. Theoretically and empirically proved auction market design with low levels of complexity for bidders may facilitate bidding strategies intended to optimize outcomes, including ESG.

- A design strategy to improve realization rates: (i) high financial prequalification and adjusted physical prequalification relative to sunk costs, (ii) penalties covered by financial prequalification, (iii) increased competition, and (iv) incorporating complementary policy instruments rather than one policy instrument

2. ESG goals in auctions should be part of project definition and prequalification, allowing awards based solely on price.

- Integrating auction designs within geospatial least-cost electrification roll-out plans, could facilitate exploiting synergies between the energy sector and the broader economy to optimize the benefits of green transitions.
- Designs that integrate ESG and just and inclusive energy transitions may require policy support and grants that recipients win competitively and adhere to monitoring, reporting, and verification (MRV) requirements.

3. Transition to 24/7 clean energy may drive higher ESG scores, which might facilitate access to cheaper capital in financial markets eager to greenify investment portfolios.

- An initial step for enterprises in ASEAN and East Asia to build 24/7 clean energy: (i) trade energy attribute certificates, and (ii) MRV capacity building of energy used, to help remain in global value chains and more competitive.