

# Capacity Building Series: Electricity Market Principles

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**Greater Mekong Subregion  
ENERGY TRANSITION TASK FORCE  
May—June 2024**

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# INTRODUCTION

## A market-based regional electricity trade

The Asian Development Bank (ADB), acting as secretariat to the Greater Mekong Subregion Energy (GMS) Transition Task Force (ETTF), and in collaboration with the ADB Institute (ADBI) in Tokyo, organized a course on electricity market principles. The course was delivered by Dr. Mark Thurber, Associate Director at Stanford University's Program on Energy and Sustainable Development. Twenty-three (23) participants, seven of whom are women, representing GMS governments, ASEAN Centre for Energy, Heads of ASEAN Power Utilities/Authorities, completed the course.

## Learning objectives

To acquire a hands-on understanding of important electricity market concepts, including

- why wholesale electricity markets are generally cleared via uniform-price rather than pay-as-bid auctions
- the operation of transmission constraints
- how wind and solar affect electricity market outcomes,
- when suppliers have incentives to exercise unilateral market power, and
- how fixed-price forward contracts can align supplier behavior with the policymaker's goal of least-cost electricity supply, including when there are transmission constraints and high shares of wind and solar.

In May 2024, Dr. Thurber provided the course participants with access to four e-learning modules, which are a requisite to the in-person workshop. The participants were required to complete each of the modules on their own.

- Fixed and Variable Costs
- Basics of Offering into Wholesale Electricity Markets
- Pay-As-Bid versus Uniform-Price Auctions and
- Unilateral Market Power.

On 7 June 2024, the participants joined the in-person sessions with Dr. Thurber at Discovery Suites Manila, in which Dean Tesushi Sonobe of ADBI gave the opening message remotely.

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# PRINCIPLES

## Principles relevant to the design of a regional power market

- **Cost-based vs. offer-based markets:** Which makes more sense in a nascent regional market?
- **Unilateral market power:** Can big suppliers push up the price for my country's consumers?
- **Auction design:** Why should we pay all suppliers the market-clearing price?
- **Effect of transmission configuration:** How does interconnection facilitate renewables integration? How do we need to take the network configuration into account in a regional market?
- **Fixed-price forward contracts for energy:** How can firm financial obligations encourage investment in regional supply, including renewable energy, and protect consumers?

## Fixed and variable costs

This module covers the fundamental characteristics of generating units that are most relevant to how units are chosen by generating companies and then operated in an electricity market, with a focus on fixed and variable costs. The learner explores how to calculate marginal cost for thermal units, what is the characteristic balance of fixed and variable costs for various technologies, and how technologies with a different balance of fixed and variable costs work together in the energy supply mix.

## Basics of Offering into Wholesale Electricity Markets

This module takes the learner through the mechanics of bid-based electricity markets and discusses the advantages and disadvantages of offer-based markets relative to cost-based dispatch. The learner plays the role of an employee at a generating company who has to determine what offer strategy the company should employ when the company's offer is unlikely to affect the market-clearing price in a uniform price auction.

## Pay-As-Bid vs. Uniform Price Auctions

In this module, a government official wonders why the electricity market pays the market-clearing price to all units that run, when it would seem cheaper to only pay them what they bid. The learner explores how incentives change in a pay-as-bid market to find the flaw in the official's logic.

## Unilateral Market Power

This module describes the concept of unilateral market power (as distinct from collusion, which is illegal), explains why electricity markets are particularly susceptible to the exercise of unilateral market power, and explores when generating companies are most able to exercise it. Acting again as an agent of a generating company, the learner decides when it might be advantageous for their company to attempt to exercise unilateral market power to serve its fiduciary duty to its shareholders – and how best to offer into the market to do so.

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# WORKSHOP

Professor Mark facilitated simulation games to give the participants “hands-on” experience with electricity market principles relevant to the design of a regional power market for the GMS and Southeast Asia. The participants formed teams and offered into simulated electricity markets as generating companies (gencos) competing against each other during these workshop sessions:

- uniform-price auctions and unilateral market power
- pay-as-bid auctions
- transmission constraints
- forward contracts
- impact of variable energy resources and
- ensuring resource adequacy through interconnection.



## Session 1: Uniform-Price Auctions and Unilateral Market Power

This session covered the basics of how gencos offer into wholesale electricity markets with uniform-price auctions, where the market-clearing price is paid to all units that run. The participants, playing gencos, explored how and when they could exercise unilateral market power through their offers.

## Session 2: Pay-As-Bid Auctions

The session showed why uniform-price auctions are near universal in wholesale electricity markets, even when they require paying the market-clearing price even to units whose marginal costs are significantly lower than this price. Professor Mark ran a market with a pay-as-bid auction to investigate potential to ratepayers from using a “pay-as-bid” approach.

### 13 Cost-Based vs. Offer-Based Markets

Cost-Based	Offer-Based
Regulator audits power plant parameters (heat rate, fuel cost, etc.) to estimate costs	Generators can offer any price between offer floor and offer cap
Estimated costs may not be perfectly accurate	If market is competitive, generators will reveal their costs through their offers (in a uniform-price auction)
<b>Unilateral market power is less of a concern</b>	Regulator needs to monitor and mitigate unilateral market power

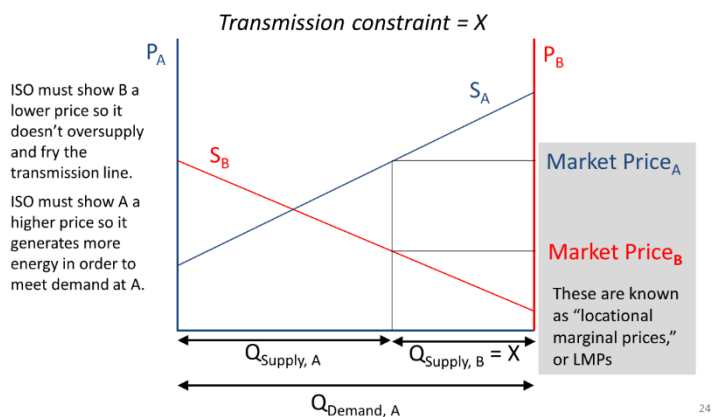
- A number of countries have successfully deployed cost-based markets, especially in Latin America
- A cost-based approach could reduce concerns about the exercise of unilateral market power in a regional power market
  - Need transparent model and data for estimating costs

Transmission constraints crucially affect: (i) Our ability to access cheap renewable energy at locations distant from consumer demand. (In a regional power market, cross-border interconnection can help us integrate renewable energy more cheaply!) and (ii) Market competitiveness (i.e. how many gencos can serve demand at a given location at a given point in time).

## Session 3: Transmission Constraints

### How Transmission Constraints Work

- Consider two regions: A (supply and demand), B (supply)



Transmission constraints can cause congestion on the grid, limiting how many gencos can compete to supply electricity at a particular location. Transmission becomes even more important with the introduction of significant quantities of variable energy resources. The session explored how congestion causes locational marginal prices to vary across the network and influences the ability of suppliers to exercise

unilateral market power.

## Session 4: Forward Contracts in Electricity Markets

Fixed-price, fixed-quantity forward contracts play a crucially important, but not widely understood, role in electricity markets. Many electricity market problems (and notably the California Electricity Crisis of the early 2000s) can be traced in part to a failure to ensure that gencos hold fixed-price forward commitments for most of their energy supply. Once gencos have sold forward contracts, they no longer have the incentives to exercise unilateral market power that were demonstrated in the previous sessions. The session showed how this works in a game where genos are pre-assigned forward contract positions.

### <sup>32</sup> All contracts for electricity are financial!

- You can't see electrons or trace where they went (except in the case of a DC transmission line)
- All you can measure is:
  - How much energy a generator injected into the grid at their location
  - How much energy a consumer withdrew from the grid at their location
- Every electricity market that runs before real-time dispatch, such as a day-ahead market, produces firm *financial* commitments



Forward contract obligations can be a powerful regulatory tool to improve market functioning.

## Session 5: Impact of Variable Energy Resources on Electricity Markets

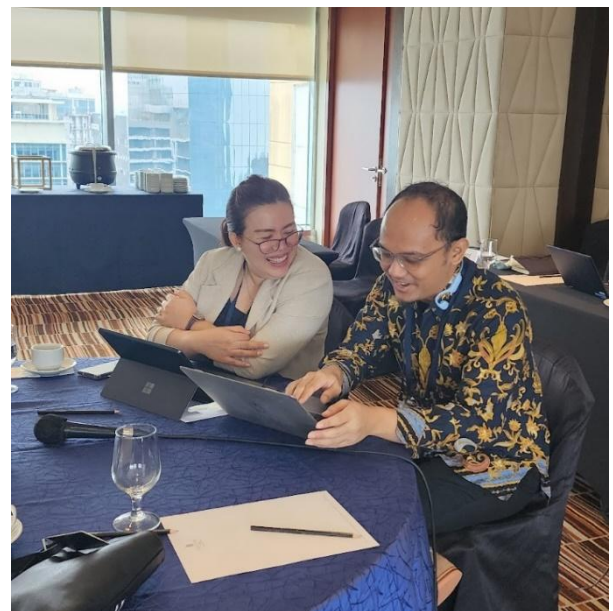
Intermittent renewable resources like wind and solar can increase wholesale electricity price volatility and alter the economics of dispatchable units in the market. The session ran a market with high shares of wind and solar to explore these effects and illustrate the “resource adequacy” problem.

### <sup>45</sup> Incentives for Generators with Renewable PPAs

Renewable PPA:  $Q_{contract}$  is set equal to the  $Q_{spot}$  of the renewable unit in every hour

$$\begin{aligned}
 \text{Revenue from spot sales} & \quad \text{“Difference payments”} \\
 & \quad \text{under contract} \\
 \text{Var. Profits} &= [Q_{spot}(P_{spot} - MC)] + [Q_{contract}(P_{contract} - P_{spot})] \\
 &= [\cancel{Q_{spot}} - \cancel{Q_{contract}}](P_{spot} - MC) + [Q_{contract}(P_{contract} - MC)] \\
 & \quad \text{Seek to maximize} \quad \quad \quad \text{Constant} \\
 & \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \text{(assuming constant MC)}
 \end{aligned}$$

- Forward Contract considered previously is fixed-price, fixed-quantity
- But in a Renewable PPA, the seller is paid a fixed  $P_{contract}$  for every MWh the renewable unit generates, when it generates it
- In other words,  $Q_{contract}$  is set equal to  $Q_{spot}$  in every hour
- This means the seller (i.e. renewable developer) in a Renewable PPA has no quantity risk and the buyer (i.e. retailer) has all the quantity risk!



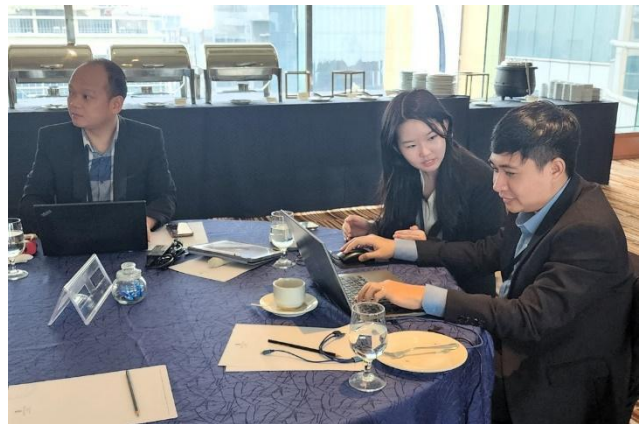


## Session 6: Ensuring Resource Adequacy with High Shares of Wind and Solar through Interconnection

When renewable energy incentives push large quantities of new zero-marginal-cost capacity into the energy mix, there is a risk that dispatchable units may be retired for economic reasons, even as their energy becomes crucial in times of low wind and solar output.

- <sup>60</sup> **Advantages of SFPFCs relative to simple, bilateral forward contracts**
- Standardized forward contract *product*
    - Provides confidence SFPFCs are a meaningful hedge
  - Standardized forward contract *procurement*
    - Rolling auctions several years ahead of delivery cover 100% of expected demand => avoids “first mover disadvantage” for buyers in bilateral contracts, obtains better price by allowing new capacity to compete
  - Retroactive adjustment to realized load shape incentivizes gencos to manage demand risk
    - If genco offers “hockey stick” after covering *expected* demand in a given hour, risks having to buy shortfall at high spot prices if realized demand is higher

Professor Mark facilitated a market game in which forward contracts for all of the expected demand were auctioned off as part of a “long-term resource adequacy mechanism” that can help avoid the resource adequacy issues seen in previous sessions.



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# CONCLUSION

## Some final thoughts on regional power market integration

There is no one “right way” to build out regional power markets, but some pain can be avoided by understanding key principles, such as

- Why does pay-as-bid not work well?
- How factoring in the configuration of the transmission network can improve outcomes.
- One cannot trace electrons; all electricity contracts are financial!
- Fixed-price, fixed-quantity forward contracts are a powerful tool for regulators.

Regional power market integration is an incremental process, and jumping to so-called “best practices” is not always the best approach.

# GRADUATION

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At the close of the workshop on 7 June, the 23 learners who completed the online modules and in-person workshop each received a certificate.

