# Power Markets and Renewables Deployment in Developing Countries

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# Outline of Presentation

- What is electricity industry re-structuring and why is important to economic development?
- Lessons from electricity re-structuring processes for developing countries
  - Match between market mechanism and actual system operation
    - Multi-settlement Locational Marginal Pricing (LMP) market
  - Long-term resource adequacy mechanism
    - Focus on developing a liquid forward market for energy
  - Managing mitigating system-wide and local market power
    - Local market power mitigation mechanism (LMPM)
  - Active involvement of final demand in wholesale market
    - Technology, Information, and Pricing
  - Policies to facilitate renewables deployment
- Topics for future research
  - Long-term resource adequacy for dispatchable generation units
  - Short-term price risk management with an increasing share of renewables
  - Actionable information for active involvement of final demand
  - Optimal mix of technology and pricing in distribution and transmission grids

# What is Restructuring?

- Replace explicit regulation with market mechanisms to set prices and determine how electricity is supplied
  - Price-regulated open access to
    - High-voltage transmission network
    - Local distribution network
  - Market mechanism to set prices for wholesale power and determine which generation units produce energy
  - Market mechanism to set prices for retail electricity and determine which retailers sell electricity to final consumers

# Electricity Industry Re-Structuring

- Alternative form of regulation of industry
  - Replace administrative pricing mechanism with market-based pricing at various stages of production process
    - Extent of competition a firm faces is a determinant of price
  - Replace government-owned firm with privately-owned firms
  - Replace price set by government ministry by price set by independent regulator
- Choice is not deregulation versus regulation, but how much and where to regulate
  - Re-structure to improve short and long-term productive efficiency of industry
    - Markets provide strong incentive for least-cost production

# Match Between Market Mechanism and Actual System Operation

# Physical Realities of Transmission Network Operation

- If suppliers know that model used to set prices is inconsistent with actual reality of how grid operates they will take actions to exploit this divergence
- Classic example—Financial market assumes no transmission constraints in network in determining market price
  - Realities of network operation imply unrestricted merit order is not feasible with actual network configuration
  - Typically use non-market mechanism to
    - Pay needed suppliers above market price to supply more
    - Buy power from constrained suppliers to produce less
  - Suppliers quickly figure out how to take advantage of this divergence between financial market and physical realities of system operation for their financial gain
    - Many examples from industrialized and developing country markets

# Locational Marginal Pricing

- Prices all relevant network and other operating constraints
  - Minimize as-bid cost to meet demand at all locations in network subject to all relevant network and other operating constraints
  - Limits divergence between financial market and physical realities of grid operation
- All US markets currently operate LMP markets
  - New Zealand and Singapore do as well
- Can manage political challenge of charging different prices to different locations in grid through load-aggregation point (LAP) pricing
  - Charge all loads quantity-weighted average LMP over all points of withdrawal in retailer's service territory

# Multi-Settlement Market

- All US wholesale electricity markets operate a day-ahead forward market and real-time imbalance market using LMP mechanism
- Both markets trade "megawatt-hours (MWhs) of energy delivered in hour h of day d“
  - Firm financial commitment to sell energy at a firm price
- Supplier receives revenue from day-ahead forward market sales *regardless of real-time output of its generation unit*.
  - Sell 40 MWh at a price of $25/MWh receive $1,000 for sales.
  - Any deviation from day-ahead generation or load schedule is cleared in real-time market.
  - If supplier only produces 30 MWh, it must purchase 10 MWh of day-ahead commitment from real-time market at real-time price

# Multi-Settlement Market

- Each time LMP market is run, the system operator's best estimate of real-time configuration of grid is used to price transmission congestion and other operating constraints
  - Ensures physical feasibility of market outcomes
- Prices reliability of energy supply
  - Suppose that a dispatchable thermal unit sells 100 MWh at price of $50/MWh in day-ahead market and intermittent resource sells 80 MWh in day-ahead market at same price
  - In real-time, significantly less wind is produced than was scheduled
    - Wind produces 50 MWh, so must purchase 30 MWh from real-time market at $90/MWh
  - Dispatchable thermal units must maintain supply and demand balance, which explains high real-time price
    - Sells 30 MWh at real-time at $90/MWh
  - Average price paid to thermal and intermittent units
    - $59.23 = 100 MWh*$50/MWh + 30 MWh*$90/MWh)/130 MWh)
    - $26 = (80 MWh*$50/MWh – 30 MWh*$90/MWh)/50 MWh
  - Dispatchable unit rewarded with higher average price than intermittent unit

# Mechanisms for Ensuring Long-Term Resource Adequacy

# Resource Adequacy Internationally

- Two dominant resource adequacy paradigms outside of US
- Capacity-based resource adequacy mechanism
  - Some or all units receive administrative $/KW-year payment
  - Cost-based energy market
    - Suppliers do not offer into day-ahead or real-time markets
    - System operator uses technical characteristics of units to dispatch and set an imbalance price
  - Paradigm exists in virtually all Latin American countries—Chile, Brazil, Peru, Argentina
- Energy-based resource adequacy process
  - Forward energy contracting primary means to hedge day-ahead and real-time price risk and finance new investment
  - Virtually all industrialized countries—Australia, New Zealand, Nordic Market, ERCOT (Texas), California

# US Approach to Resource Adequacy

- Bid-based capacity payment mechanism with bid-based energy prices exists primarily in eastern US markets
  - Pay market-clearing price for both energy and capacity
- "Rationale" for capacity payment mechanism in US
  - Historically offer caps on energy market necessitated by inelastic real-time demand for electricity due to fixed retail prices that do not vary with hourly system demand
  - Capped energy market creates so called "missing money" problem because of argument that prices cannot rise to level that allows all generation units to earn sufficient revenues to recover costs
  - "Conclusion"--Capacity payment necessary for provide missing money
- Capacity payment mechanism requires all retailers to purchase a pre-specified percentage (between 15 to 20 percent) above of their peak demand in installed capacity
  - Strong incentive for system operator and stakeholders to set a high reserve margin

# US Approach to Resource Adequacy (RA)

- Problems with logic underlying standard rationale for capacity payment mechanism
  - In a world with interval meters, customers can be charged default retail price that varies with hourly system conditions
    - For all system conditions hourly price can be set to equate hourly supply and demand, which eliminates missing money problem
  - Setting required level of capacity likely to create missing money problem
    - By setting a high capacity requirement relative to peak demand, there is excess generation capacity relative to demand, which depresses energy prices, which creates need for capacity payment mechanism
  - Capacity markets are extremely susceptible to exercise of unilateral market power
    - Vertical supply (installed capacity) meets vertical demand
    - Capacity payment mechanisms are only markets in name, administrative payment loosely based on cost in reality
  - Conclusion—”Capacity market” becomes very inefficient form of cost of service regulation layer on top of energy market

# Benefits and Costs of Capacity-Based RA Process

- Most important feature of capacity-based resource adequacy process—It does not address primary resource adequacy problem which is sufficient energy available to meet system demand for all states of the world
  - Large share of intermittent resources
  - Elimination of nuclear generation capacity
- Capacity shortfall highly unlikely to occur
- Inadequate energy to meet demand far more likely
  - Fixed price forward contracts *for energy* insure against this risk
- Having sufficient installed capacity provides little guarantee that generation capacity owners will sell energy
  - During June 2000 to June 2001 in California, all rolling blackouts occurred during time period with peak demands less than 34,000 MW
  - Peak demands above 44,000 MW occurred during summers of 2000 and 2001 without reliability incidents

# System-Wide and Local Market Power Mitigation

# Local Market Power Problem

- Transmission network was built for former vertically integrated utility regime
  - Built to take advantage of fact that both transmission and local generation can each be used to meet an annual local energy need
    - Captures economies of scope between transmission and generation
  - Vertically-integrated utility considered local generation and transmission on equal basis to find *least-cost system-wide* solution to serve load
  - Transmission capacity across control areas of vertically-integrated monopolists built for engineering reliability
    - Sufficient transmission capacity so imports could be used to manage large temporary outages within control area
    - Few examples where transmission capacity was built to facilitate significant across-control-area electricity trade--California/Oregon

# Origins of Local Market Power

- Transmission network configuration, geographic distribution of wholesale electricity demand, concentration in local generation ownership, and production decisions of other generation units combine to create system conditions when a single firm may be only market participant able to meet a given local energy need
  - Firm is monopolist facing completely inelastic demand
  - No limit to price it can bid to supply this local energy
- Regulator must design local market power mitigation mechanisms
  - Limits ability to supplier to exercise unilateral market power and distort market outcomes

# Local Market Power Mitigation

- All US markets have form of ex ante automatic mitigation procedure for local market power
  - History of US industry led to transmission network poorly suited to wholesale market regime
- All AMP procedures follow three-step process
    - Determine system conditions when supplier is worthy of mitigation
    - Mitigate offer of supplier to some reference level
    - Determine payment to mitigated and unmitigated suppliers
- Two classes of AMP procedures
  - Conduct and impact
    - NY-ISO, ISO-NE
  - Market Structure-Based
    - CAISO, PJM, ERCOT

# Active Involvement of Final Demand in Wholesale Market

# Retail and Wholesale Market Interactions

- Symmetric treatment of producers and consumers of electricity
- Folk Theorem—Restructuring improves efficiency only if all market participants face appropriate price signal
  - Unless policymaker is willing do this, don't restructure
- Default price for "marginal (not all) consumption" of all consumers should be hourly wholesale price
  - Consumer is not required to pay this price for any of its consumption, just as generator is not required to sell any output at spot price
  - To receive fixed price, consumer must sign a hedging arrangement with load-serving entity or electricity supplier
- There is nothing unusual about hedging spot price risk
  - Health, automobile and home insurance, cellular telephone

# Benefits of Active Participation

- Why active participation of consumers is essential
  - Managing intermittency
  - Managing unilateral market power
- Three necessary conditions for active participation
  - Technology--Interval meters
  - Adequate information
  - Dynamic pricing
- **Dynamic Pricing** versus **Time-of-Use Pricing**
  - Dynamic pricing plans
    - Hourly Pricing (HP)
    - Critical Peak Pricing (CPP)
    - Critical Peak Pricing with Rebate (CPP-R)

# Policies to Stimulate Renewables Deployment

# Policies to Promote Renewables

- A number of policies are used to promote renewables
  - Feed-in tariffs (FIT)
  - Renewables portfolio standards (RPS)
  - Power Purchase Agreements (PPA)
- All current approaches have shortcomings that limit their effectiveness at scaling renewables deployment
- New support mechanisms are needed to achieve high levels of renewables deployment
- Multi-settlement LMP markets ideally suited to scale renewables because all relevant operating constraints are priced
- Energy contracting approach to long-term resource adequacy better suited than capacity markets to scaling renewables
  - Energy shortfalls not capacity shortfalls are key risk to manage

# Directions for Future Research

# Directions for Future Research

- New products in multi-settlement LMP markets needed to scale renewables deployment
- Resource adequacy mechanisms to ensure adequate amounts of fast-ramping dispatchable energy is available to serve demand all hours of the day
- Short-term price risk management with an increasing share of renewables
- Actionable information for active involvement of final demand
- Mix of technology and pricing in distribution and transmission grids

Questions/Comments

For more information

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