Efficient Pricing: The Key to Benefitting Consumers from Electricity Sector Reform

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Electricity Industry in Brazil

- Increasing amount of intermittent renewable generation capacity in system
  - 13.7 Gigawatts (GW) of wind capacity
  - 1.6 GW of solar photovoltaic capacity
  - 0.5 GW of distributed (rooftop) solar
- Amount of grid-scale wind and solar generation capacity expected to increase significantly
- Amount of rooftop solar capacity is also expected to increase
- Additional intermittent renewable capacity will present significantly greater operational challenges

Electricity Industry in Brazil

- To manage these operational challenges Brazil currently moving to hourly pricing of electricity from weekly pricing
- Transitioning to bid-based market from cost-based market has the potential to manage these operational challenges at lower cost
- Increasing the number of customers that are free to choose retail supplier could produce downward pressure of retail prices
- More efficient retail pricing will ensure that least cost mix of grid-scale versus distributed solar PV capacity is built

Outline of Talk

- Features of wholesale market design to ensure competitive bid-based market with significant intermittent renewable energy share
- Features of wholesale and retail market design to ensure competitive retail market for smaller customers
- Features of retail and wholesale market design to ensure least cost mix of grid-scale versus distributed solar PV capacity is built

Ensuring a Competitive Bid-Based Wholesale Market with Significant Intermittent Renewable Generation

Wholesale Market

- Four aspects of wholesale and retail electricity pricing that are essential to achieve efficient *bid-based* wholesale market outcomes with a significant share of intermittent renewable capacity
  - Match between market mechanism and actual system operation
  - Managing mitigating system-wide and local market power
  - Symmetric treatment of load and generation in wholesale market
  - Long-term resource adequacy mechanism designed to address risk of future *energy* shortfalls

Four Lessons for Efficient Wholesale and Retail Pricing with Significant Intermittent Renewable Generation

Lesson #1: Match Between Market Mechanism Used to Set Prices 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 submit offers into short-term market to exploit this divergence
- Classic example—Financial market assumes no transmission constraints in network (copper plate) for purposes of determining market price
  - Reality is that many low-offer price generation units cannot be accepted to supply energy because of configuration of network
    - Ordering offer prices from lowest to highest requires skipping many offers because of transmission constraints

Physical Realities of Transmission Network Operation

- Typically use *ad hoc* non-market mechanisms to
  - Pay 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
- This is activity is typically called "re-dispatch process," and in regions that do not respect this lesson in setting wholesale prices, these costs have rapidly grown
  - Positive and negative reconciliations in Colombian market
  - Similar experience in many zonal markets in Europe

Solution: Locational Marginal Pricing

- Price 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
    - Market operator computes optimal schedule of production for generation units given offer curves and start-up cost offers submitted for all 24 hours of following day
  - Limits divergence between financial market and physical realities of grid operation
    - Only physically feasible outcomes are allowed to emerge from energy market
- All US markets currently operate LMP markets
  - New Zealand and Singapore do as well

Solution: Locational Marginal Pricing

- Objection to LMP often raised that it unfairly punishes customers that live in major load centers with higher locational prices
  - Grid would be planned differently if LMP pricing had been in place since start of electricity industry
  - Customers in San Francisco pay more than customers in Bakersfield in Central Valley of California
- 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
  - This is even done in Singapore where all customers pay Uniform Singapore Electricity Price (USEP)

Multi-Settlement Market

- To manage larger share of intermittent renewable capacity dispatchable generation units may need to
  - Start and stop much more
  - Ramp up and down more often
  - Operate at minimum generation level more frequently
- A multi-settlement market can
  - Reduce the cost of managing intermittent supply of renewable energy
  - Reward dispatchable energy for greater reliability of their energy
  - Facilitate entry of storage, demand response, and other load-shifting technologies

Multi-Settlement Market

- All US wholesale electricity markets operate a day-ahead forward market and real-time imbalance market using LMP mechanism
  - Day-ahead forward market simultaneously solves for output levels and prices *for all 24 hours of following day*
    - Suppliers can obtain least cost schedule of output for their generation units for all hours of the day
- Both markets trade "megawatt-hours (MWhs) of energy delivered in hour h of day d“
  - Day-ahead market is a purely financial market
  - Real-time market buys and sells actual energy produced by generation units and consumed by loads

Multi-Settlement Market

- 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 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
- Buyer pays for day-ahead forward market purchases *regardless of real-time consumption of energy*
  - Buy 40 MWh at a price of $25/MWh and pay $1,000 for energy
  - Any deviation from day-ahead load schedule is cleared in real-time market
  - If buyer only consumes 30 MWh, it sells 10 MWh of day-ahead commitment in real-time market at real-time price

Multi-Settlement Market

- Each time the 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
  - Day-ahead market uses system operator's best estimate of real-time configuration of transmission network
  - Ensures physical feasibility of dispatch and load schedules, which eliminate need for re-dispatch process
- In real-time market, system operator minimizes the as-offered cost of meeting real-time demand subject to all relevant operating constraints using real-time configuration of grid
  - Most US markets operate real-time LMP market every 5-minutes
  - Sets 5-minute prices and dispatch levels for all dispatchable resources—generation units, loads, batteries, etc.
  - 5-minute real-time markets reduces scope and size of ancillary services markets

Multi-Settlement Market

- Multi-settlement market rewards suppliers for reliability of supply, yet still pays same LMP to all resources at same location in both day-ahead and real-time markets
  - Very important feature of market design for regions with ambitious intermittent renewable energy goals
- Consider a market with significant intermittent resources
  - Supply of intermittent resources typically highly correlated
    - Wolak (2016) “Level versus Variability Trade-offs in Wind and Solar Generation Investments: The Case of California,” The Energy Journal (available at http://www.Stanford.edu/~wolak)

Multi-Settlement Market

- 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 imbalance market at $90/MWh
- Thermal unit supply must maintain supply and demand balance, which explains high real-time price
  - Sells additional 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

Multi-Settlement Market

- Case of unexpectedly high intermittent resource output yields a similar outcome of rewarding dispatchable resource with higher average price
  - Intermittent resource sells only 50/MWh in day-ahead market and thermal unit sells 130 MWh, both at $50/MWh
  - Intermittent resource produces 80 MWh, which implies that it sells 30 MWh in real-time market at $20/MWh
    - Low real-time price because of unexpectedly large intermittent output
  - Thermal resource buys back 30 MWh in real-time at $20/MWh
- Average prices paid to thermal and intermittent units
  - $59 = (130 MWh*$50.MWh – 30 MWh*$20/MWh)/100/MWh
  - $38.75 = (50 MWh *$50/MWh + $30 MWh*$20/MWh) /80 MWh
- Facilitates active demand-side participation in wholesale market because loads can buy energy in day-ahead market and sell it in real-time market
  - Consuming less than day-ahead purchase implies a sale of energy in the real-time market
  - Solves "baseline problem" for demand response programs

Multi-settlement LMP Market

- Wolak (2011) "Measuring the Benefits of Greater Spatial Granularity in Short-Term Pricing in Wholesale Electricity Markets" *American Economic Review*
  - Finds ~3 percent reduction in variable operating cost of operating thermal units from transition to multi-settlement LMP market from multi-settlement zonal market design in California
  - Roughly $110 million in annual operating cost savings associated with introduction of LMP market
- Even larger savings seem possible for Brazilian market with significant amounts of intermittent renewables
  - Accounts for configuration of transmission network and other operating constraints in energy and ancillary services procurement
  - Eliminates need for re-dispatch process, only need to respond to changes in demand, supply and grid configuration
  - Frequent settlement in real-time limits size and scale of ancillary services markets

Lesson #2:
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 of supplier to exercise unilateral market power and distort market outcomes

Local Market Power Mitigation

- All US LMP markets have some form of ex ante automatic mitigation procedure (AMP) 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

Local Market Power Mitigation

- As share of energy from intermittent renewables increases, need for explicit local market power mitigation mechanism increases
  - When wind or solar energy is unavailable, remaining suppliers can have a substantial ability to exercise unilateral market power at their location in transmission network
- Existence of a local market power mitigation mechanism increases likelihood that scarcity is cause of high prices at certain locations in grid
  - Pricing local scarcity stimulates efficient deployment of storage, load-shifting and automated response technologies

Lesson #3:
Symmetric Treatment of Load Generation

Symmetric Treatment of Load and Generation

- Folk Theorem—Restructuring benefits consumers only if all market participants (including consumers) face efficient price signals
  - Unless policymaker is willing do this, don't restructure
- This means default price for "marginal (not all) consumption" of all consumers should be real-time 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 real-time price
  - To receive fixed price, consumer must sign a real-time price hedging arrangement
    - This is true in all markets—Air travel, health care, etc.
- There is nothing unusual about hedging spot price risk

Day-Ahead versus Real-Time Dynamic Pricing

- Symmetric treatment of consumers and producers
  - Default price that producer receives and consumers pays is real-time price
  - Only if producer sells (consumer buys) in day-ahead forward market can it be paid (or pay) the day-ahead price, but only for quantity sold (bought) in day-ahead market and not for actual production (consumption)
- *If default price that all consumers pay and generators receive is real-time (not day-ahead) price, this will foster investments in storage, automated and manual demand response, and other innovative technologies for providing flexibility*

Lesson #4:
Mechanism for Ensuring Future Energy Adequacy

Resource Adequacy Internationally

- Two dominant resource adequacy paradigms outside of US
- Capacity-based resource adequacy mechanism
  - Some or all units receive administrative $/MW-year payment
  - Cost-based energy market
    - 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
  - Long-term forward contracts for energy 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 market exists primarily in eastern US markets
  - Pay market-clearing price for both energy and capacity
- "Rationale" for capacity payment mechanism ("market") 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 "firm capacity" (amount of energy unit can supply under worst-case supply conditions)
  - Strong incentive for system operator and stakeholders to set a high margin (make life easier for system operator and produces more revenue for generation sector)

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 price equal to hourly real-time price for their hourly demand
    - For all system conditions, hourly price can be set to equate hourly supply and demand, which eliminates missing money problem
  - Setting required amount of capacity to be purchased is 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 to increase in capacity payment
  - 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 layered on top of energy market

Benefits and Costs of Capacity-Based RA Process

- Capacity-based resource adequacy process does not address primary resource adequacy problem with a large intermittent renewables share
  - Sufficient energy available to meet system demand for all states of the world with a large amount of intermittent resources
  - McRae and Wolak (2016) “Diagnosing the Causes, of the Recent El Nino Event and Recommendations for Reform” provide analysis of problem for Colombian electricity supply industry
- Capacity shortfall highly unlikely to occur
  - Inadequate energy to meet demand far more likely
  - Fixed price forward contracts *for energy* insure against this risk
    - Wolak (2017) “The Benefits of Purely Financial Participants for Wholesale and Retail Market Performance: Lessons for Long-Term Resource Adequacy Mechanism Design,” on web-site
- McRae and Wolak (2016) and Wolak (2017) describe energy based long-term resource adequacy process much better suited to regions with significant intermittent renewable generation capacity

Benefits and Costs of Capacity-Based RA Process

- 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 were met during summers of 2000 and 2001 without reliability incidents
- Having sufficient fixed-price forward contract obligations causes generation unit owners to offer at least this quantity of energy into short-term market at very competitive prices
  - Strong incentive sell at least this quantity energy in short-term market
    - Wolak (2000) “An Empirical Analysis of the Impact of Hedge Contracts on Bidding Behavior in a Competitive Eectricity Market,” provides empirical support for existence of these incentives

Benefits of an Energy-Based RA Process

- No need to specify level of reserve margin or mix of generation capacity needed to serve demand
  - With adequate forward contracting for energy and ancillary services in place, suppliers then determine least cost mix of generation to meet these obligations
- System operator can still assess likely mix of capacity available day-ahead, week-ahead, month-ahead, and year-ahead is sufficient to operate system
  - Regulator manages this by increasing fraction of demand energy that must be contracted for in advance and how far in advance of delivery contracting must take place

Necessary Conditions for Competitive Retail Market

Benefits of Active Participation

- Besides symmetric treatment of load and generation, there are four conditions likely to maximize benefits consumers obtain from retail competition
  - Technology--Interval meters
  - Adequate information
  - Dynamic pricing
  - Regulatory Oversight of Retailer Risk
- See Wolak (2013) “Economic and Political Constraints on the Demand-Side of Electricity Industry Re-structuring Processes,” *Review of Economics and Institutions*, describes the rationales for these necessary conditions

Retail Competition without Interval Meters

- Without interval metering, retailers can only sell electricity based on monthly quantity consumed
  - Conventional meters only measure total monthly consumption
    - Read meter at beginning of month and end of month, monthly consumption is difference between two meter reads
- Retailers have no idea (and little incentive to care) who in a given customer class is more expensive to serve in terms of true wholesale energy purchase costs
- Retailers are *assigned* hourly “wholesale withdrawals” for their customers based on standardized load profiles
  - w(h,d) = load profile weight for hour h of day d
  - Q(m) = monthly consumption
  - Q(m)*w(h,d) = assigned hourly consumption during hour h of day d for customer, which may bear no relation to actual hourly consumption of customer

Retail Competition without Interval Meters

- Retail competition without interval metering involves competition to supply monthly energy purchased on an hourly basis using a standardized load shape
  - Hard to see how consumers realize significant benefits from this form of retail competition
- Without interval metering, customer reduces monthly bill by same amount by reducing consumption by 1 KWh during hour when wholesale price is $1,000/MWh as he does when price is $0/MWh or negative
  - It is likely to be much easier for customer to reduce demand during periods of low wholesale prices
    - On hot, high-priced day, consumer is unlikely to reduce air conditioning use during peak hours of day, instead consumer reduces demand in middle of night when outside temperature is lower

The Impact of Interval Meters

- With hourly metering, retailers can be required by regulator to purchase customer's *actual* hourly consumption at *hourly price wholesale price*
  - This is *symmetric treatment of load and generation*
  - Customer's actual consumption during the hour can be measured, so actual cost of serving customer is known
  - Little reason for regulator not to require that retailer pay for actual hourly consumption of customer rather than load-profiled monthly consumption
- Initial condition--Retail competition for customers with interval meter should involve serving consumer at actual hourly cost, rather than load-profiled cost
  - Can charge customer an hourly price that reflects cost of serving customer than hour
  - Substantial potential benefits to consumer and market from substituting away from high-priced hours to low-priced hours

Information and Consumer Behavior

- Customers must have “actionable information”
  - How electricity consuming actions translate into costs
- Two potential barriers to consumers making efficient electricity consuming decisions in most US jurisdictions
  - Electricity demand is a derived from the demand for services from electricity-consuming durable goods
    - Watching television, washing clothes or dishes, using computer
  - Electricity is sold using nonlinear prices
    - Rate at which energy-using appliance use translates into dollars depends on where customer is on nonlinear price schedule
- Examples of the importance of providing customers with actionable information for them benefit from active participation in wholesale market
  - Kahn and Wolak (2013) “Using Information to Improve the Effectiveness of Nonlinear Pricing: Evidence from a Field Experiment”
  - Wolak (2015) “Do Customers Respond to Real-Time Usage Feedback? Evidence from Singapore”

Day-Ahead versus Real-Time Dynamic Pricing

- **Dynamic Pricing** versus **Time-of-Use Pricing**
- All US dynamic pricing plans currently based on day-ahead prices
  - Critical peak pricing (CPP), CPP with rebate, Hourly pricing (HP) plans
  - Day-ahead prices are substantially less volatile than real-time prices
  - Consumers adjust day-ahead schedules based on day-ahead prices
- Day-ahead price-responsiveness of customer assessed in
  - Wolak, Frank (2010) "An Experimental Comparison of Critical Peak and Hourly Pricing: The PowerCentsDC Program," on web-site
  - Wolak, Frank (2006) "Residential Customer Response to Real-Time Pricing: The Anaheim Critical-Peak Pricing Experiment," on web-site
- Real-time responsiveness assessed in
  - Andersen, Hansen, Jensen, and Wolak (2017) "Using Real-Time Pricing and Information Provision to Shift Intra-Day Electricity Consumption: Evidence from Denmark" on web-site

Retail Competition and Hourly Meters

- Retail competition without hourly meters, actionable information and dynamic pricing plans unlikely to deliver significant benefits
  - Retail competition for all customers with hourly meters as long a retailer's hourly cost to serve customer is equal real-time price times customer's actual hourly consumption
- Regulator can coordinate a competitive procurement process for provision of interval metering infrastructure
  - Metering services can be sold as a regulated distribution service
  - Almost all meters currently sold are intervals meters, so it only a question of time when everyone will have them
- Purchase cheapest meter needed to read hourly consumption
  - Internet and smart phones can be source of all intelligence and interactivity
  - Automated response technology and behavioral response through these devices, not through meter

Regulator Must Ensure Retailers Only Take on Reasonable Levels of Risk

- Retailers can sell fixed-price retail and purchase wholesale energy from short-term market
  - Very risky if high price period in wholesale market occurs
  - Wholesale price can rise above implicit wholesale cost in fixed retail price
    - Retailer can go bankrupt
- Regulator must make sure retailers are adequately hedged for fixed-price retail market obligations
  - Retailer sells demand for 100 MWh at $150/MWh
  - Retailer should purchase forward contract for 100 MWh to hedge the wholesale cost of serving this load

Retail Pricing to Support Cost Effective Grid-Scale versus Distributed Renewable Generation Deployment

Retail Pricing Historically

- Historically all costs are recovered through a cents per kilowatt-hour charge
- Distributed solar provides consumer with ability to avoid purchases from grid
  - Consumer pays $/KWh charge only on electricity withdrawn from grid
  - Retail price is avoided cost of energy from solar panels
    - P(retail) = P(Energy) + P(Trans) + P(Dist) + Other
    - Other = retailing margin, energy efficiency programs, above market cost of Renewables Portfolio Standard (RPS) energy, low-income energy programs, distributed generation and storage support mechanisms
- Conclusion—Customer that installs distributed (rooftop) solar system avoids paying for many other costs besides energy

Inefficient Network Pricing in CA

- Current average residential price in California is ~23 cents/KWh
  - All three investor-owned utilities have increasing block prices for retail electricity
    - Highest marginal price is 40 cents/KWh
  - At $3.50/Watt installed, rooftop solar photovoltaic (PV) panels have a levelized cost equal to ~18 cents/KWh (at 3 percent real discount rate)
    - Going solar requires no subsidies to make it privately profitable for "average" California consumer
- Average wholesale cost of energy in California in 2017 was 4 cents per KWh
  - Socially unprofitable to invest in rooftop solar, because it is much cheaper for customer to get electricity from wholesale market

Inefficient Retail Pricing in CA

- Divergence between privately optimal decision and socially optimal decision due to inefficient pricing
  - More than 18 cents/KWh = (23 – 4 – ~1) cents/KWh difference between average retail price and average hourly marginal cost of grid-supplied electricity
  - Economically inefficient bypass of grid-supplied electricity
  - Much cheaper on a system-wide basis to supply customer with ~5 cents/KWh electricity from grid rather than 18 cents/KWh from distributed solar
    - Customer chooses distributed solar because this avoids average price per KWh of 23 cents/KWh
- In world without distributed solar, inefficient retail pricing did not lead to bypass
  - Customer’s bypass option was no electricity rather than electricity from solar PV capacity

The “Utility Death Spiral”

- Two reasons for increase in $/KWh retail price due to 7,000 MW of distributed solar PV installations between 2003 to 2018
  - (1) Mechanical—Less electricity withdrawn from grid on annual basis (same total cost divided by less electricity withdrawals)
  - (2) Grid integration costs—Upgrades of distribution network to accommodate more distributed solar (increases distribution costs)
- “Utility Death Spiral”
  - Higher prices lead to more rooftop solar, which leads to less withdrawals, which leads to higher prices and more rooftop solar and less withdrawals, which leads to higher prices...
- Wolak (2018) “Evidence from California on the Economic Impact of Inefficient Distribution Network Pricing” available on web-site
  - Roughly 1/3 of $/KWh increase in average retail prices since 2003 due to “Mechanical” effect
  - Roughly 2/3 of $/KWh increase in average retail prices since 2003 due to “Grid Integration Costs” effect

Improving Efficiency of Retail Pricing

- Base retail prices charged on cost causation principles and willingness to pay
  - Proposed solution: Recover most of sunk costs in monthly fee based on willingness to pay
    - Distribution network charges look much more like cable television or high-speed internet bill
    - Small, less than 1 cent/kWh, per KWh charge set to vary with real-time conditions in grid (charge for marginal distribution losses)
- Monthly cable television bill approach to retail electricity pricing
  - Customer pays fixed monthly charge for option to purchase grid supplied electricity at hourly marginal cost of delivering electricity to customer through grid
  - This will cause customers to make lowest social cost choice between grid scale and distributed renewables

Concluding Comments

Concluding Comments

- Bid-based multi-settlement LMP market
  - Significant realized benefits where it has been implemented
  - Can manage intermittent renewables at least cost
- Feasible to implement this market design in Brazil
  - At least day-ahead hourly market and real-time market
  - Price all relevant transmission and operating constraints
- Significant benefits likely to occur as a result of adopting this market design
  - Increasing share of thermal capacity and intermittent renewables make benefits even greater
- Bid-based short-term market **must** have local market power mitigation mechanism in place
  - Many existing mechanisms can be easily adopted
- Symmetric treatment of load and generation essential for active participation of load in wholesale market

Concluding Comments

- Capacity-based long-term resource adequacy process poorly suited to market with significant intermittent renewable generation
  - Long-term energy-contract based long-term resource adequacy process much better suited to addressing risk of future energy shortfalls
- Retail competition without interval meters, actionable information and dynamic pricing plans is unlikely to deliver significant consumer benefits
  - Multi-settlement wholesale market helps to facilitate active demand-side participation
- Transitioning to lower variable charge (marginal cost of grid-supplied energy delivered) and higher monthly fixed charge reduces incentive for inefficient bypass of grid supplied electricity
  - Address this before there is a large installed base of distributed solar capacity receiving private benefits of inefficient retail pricing

Questions/Comments

For more information

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A Bid-Based Market for Brazil?

Bid-Based versus Cost-Based Market

- In bid-based market suppliers submit their willingness to supply energy
  - Market price is highest offer price necessary to meet demand
- In cost-based market suppliers submit heat rates and other information about variable costs to system/market operator
  - Price is highest variable cost necessary to meet demand
- Under both regimes suppliers receive market price and loads pay the market price for deviations from their forward contract positions
- System/market operator creates opportunity cost of water for hydro units in cost-based market to manage water
  - Opportunity cost of water is hydro supplier's "variable cost"
- Choosing between two approaches requires taking account of both politics and economics of electricity prices
  - Is it time for Brazil to switch to a bid-based market?

Political Economy of Bid-Based Market

- Electricity prices are very politically visible
  - All voters purchase electricity
- In bid-based short-term market, suppliers are free to offer energy at whatever price they would like subject to market rules
  - Offer cap and offer floor are common in bid-based markets
- Offer prices will be far above variable cost of production when it is in unilateral interest of supplier to do so
  - Suppliers exercising unilateral market power
- In bid-based, short-term market wholesale electricity prices can rise to levels vastly in excess of any measure of variable production costs of any generation unit operating
  - Massive wealth transfers can occur as a result

Mechanisms to Limit Market Power

- Fixed-price long-term contracts between suppliers and retailers and free consumers negotiated far in advance of delivery
  - Long enough horizon to delivery for new entry to compete
- Bid cap on short-term market
  - Maximum bid that any supplier can submit
  - All US ISOs have a bids caps on energy and ancillary services
  - All markets around the world have explicit or implicit bid cap on short-term energy market
- Price cap on short-term market
  - Maximum value of market-clearing price
- Local market power mitigation mechanism
  - Automatic intervention mechanism to mitigate bids of suppliers that possess local market power
    - All US markets and virtually all international markets have these

Benefits of Bid-Based Short-Term Market in Brazil

- Assuming market power problems in short-term market are addressed as described above, what are benefits of bid-based short-term market in Brazil?
  - Lower cost short-term solution to meet demand despite multiple hydro unit owners on same river system
  - Lower cost long-term solution due to improved estimate of current opportunity cost of water relative to cost-based system
  - Active demand side participation in short-term wholesale market
    - Willingness-to-consume determines short-term price
- Bid-based market allows all generation unit owners to determine when units are operated
  - Prices reflect consensus willingness to use water of generation unit owners
  - Market prices can aggregate all information market participants have about future system conditions

Lower Cost Short-Term Solution

- An often-claimed reason for cost-based dispatch in Brazil is need to co-ordinate production by multiple generation unit owners on same river system
  - Actions by upstream unit owner imposes costs or “negative externalities” on those downstream
- Coase Theorem—named for Sir Ronald N. Coase, Nobel Prize-winning economist
  - As long as property rights are well-defined (enforceable) and transactions costs are small enough, market mechanism will find efficient solution regardless of how property rights are assigned

Lower Cost Short-Term Solution

- Coase Theorem applied to problem of multiple unit owners on same river system
  - As long as property rights to upstream water are well-defined, efficient allocation of water across units will occur as long as costs of communication between unit owners is small
    - Can assign rights to water to downstream unit or upstream unit (same use of water will result)
    - Transactions costs are likely to be small because there are a few suppliers on each river system
- With 100% fixed-price forward contract coverage of load mandated by Brazilian market rules all unit owners on river system should have a common interest in serving load at least cost
  - All unit owners have common interest finding least cost solution serve forward contract obligations
  - Solution reflects information about hydro conditions of all generation unit owners as opposed to information of single system operator and model of system operation

Lower Cost Short-Term Solution

- Example of Coase Theorem:
  - Owner U = Upstream
  - Owner D = Downstream
- Two modes of operation
  - Mode A--U earns $1000 and $D earns $500
  - Mode B--U earn $900 and $D earns $800
  - Mode B is efficient solution to water allocation problem
    - Total surplus is $1700 versus $1500 under A
- If U assigned rights to water then D could promise to pay U $150 to choose Mode B
    - U earns $1050 which is better than it would under A
    - D earns $650 which is better than it would under A

Lower Cost Long-Term Solution

- Current cost-based market in Brazil solves water allocation problem over time using stochastic dynamic programming problem with historical inflows
- Large literature in economics demonstrating that market mechanisms can aggregate relevant information possessed by all market participants into market price
  - Market price is “sufficient statistic” for all relevant information possessed by all market participants about current value of holding water in storage
- Distribution of historical inflows (used in current price-setting process in Brazil) may be very poor predictor of distribution of future water inflows
  - Global climate change may cause significant deviation from historical distribution
  - Market participants have private information about water conditions specific to location of their generation unit

Lower Cost Long-Term Solution

- If suppliers face sufficient competition, then their offers into the wholesale market reflect their best guess of current value of holding water in storage
  - Recall that with 100% fixed-price forward contract coverage negotiated far in advance of delivery suppliers have strong incentive to minimize cost of serving load
- Suppliers will only want to operate fossil units when it is least cost do so given the information they have about future inflows and weather conditions that impact electricity supply and demand

Lower Cost Long-Term Solution

- A complaint with current cost-based solution is that model solution contradicts consensus of market participants and policymakers on water use
- Under bid-based market, water will be used when consensus of market participants believes it should be used
- Mathematical programming solution is only optimal conditional on
  - Assumptions made on distribution of historical inflows
  - Assumptions made on future fossil fuel availability
  - Assumption made on future demand growth
- Suppliers' offers to supply water reflects private information each supplier has about these factors
  - Market price can aggregate this information

Lower Cost Long-Term Solution

- Current cost-based market uses an assumed "cost of deficit parameter" that is below price at which demand would actually curtail
  - R$ 388.84/MWh is approximately $US 100/MWh at current exchange rates
    - All offer caps in US markets are at or above $1,000/MWh
- Brazil's cost of deficit parameter implies an unrealistically low cost of energy shortfalls
  - Results in over-use of water relative to case of market realistic cost-of-deficit parameter
- Bid-based market would eliminate need to specify cost-of-deficit parameter
  - Price set by willingness of suppliers to sell water

Greater Flexibility to Respond to Extreme Conditions

- New Zealand and Colombia experienced rationing period during 1992 before bid-based market regime implemented
- During bid- based market regime, both countries have experienced period of low water inflows
  - Colombia 1997 to 1998
  - New Zealand 2001 and 2003
  - Market prices rose to reduce water use and increase fossil fuel generation use far enough in advance to avoid need for rationing
- Conclusion--Market participants' willingness-to-supply hydroelectric energy can manage potential shortage periods

Initial Conditions for a Bid-Based Short-Term Market

- Market power problems in short-term market can result in substantial wealth transfers
- High levels of fixed-price long-term contracts between suppliers and loads is a pre-condition for a bid-based short-term market
  - Large hydro share in Brazil makes this requirement essential
  - Higher electricity prices do not cause more rainfall
    - Buy insurance against low water outcome from thermal unit owners
- Second necessary condition is a local market power mitigation mechanism
  - Automatic intervention mechanism to mitigate bids of suppliers that possess local market power

Forward Contracts and Spot Market Power

- Forward contracts must be signed far enough in advance of delivery to obtain contestable market price
  - Must allow new entrants to compete with existing suppliers to provide long-term contract
    - Emphasizes importance of streamlined generation siting process
  - New Combined Cycle Gas Turbine (CCGT) can compete at 2-year delivery horizon in forward contract market
- Signing forward contracts 3-months, 6-months or even one-year in advance of delivery may not provide any short-term market power mitigation benefits of fixed-price forward contracts
  - May simply pay for expected market power in short-term market on installment plan in forward contract price
  - Short-term prices will subsequently reflect less unilateral market power, but consumers must still pay higher forward contract price

Bid-Based Market with State-Owned Firms

- Many bid-based markets have significant participation by state-owned firms
  - Australia—Virtually all units in New South Wales state-owned
    - Roughly 50% of Australian generation capacity
  - New Zealand-Only one large privately-owned firm, Contact Energy
    - Roughly 70% of capacity is state-owned
  - Colombia—Significant participation by state-owned firms
  - Norway
    - Virtually all units owned by state or local government entities
- As long as state-owned companies are corporatized and there are enough firms, bid-based market can achieve market designer's goals even with significant government-owned firm participation
- Bid-based dispatch also makes it much more difficult for government to intervene in price-setting process
  - No parameter of model or modeling assumption for government to influence

Implementing Bid-Based Market in Brazil

- Bid-based market easier to implement in hydro-dominated systems with sufficient number of suppliers
- Hydro based-systems typically have very large margins in installed capacity above peak demand
- Hydro units with energy available discipline ability of fossil fuel suppliers to raise wholesale prices by bidding higher or withholding output
  - Fossil units withholding replaced by hydro suppliers with little change in market price
  - California 1998 and 1999
    - Market performance superior to eastern markets because there was plenty of water even though there was very little fixed-price forward contracting by loads

Bid-Based Market is Feasible for Brazil

- Market mechanisms are very good at aggregating information of all market participants
  - Short-term market should set a forward looking price of water that aggregates information of all market participants
  - Prices be set using historical distribution of inflows can be extremely inaccurate
- Market mechanisms can efficiently solve problem of externalities in water use on a single river system
- Market mechanisms can allow active demand-side participation in wholesale market
- Comprehensive short-term market power mitigation mechanism must be in place for bid-based market
  - 100% mandated forward contracting level by loads signed far in advance of delivery of contract
  - Local market power mitigation mechanism

Purpose of Talk

- Answer three questions for Brazilian market
  - How should wholesale market mechanisms change for transition to bid-based market from cost-based market?
  - How should retail market mechanism change to increase the number of customers that are eligible to choose retail supplier?
  - How should wholesale and retail market mechanisms change to ensure that least cost mix of grid-scale versus distributed solar PV capacity is built?

Benefits of an Energy-Based RA Process

- Renewable energy suppliers must re-insure with fossil fuel or dispatchable demand
  - Solves problem of determining “reliable capacity” of intermittent renewable resources
  - Provides additional revenue stream for fossil fuel units
- Universal interval metering can provide substantial consumer benefits and prevent cross-subsidies from incumbent to competitive retailers
  - Customers that lean on day-ahead or real-time market can be subjected to extremely high energy prices
- Must provide strong incentives or regulatory mandate for retailers to engage in adequate levels of fixed-price forward contracting
  - Raising offer cap on day-ahead and real-time markets is desired solution, but this should be done with a gradual transition to path to ensure no surprises
- Offer cap on energy market should set high even to cause sufficient active demand side participation to maintain desired level of reliability
  - No need to eliminate offer cap
  - Offer cap only needs to be high enough yield amount (say, 10% of day-ahead scheduled load) of negawatt suppliers desired by operators