Long-Term Resource Adequacy to Benefit Electricity Consumers

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Motivation for Presentation

- Re-structured electricity markets have existed for more than 15 years in US and Canada
- Most significant defects in short-term markets in US and Canada have been addressed
- Remaining challenge to ultimate success of re-structuring is long-term resource adequacy
  - Largest potential source of benefits of re-structuring
  - Capacity payment mechanisms in US markets have been plagued by significant problems
    - Difficult to argue they are solution to long-term resource adequacy
- Long-term resource adequacy process should not only ensure reliable supply of energy, *but do so at least cost to electricity consumers annually*
  - Goal of this talk is to propose such a process
  - Alberta has initial conditions to support this process

Outline of Presentation

- Rationale for regulatory intervention to ensure long-term resource adequacy in wholesale markets
  - Reliability in vertically-integrated monopoly regime versus wholesale market regime
- Contract adequacy approach to long-term resource adequacy
- Comparison of capacity payments and forward contracts for energy markets
- The role of symmetric treatment of load and generation
- The role of competition-enhancing transmission expansions
- The role of regulatory oversight in long-term resource adequacy

Reliability under Vertically-Integrated Monopoly versus Wholesale Market

- Vertically-integrated monopoly—A single firm is responsible for ensuring a reliable supply of electricity
  - Single firm responsible for ensuring sufficient generation, transmission, and distribution to serve demand
  - Regulator or government can penalize firm for failure to meet reliability standards
- Wholesale market—No single firm is responsible for reliability of supply
  - Independent system operator (ISO) runs system, but can only do so with generation units suppliers make available and existing transmission and distribution networks
  - Each segment of industry can and often does blame other segments for any reliability issues that arise
    - Regulator or government has a difficult time penalizing any single market participant for a reliability issue

Reliability under Vertically-Integrated Monopoly versus Wholesale Market

- Reliability of supply is managed in most markets through price mechanism
  - In oil market, price is allowed to rise to the level necessary to match available supply with demand
- Currently, there are both technological and political barriers to using this approach to address problems with the reliability of supply of electricity
  - Cannot measure hourly consumption of customers without hourly meters which precludes charging based on hourly price
  - Setting hourly prices high enough for reduce demand to equal available supply may not be politically possible
- Conclusion—Regulatory intervention needed to ensure supply is sufficient to meet demand with a high level of reliability into distant future
  - Consistent with goal of achieving lowest annual average delivered price of electricity to consumers while maintaining long-term financial viability of industry

Long-Term Reliability Challenge in Wholesale Electricity Market

- In wholesale market regime, no industry participant with strong incentive to ensure supply equals demand into distant future
- Without interval meters and political will to set wholesale price to make hourly demand equal to available supply regardless of price, regulatory intervention is necessary to ensure supply equals demand into distance future
- Conclusion—Long-term resource adequacy must rely on some regulatory intervention
  - Should be done in a manner that minimizes annual electricity costs to consumers consistent long-term financial viability of industry

Reliability Challenge with Significant Share of Intermittent Renewables

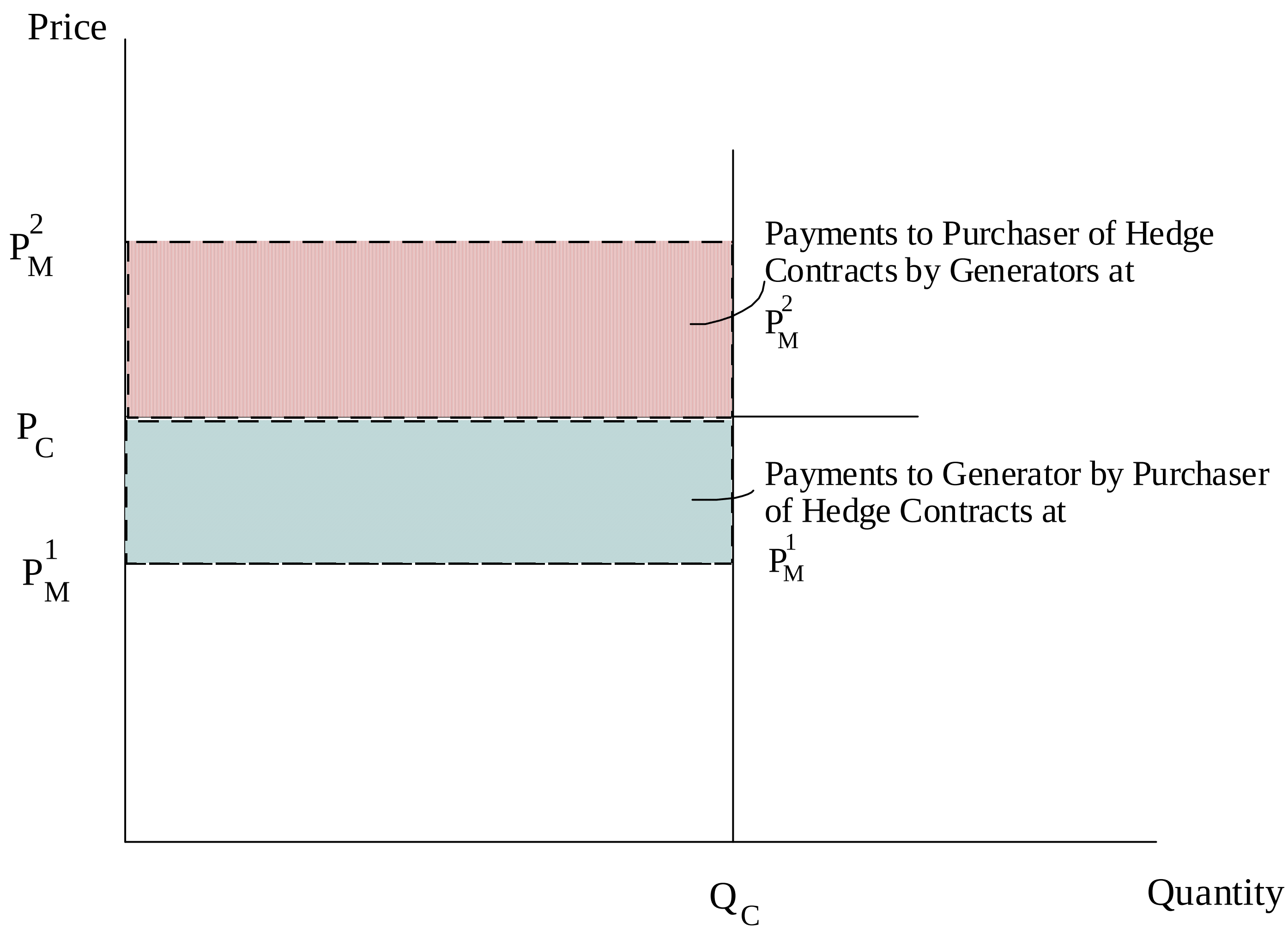
- If wind does not blow or sun does not shine for a sustained period of time, there can be *insufficient energy* to meet demand
- Even if the installed capacity of intermittent renewable generation resources exceeds peak demand by a substantial margin, *energy shortfalls* can still occur
- Energy shortfalls are primary reliability challenge facing wholesale electricity markets
  - No wholesale markets have experienced capacity shortfalls
  - Challenge even greater in markets with a significant share of intermittent renewables
- Fixed-price forward contracts for energy are financial instruments for insuring against energy shortfalls
  - Regulatory intervention should focus on insuring adequate levels of forward contracting at all delivery horizons

Forward Market for Energy

Forward Financial Instruments

- Forward financial contract
  - Contract that obligates seller to “deliver” to buyer a fixed quantity of MWh at an agreed-upon date in the future at an agreed upon price
- Because electrons cannot be delivered to specific locations in the network, a forward contract obligates the seller to guarantee the price at which buyer of contract can purchase agreed upon quantity of energy at that location and date
- If seller agrees to “deliver” 100 MWh at \$50/MWh at location A at date T, then the seller agrees to guarantee that buyer of contract can purchase 100 MWh at location A at date T for \$50/MWh, regardless of realized spot price at that location
- Swap contract is a sequence of forward financial contracts
  - If a supplier sells QC swap contracts at a price equal to PC, then the seller’s profit or loss from this action in period t is (PC – p(t))QC, where p(t) is the spot price on during delivery period t
- All buyers and seller settle with ISO based on real-time price for real-time supply and demand but difference payments flow between to two parties
  - Supplier’s Variable Profits: $\pi_{id}(p) = (DR_{id}(p) - QC_{id})(p - MC) + (PC_{id} - MC)QC_{id}$

Two-Sided Hedge Contract Payments Streams



Forward Financial Instruments

- Call option
  - Contract that gives buyer the option to “purchase” QC MWh of energy at price E at an agreed upon location in the network and future date
    - E = exercise price of cap contract, QC = contract quantity
  - Payoff to owner of call option is max(0,p-E)*QC, where p is spot price at agreed upon location and future date
  - Different from swap contract, seller typically charges an up-front fee to buyer of call option for “insurance” against prices above E
    - For swap contracts, PC is agreed upon trading price at future date
- Cap contract is sequence of call options
  - For example, option to “purchase” 50 MWh at $100/MWh during peak hours of weekdays during month of June at node A
  - Financial settlement of cap contract implies that during all hours, t, covered by contract, seller pays buyer max(0,p(t)-E)*QC

Forward Financial Instruments

- Put option
  - Contract that gives option to sell QC MWh at a price E at agreed upon location in the network and future date
    - E = exercise price of cap contract, QC = contract quantity
  - Payoff to owner of put option is max(0,E-p)*QC, where p is spot price at agreed upon location and future date
  - Seller typically charges an up-front fee to buyer of put option for insurance against prices below E
- Floor contract is sequence of put options
  - For example, option to "sell" 50 MWh at $30/MWh during off-peak hours of weekdays during month of June at node A
  - Financial settlement of floor contract implies that during all hours, t, covered by contract, seller pays buyer max(0,E – p(t))*QC

Forward Financial Instruments

- Can combine these options in a variety of ways to construct more exotic options
  - Asian option—Option on average prices over some time period
  - Swaption—Option to obtain a swap contract at agreed upon PC
- Relationship between payoffs of call, put and forward contract
  - Buy Call at E + Sell Put at E = Buy a Swap at E
  - $\text{Max}(0,p-E) - \text{Max}(0,E-p) = p - E$

Forward Market for Energy

- High-level of fixed-price forward contract coverage of expected sales provides strong incentives for suppliers to submit offer curves close to their marginal cost curve
  - Increases competitiveness of short-time market outcomes
    - See Wolak (2000) “An Empirical Analysis of the Impact of Hedge Contracts on Bidding Behavior in a Competitive Electricity Market,” on web-site
    - McRae and Wolak (2009) “How Do Firms Exercise Unilateral Market Power: Evidence from a Bid-Based Wholesale Electricity Market,” on web-site
- Political constraints and existing technology make it difficult to provide the efficient incentive for retailers to purchase a sufficient quantity of long-term contracts
  - Political constraints prevent setting hourly prices sufficiently high to clear market under all system conditions
  - Lack of technology to curtail individual customers or record their hourly consumption (not all customers have interval meters)
  - *Important fact--Retailers and large consumers know that system operator can only curtail demand to specific areas, not specific consumers*

Forward Market for Energy

- Customers recognize that purchasing forward contracts benefits all customers, but only costs them
  - This is “reliability externality”, which creates incentive for under-contracting by retailers and final consumers
  - Justification for regulatory intervention to ensure sufficient levels of fixed-price forward contract coverage of aggregate demand
- Forward contracts purchased by retailers
  - Provide fixed revenue stream necessary to finance investments in new generation capacity
  - Provide strong incentive for seller of contract to provide contract quantity of energy at least cost
- If forward contract is signed far enough in advance of delivery, seller will construct new generation capacity or contract with new entrant to provide energy
  - Supplier of forward contract delivering more than two years in advance of delivery faces competition from existing suppliers and potential new entrants

Forward Markets and Renewables

- How renewables are typically paid eliminates short-term market-efficiency benefits of fixed-price forward contracts
- Feed-in tariff pays fixed price for all output sold by renewable resource owner
- Variable profit function of resource owner

$$\pi_{id}(p) = (DR_{id}(p) - QC_{id})(p - MC) + (PC_{id} - MC)QC_{id}$$

- Under feed-in tariff, first term is zero for all hours, because supplier is paid PC for all output produced, i.e., DR(p) = QC for all periods by definition of feed-in tariff
- No incentive for supplier to manage risk of intermittency
  - Feed-in tariffs completely undermine market efficiency-enhancing benefits of forward contracts
  - Provides implicit subsidy to renewable resources being paid according to feed-in tariff

Energy Contract Approach to Resource Adequacy

Energy-Based Resource Adequacy

- Regulatory mandate for fixed-price forward contract coverage of retail load obligations for pre-specified fractions of forecast demand at various horizons to delivery
  - 100% of expected demand one year in advance
  - 90% of expected demand two years in advance
  - 85% of expected demand three years in advance
  - 80% of expected demand four years in advance
- Contracts can be a mix of swap and cap contracts
- Contracting mandates are regulator's security blanket to ensure adequate supply of energy into distant future
  - Allows offers caps on day-ahead and real-time markets
- Higher levels of mandated contracts implies greater reliability of supply because seller of contract has strong incentive to build physical hedge against risk of energy shortfall
  - Build new generation capacity or re-insure with owner of generation capacity

Energy-Based Resource Adequacy

- No installed capacity requirement
  - Let suppliers figure out least cost way to meet expected demand
  - No technological preference for new generation investments
  - Creates level playing field for demand-side and supply-side solutions
  - Focuses on primary reliability problem—adequate energy to meet demand
- This approach used throughout Latin America, typically with cost-based energy market
  - Under cost-based energy market suppliers submit heat rate and fuel contracts to system operator who computes variable cost of each generation unit
  - System operator dispatches system and manages imbalances using its estimates of each generation unit's variable cost
  - Generation unit owners do not submit offer prices and are penalized if plants are not made available to system operator

Benefits of an Energy-Based RA Process

- Must provide strong incentives or regulatory mandate for retailers to engage in adequate levels of fixed-price forward contracting
  - Raising offer cap on short-term markets is desired solution, but this should be done with a gradual transition to path to ensure no harmful (to consumers) surprises
  - Typically impose financial penalties on retailers that fail to comply with mandate
- Offer cap on energy market should be set high enough to cause sufficient active demand-side participation to maintain desired level of reliability for level of energy contracting
  - 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 regulator

Benefits of an Energy-Based RA Process

- Renewable energy suppliers must re-insure with fossil fuel or dispatchable demand
  - Energy contract resource adequacy process solves problem of determining “reliable capacity” of intermittent renewable resources
  - Provides additional revenue stream for fossil fuel units
  - Re-insurance problem is source of supply shortfalls in hydro-dominated markets
- Universal interval metering can provide substantial consumer benefits and prevent cross-subsidies from incumbent to competitive retailers
  - Retailers and large customers that rely on short-term wholesale market can be subjected to extremely high prices

Forward Market for Energy

- Regulator-mandated levels of fixed-price forward market coverage of final demand by all electricity retailers at various horizons to delivery addresses “reliability externality”
  - Forward contracts can be standardized products sold through an auction market operated by system operator
    - Retailers can “undo” these contracts at their own risk
  - Monthly quantity of energy delivered according to system-wide hourly load shape within the month
- No stranded contract problem for retailers
  - If lose load can sell forward contract to retailer that gains load
  - Little likelihood that aggregate load will fall by 20% relative to four-year ahead forecast
- If retailers are financially separate from generation unit owners then imposing purchase mandate on each retailer ensures adequate revenue stream to finance new generation capacity needed to meet demand
  - Complication with vertically-integrated retailers

Forward Market for Energy

- To address vertically-integrated retailer issue, could require all purchases of standardized products to be held to "delivery" in real-time market
  - This would allow regulator to compute bundled forward contract prices for wholesale energy
    - Price at delivery is 0.80 price of contracts four years ago, 0.05 price of contracts three years ago, 0.05 two years ago, and 0.05 one year ago
    - These bundled prices could be made available to customers so that they can price retail price offers they receive from vertically-integrated retailers
  - "Wholesale energy price-to-beat" for all retail energy contracts
- Retailers would clear these contracts on delivery date
- Consumers know that all retailers (even vertically integrated) have ability to sell at "wholesale price-to-beat" because each retailer had to purchase this bundle of contracts
  - All retail electricity could be sold relative to these bundled forward contract prices

Common Misconceptions

- Spurious Claim--Annual average of short-term energy prices (that do not support new investment) indicate a failure of resource adequacy process
- If fixed-price forward contracts for energy and ancillary services are primary revenue source to finance new entry and maintain financial viability of existing generation units, then
  - Low average short-term energy prices indicate more than adequate amounts of fixed-price energy contracting relative to level of demand
- Failure of long-term resource adequacy process is indicated by annual average short-term energy prices that do support new investment
  - Indicates inadequate amounts of fixed-price forward contracts to finance new investment

Common Misconceptions

- Claim—An energy-based resource adequacy mechanism requires energy and ancillary services markets with no bid cap
- If fixed-price forward contract coverage of final demand for energy and ancillary services is high enough, bid cap must only be above variable cost (properly computed) of highest variable cost unit on system
  - With 100 percent coverage of final demand only need offer cap above variable cost of highest cost unit in system
- Can require higher level of coverage of forecast of final demand to account for unexpectedly high levels of actual demand relative to forecast
  - Cap contracts are ideally suited to provide price spike insurance for these circumstances
- Cost of purchasing last 5 to 10 percent of forward contract coverage of final demand may be very expensive relative to allowing short-term prices and active demand-side participation to clear these energy and ancillary services markets for customers with interval meters or other interactive devices

Energy Contract Adequacy
versus
Generation Capacity 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 short-term markets
    - System operator uses technical characteristics of units to dispatch and set market 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 short-term price risk and finance new investment
  - Virtually all industrialized countries—Australia, New Zealand, Nordic Market, ERCOT (Texas), California

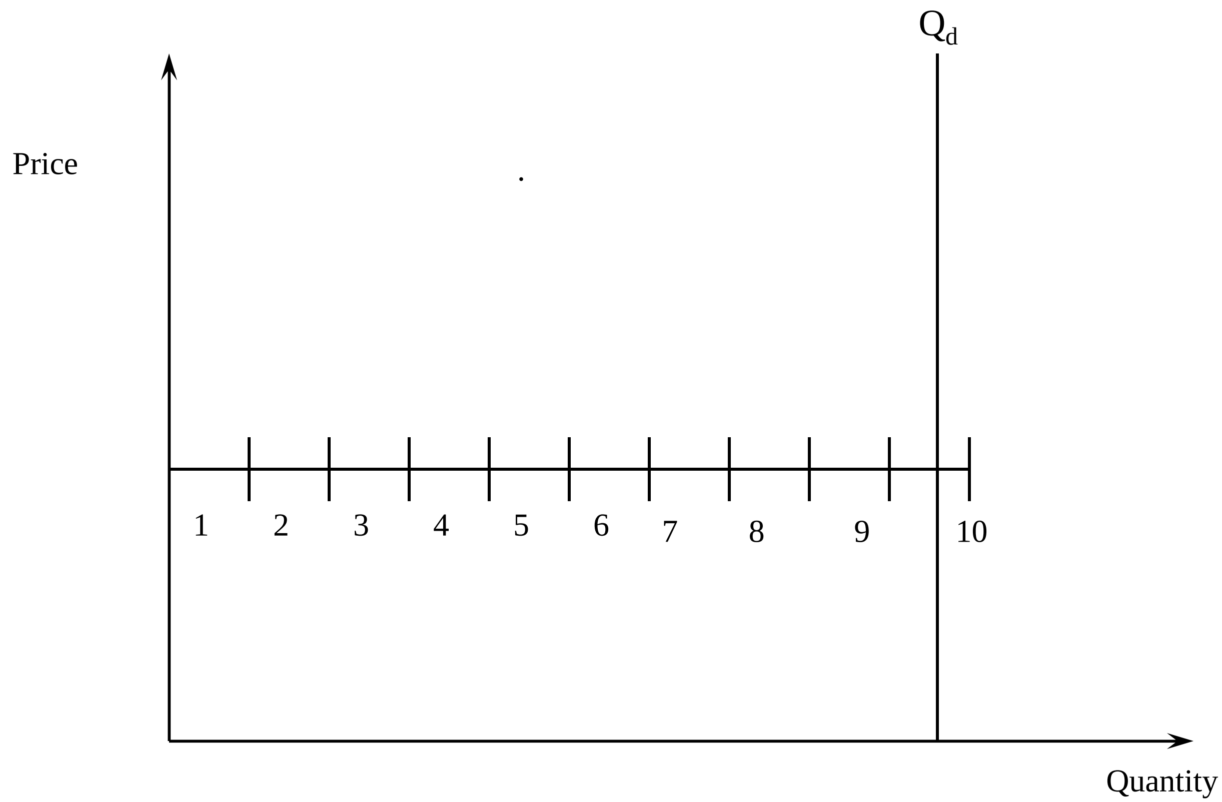
Capacity Approach to Resource Adequacy

- Bid-based capacity payment mechanism with bid-based energy prices exists primarily in US
  - Pay market-clearing price for both energy and capacity
  - Can be very expensive for electricity consumers
- “Rationale” for capacity payment mechanism in US
  - Historically, offer caps on energy market were 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 regulator-specified percentage (between 15 to 20 percent) above of their peak demand in “installed capacity” product
  - Strong incentive for system operator and stakeholders to set a high reserve margin

Capacity Approach to Resource Adequacy

- Problems with logic underlying "standard rationale" for capacity payment mechanism
  - In a world with interval meters, customers can be charged 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 (reverse order of causation)
    - *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 Auction--Pivotal Supplier



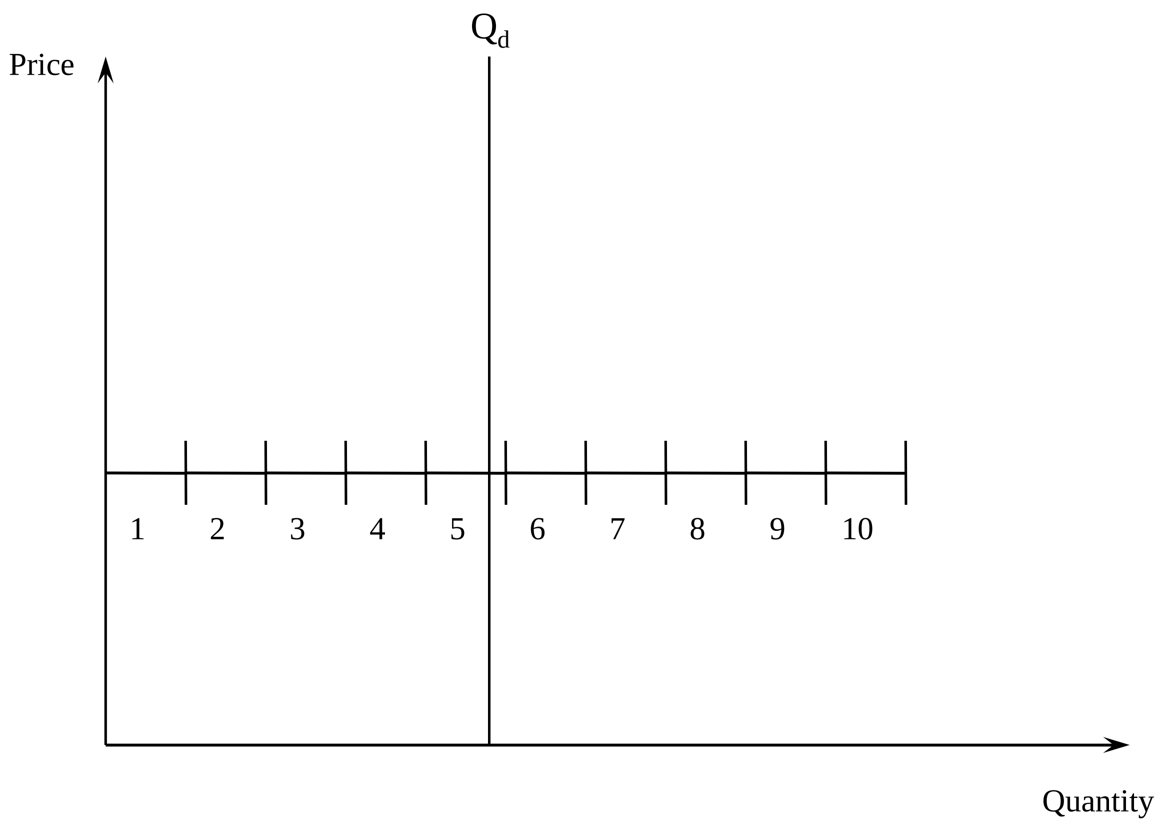
10 Firms--Each has 1 MW to sell, Market Demand is 9.5 MW

Marginal Cost = $0/MW, Price Cap of $10,000/MW

Auction Equilibrium

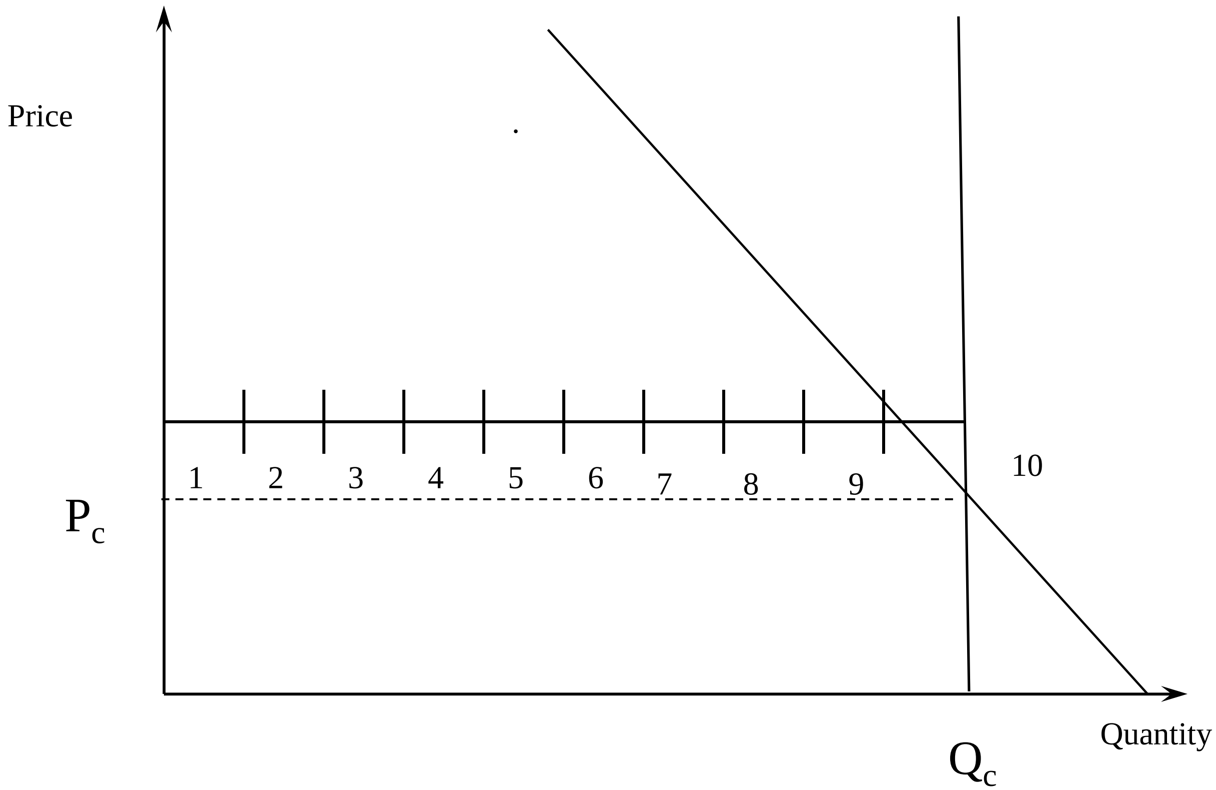
- 9 firms all bid $0/MW for one 1 MW
- 1 firm bids $10,000/MW for 1 MW
- Equilibrium price is $10,000/MW
- Each of 9 firms bidding $0/MW has no incentive to unilaterally change its bid
  - Earns highest possible profit given capacity
- 1 firm bidding $10,000/MW has no incentive to unilaterally change its bid
  - Cannot increase price
  - Decreasing price only reduces profit
  - Reductions in quantity can only reduce profit

Capacity Auction—No Pivotal Supplier



A Nash equilibrium to this auction is that all firms bid zero and each sell $Q_d/10$.

Capacity "Dee-mand Curve"



10 Firms--Each has 1 MW to sell, Market Demand is 9.5 MW

Marginal Cost = $0/MW, Price Cap of $10,000/MW

Benefits and Costs of Capacity-Based Approach

- Benefits of capacity mechanism accrue primarily to incumbent retailers and generation unit owners, not consumers
  - System operator determines the number MWs of “reliable capacity” a unit owner can sell
    - System operators attempts to ensure owner does not sell more than it can “reliably supply”
    - Difficult to define reliable capacity from an intermittent renewable resource
      - -Political rather than economic or engineering determination
  - Total costs of capacity procurement can be allocated to final consumers because energy is priced separately from capacity
  - Low bid caps or even cost-based bids into energy market are possible because of capacity payment mechanism
    - Avoids need for regulators to explain high hourly energy prices
    - Regulator can mitigate in short-term markets because suppliers receive capacity payments

Benefits and Costs of Capacity-Based Approach

- Costs of capacity-based resource adequacy process falls primarily on final consumers
  - *Very hard, if not impossible, for regulator not to provide sufficient revenues to all capacity that is built, which raises average retail prices to consumers*
    - *They pay market-clearing price for energy, ancillary services and capacity*
  - Unless capacity is purchased far enough in advance of delivery to allow new entrants to discipline market power of large incumbent generation unit owners, an administrative or regulatory pricing mechanism is necessary
    - Severe market power problems can arise even with “administrative dee-mand curve” approach used in eastern US
  - With bid-based short-term market, high-levels of fixed-price forward contracting for energy is still necessary to limit incentive of large suppliers to exercise unilateral market power in energy market
  - Conclusion--Capacity payment mechanisms do not have short-term market efficiency enhancing benefits that energy contracting approach does

Benefits and Costs of Capacity-Based Approach

- 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
- Capacity shortfall highly unlikely to occur in US or Canada
- 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
- Conclusion—Focus long-term resource adequacy process on ensuring consumers have what they want--"a reliable supply of energy"--not want they don't want--"installed generation capacity"

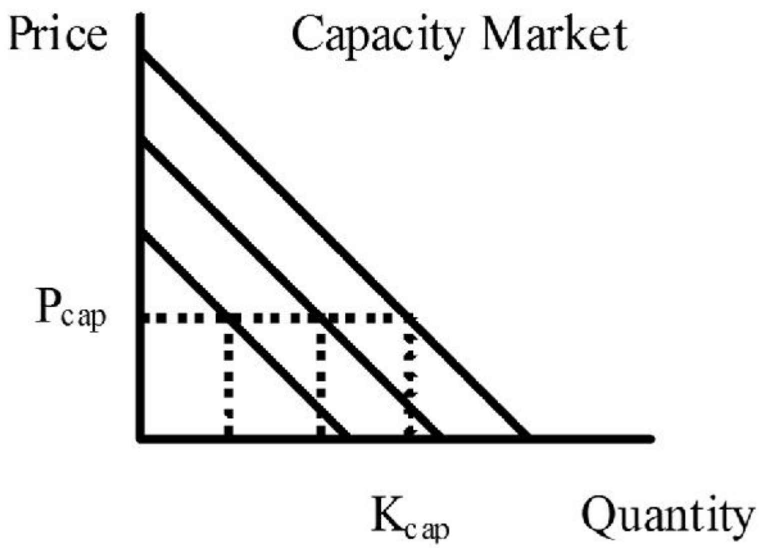
Fundamental Policy Questions

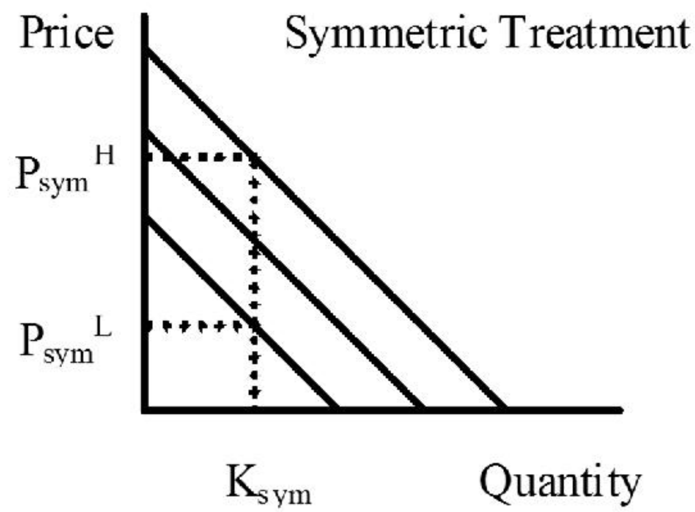
- Capacity payment mechanism makes very little sense in world with significant intermittent renewable capacity
- Reliable capacity of an intermittent unit is very difficult to define politically
  - How much energy can capacity provide during stressed system conditions?
  - Intermittent resources typically are able to supply a very small fraction of their installed capacity during these conditions
- Why embark on a resource adequacy process that will to make active demand-side participation in wholesale market much less economic?
- Why pay all generation units a capacity payment to obtain a service is needed only from few units each day and can be provided by decreasing fraction of units in the control area?
  - How valuable is installed capacity from an intermittent resource?

Eliminating Rationale for Capacity Payments

- Interval meters eliminates primary technology-based rationale for capacity payments
  - They are not necessary for energy-based approach, but are likely to reduce annual costs to consumers, relative to pure energy-contracting solution to hedge wholesale price risk
- Symmetric treatment of load and generation eliminates regulatory need for a capacity payment mechanism
  - Default price that all consumers with interval meters pay is same default price paid to all generation unit owners
- To avoid paying short-term price customer must purchase hedging arrangement from electricity retailer
  - To avoid being paid short-term price generation unit owner enters into hedging arrangement with retailer
  - Wolak (2013) "Economic and Political Constraints on the Demand-Side of Electricity Re-structuring Processes," on web-site.
- Capacity markets very likely to procure more capacity than would be needed to serve same demand with symmetric treatment of load and generation
  - This difference is even larger in world with more renewable energy

Optimal Capacity Choice Under Capacity Market versus Symmetric Treatment of Load and Generation





$K_{cap} >> K_{sym}$

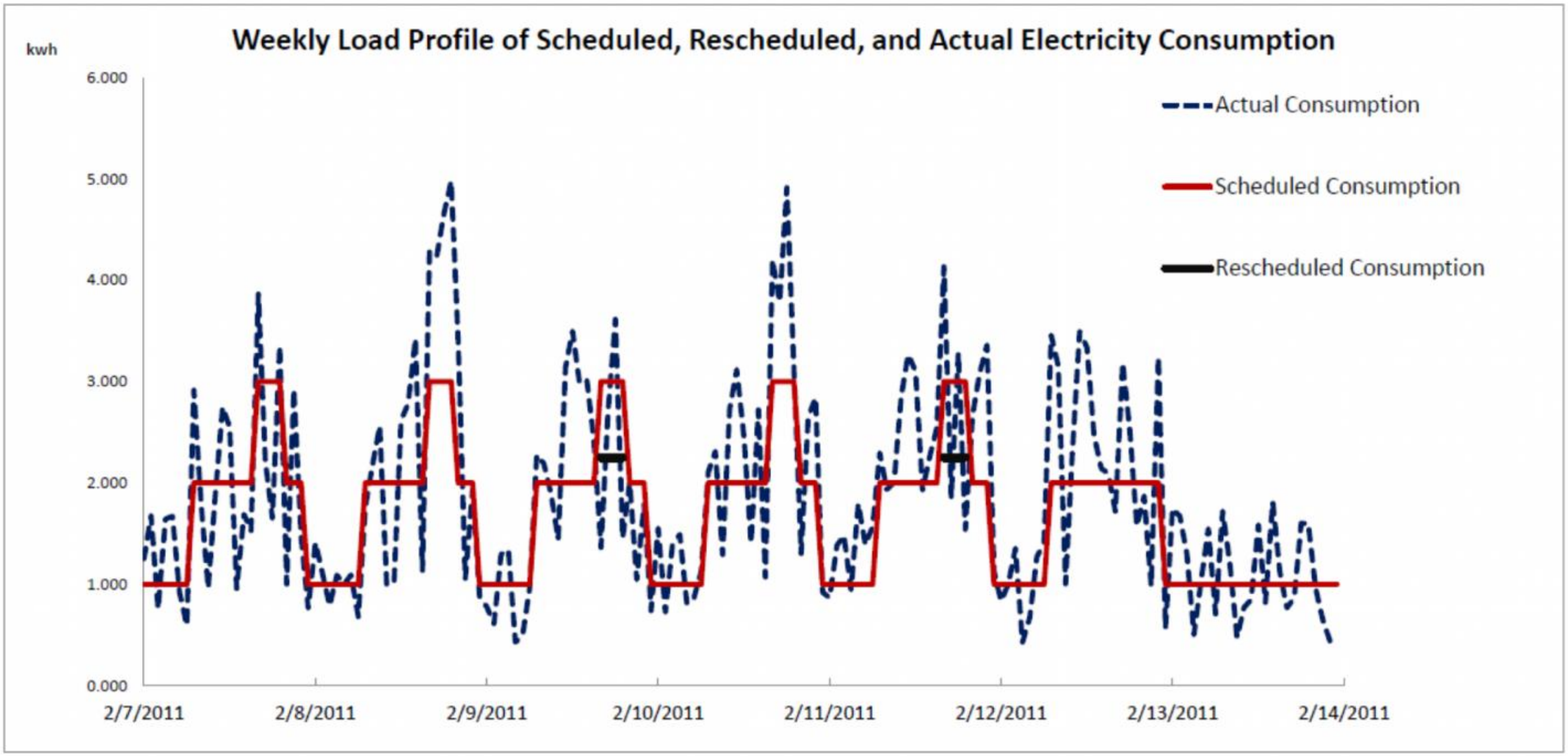
Average Retail Price$_{cap}$ >> Average Retail Price$_{sym}$

The Role of Symmetric Treatment of Load and Generation in Long-Term Resource Adequacy

Managing Short-term Price Risk

- Retail customer with interval meter purchases analogue to cellular telephone "calling plan" for electricity consumption
  - Fixed-price contract for fixed quantity of energy from electricity retailer
  - Examples
    - 7x24 for 1.5 KWh at 10 cent/KWh
    - 6x16 for 0.5 KWh at 12 cents/KWh
    - 5x4 for 0.5 KWh at 15 cents/KWh
  - This yields a load shape that approximates customers actual consumption for a fixed price of 10.47 cents per KWh
    - Customer only exposed to real-time price for deviations from this load shape, upward and downward

Load Profile: Purchased and Consumed



Weekly Consumption Monday to Sunday

Role of Symmetric Treatment

- Default real-time pricing for all consumers maximizes benefits of smart technologies
  - Makes day-ahead dynamic pricing, storage and automated load shifting technologies financially viable
  - No customer needs to pay real-time price for any consumption, only face it as a default price, just like in all other markets
- Consumers, or retailer on their behalf, purchases fixed load shape at a fixed prices
  - Consumers, or retailers on their behalf, buy and sell deviations from fixed load shapes in day-ahead and real-time markets to minimize bill risk
  - Similar to cell phone model
    - Purchase total monthly minutes at fixed price in advance
    - Real-time price per minute for consumption above total monthly minutes
    - Rollover of unused minutes similar to selling unconsumed contract quantity in day-ahead or real-time market
- Important note—Customer does not even need to know day-ahead or real-time price only have technology installed and follow instructions of retailer

Customers with Interval Meters

- Retailer “can buy out” of fixed price forward contract coverage requirement at own risk to the extent these kinds of dynamic pricing plans are in place
- For customers without interval meters, mandated hedging requirements ensure long-term resource adequacy
- Role of retail market regulator changes
  - Provide information to consumers on financial viability of retailers based on information they provide and pricing plans offered
    - Similar to credit rating for investments
  - Provide information on pricing plans available to retail customers with interval meters and suitability of plans to customers

Monitoring of Retailer Hedging Strategies

- Regulator must monitor hedging strategies of retailers to ensure they are not gambling with ratepayer's money
  – Sell fixed-price retail commitment that is not hedged with fixed-price wholesale market commitment
- Incentive for retailers to purchase from short-term market at low price and sell on retail market at low fixed-price
  – Significant bankruptcy risk for retailer associated with this strategy because short-term price may rise for sustained period of time
- A number of US retailers and retailers in other international markets have gone bankrupt pursuing this strategy with their retail customers experiencing significant economic harm because they must find an alternative retailer at a time when wholesale prices are usually very high

The Role of Transmission Expansions Policy in Long-Term Resource Adequacy

Transmission Pricing

- Market model must accurately capture reality of how transmission network and generation units operate
- Differences between market model and operating reality requires re-dispatch of generation units
  - Generation unit owners require compensation to increase and decrease output relative to what cleared in market mechanism used to set prices
- Payment for re-dispatch creates incentives for generation unit owners to take actions to cause it to occur
  - Unnecessarily increases cost of serving final demand
  - Incentive supplier to degrade, rather than improve system reliability

The “DEC Game” in California

- Under zonal market design in California, generation unit owners would sell output from certain generation units in day-ahead market that they knew would not be able to operate in real-time because of transmission constraints
- These units would have to be re-dispatched for less or even no energy output
  – Suppliers submitted decremental energy (DEC) bids to sell energy back to market operator and sold as-bid for this energy
- Suppliers could sell energy in day-ahead market at market clearing price and buy it back at zero or even a negative price (depending on their bid price)
  – This strategy became so profitable for some market participants that it was called the “DEC Game”
- Other zonal markets around to world use similar approaches to re-dispatch units, but typically regulated prices are paid and collected for re-dispatched energy
  – Colombia has positive and negative reconciliations payments

US Solution to “DEC Game”

- All US markets have adopted locational marginal pricing (LMP) which explicitly prices all transmission constraints and generation unit operating constraints
  - Limits difference between model used for pricing and actual configuration of transmission network
- LMPs are computed by minimizing the as-bid cost of meeting demand at all locations subject to configuration of transmission network and operating constraints on generation units
  - LMP at a location is increase in objective function value associated with a one unit increase in withdrawals at that location
- US started re-structuring process with extremely underbuilt transmission network
  - Little transmission investment in US since mid-1970s unit early 2000s
- European situation very different from US situation

European versus US Solution

- European solution addresses this challenge by building sufficient transmission to ensure that market model used to set prices agrees with physical characteristics of transmission network
- A successful zonal market design requires a transmission network within each zone that makes all generation units in the zone “equally effective” at serving load at all locations in the zone
- Because congestion across zones is explicitly priced, units located outside the zone need not be as effective at serving load within the zone as those located in the zone

European versus US Solution

- Little need for locational marginal pricing (LMP) if network owner commits to constructing sufficient capacity within the zone to make all units equally effective at meeting loads throughout the zone
  - If there is sufficient competition among suppliers within each zone then there is less need for local market power mitigation mechanism
- Downfall of the Texas, New England and California zonal models was lack of pre-commitment by transmission owner to building a network within each zone that makes all generation units in the zone equally effective at meeting load in that zone
  - No such commitment is necessary for LMP market

Zonal versus Nodal Market

- LMP can be used to operate virtually any transmission network if market has an effective local market power mitigation mechanism
  - Cost consequences of such an approach are unclear
  - Mitigation is likely to be far from perfect
    - Mitigated bid greater than minimum cost supply, otherwise this would imply the existence of a perfect regulator
- Zonal market requires commitment to make electricity a homogenous product within zone
  - Effective competition within zone is possible because of capacity of transmission network within zone
  - Less need for market power mitigation—Bids closers to minimum cost because there is competition within zone
  - Potential for market prices closer to competitive levels
- Alberta market design and transmission planning process is consistent with this logic
  - Measuring the Competitiveness Benefits of a Transmission Investment Policy: The Case of the Alberta Electricity Market (March 2012) on web-site

Transmission as a Facilitator of Competition

- Transmission upgrades increase number of independent suppliers that can compete to supply electricity at given location in network
  - Reduces extent to which all of these suppliers bid in excess of minimum cost marginal cost of supplying electricity
  - Suppliers have little incentive to undertake upgrades
    - Strong incentive to oppose upgrades to preserve local market power
- Engineering Reliability was criterion for determining upgrades in vertically integrated regime
  - Enough transmission capacity so that
    - Demand at all locations in network can be met with pre-specified probability
    - Assuming that virtually all generation units in network are owned and operated by same entity

Transmission as a Facilitator of Competition

- Economic Reliability should be criteria in wholesale market regime because configuration of transmission network impacts extent of market power suppliers can exercise
- Sufficient transmission capacity so that all locations in the network face significant competition from enough independent suppliers to cause them to bid close to their marginal cost curve the vast majority of hours of the year
  - All suppliers face sufficiently elastic residual demand curves a large fraction of hours of the year
- Transmission network facilitates commerce in same way that interstate highway system facilitates commerce US economy
  - US Highway system built at a cost of 330 billion 1996 dollars
  - Net economic benefits from system vastly in excess of this magnitude

Assessing Need for Transmission Upgrades

- Time lag to build transmission facilities typically longer than lag to build generation facilities
  – This provide further justification for economic reliability approach
- Building transmission in response to generation entry will be a continual process of catching up with consumers always bearing the cost of catching up
- Build transmission network in advance anticipating that supplier
  – Will enter where it is profit-maximizing to do so
  – They will bid to maximize profits once they enter
- Current cost of transmission network is small fraction of delivered price of electricity
  – Roughly 1.5 cent/KWh delivered is average cost of transmission network for California ISO control area
  – Average retail price of electricity close to 13 cents/KWh

Assessing Need for Transmission Upgrades

- Upgrades undertaken since 1998 have come closer to yielding economically reliable transmission network for California
  - More competitive wholesale market should and has led to lower average wholesale energy prices
  - Difficult to measure competitiveness effect (more on this later)
- Conclusion—Substantially larger role (than in previous regime) for regulatory oversight in planning and construction of transmission network to maximize benefits of wholesale competition, relative to vertically integrated regime
  - Extremely difficult challenge associated with realizing full benefits of wholesale competition
  - Because of initial capacity in transmission network in most in markets outside of US this issue has not yet arisen
  - Alberta's transmission expansion policy recognizes these competitiveness benefits

New Role of Regulator

Regulator Must Set Market Rules

- Because of crucial role that market rules play in limiting ability of suppliers to exercise unilateral market power, regulator must set market rules
  - Regulator cannot let market operator or stakeholder set rules
- Stakeholders can provide input to market design process, but they have strong incentive to argue public benefits for a rule in order to obtain private benefits
  - Difficult for regulator to tell the difference
  - Role for independent market monitoring function (discussed below)
- Rules best set in an open, consultative process
  - United States process of market operator develop a tariff (market rules) approved by the regulator appears to work acceptably well
  - Regulator can be prescriptive about market rules in this framework but leaves major work to market operator and stakeholder-driven process

Small Flaws Can Lead to Large Problems

- Regulator must be pro-active
  - California experience--Lack of significant forward contracting between retailers and suppliers not a problem with plenty of water in Pacific Northwest
- Less water faces all fossil-fuel suppliers with less elastic residual demand curves
  - Increases extent of unilateral market power exercised
    - Wolak (2003) "Measuring Unilateral Market Power in Wholesale Electricity Markets: The California Market 1998 to 2000, *American Economic Review*
      - Huge increase in unilateral market power possessed by five merchant suppliers in summer 2000 relative to summers of 1999 and 1998
  - Enormous wealth transfers in very short period of time possible
    - Borenstein, Bushnell, and Wolak (2002) "Measuring Market Inefficiencies in California's Restructured Wholesale Electricity Market" American Economic Review
      - $5 billion market inefficiencies in 6 months
  - Very difficult to undo these transfers once they occur
    - Prevent wealth transfers before they occur
    - No need for coordinated actions for large wealth transfers to occur

Some Market Participants May to Slow to Learn

- During initial stages of market, firms may make mistakes
  - Decision not to sign forward contracts by three large California retailers
    - May have been ex ante profit-maximizing, but was extremely risky
- Regulation of forward contracting levels
  - Set vesting contract parameters at start of market
- Oversight of prudency of hedging of retail price risk by all retailers
  - Determine mechanism for setting provider of last resort (POLR) price that customers can always switch to
- Regulator can educate small market participants about how to participate in new market regime
- Provide information on market performance to all market participants

More Sophisticated Regulator

- Counter-intuitive result that more sophisticated regulation of transmission planning and expansions process needed for wholesale market regime versus vertically-integrated regime
- Cost of re-structuring is that cannot capture potential economies to scope between transmission and distribution and generation and retailing
  - Transmission planning process is replacement
- In former vertically-integrated regime, same firm provided all four services
- In wholesale market regime, generation and retailing segments can privately benefit from configuration of transmission and distribution network and will take actions to obtain profit-maximizing (for them) configuration

Concluding Comments

Concluding Comments

- Reliability externality is justification for regulatory intervention in long-term resource adequacy process
  - Intervene with minimal harm to incentive to provide lowest annual costs to retail electricity consumers consistent with long-term financial viability of industry
- Forward contracts approach has come closest to achieving these market design goals in a number of international markets
  - Buy necessary energy far enough in advance of delivery to allow maximum flexibility of suppliers to meet these obligations at least cost and limit market power in spot market
- Contract adequacy approach can allow significant demand-side involvement as part of retailer's hedging strategy
  - With symmetric treatment of load and generation, individual loads can choose level of exposure to short-term price risk
  - Forward contracting is then tailored to hedge remaining fixed price retail obligations

Concluding Comments

- Capacity payments are a expensive mechanism for attempting to achieve capacity adequacy
  - Do not address primary reliability challenge in wholesale markets
    - Energy shortfalls
  - No guarantee that adequate capacity will be built
    - Depends on level of capacity payment
  - Little success with capacity payments in international markets outside of Latin America with cost-based markets
  - Market-based pricing of capacity extremely challenging, particularly locationally
  - No evidence that markets with capacity payments in the US have achieved higher levels of short-term or long-term reliability

Concluding Comments

- Current approach to capacity payment scheme “solves” one part of problem by focusing on need to buy in advance of delivery
  - Instead of buying what consumers don’t want—”installed capacity”-- far enough in advance to allow new entrants to compete
  - Focus on buying what consumers do want--“reliable energy”--far enough in advance to allow new entrants to compete
- Symmetric treatment for customers with interval meters can further reduce annual average costs to consumers
- Competition-enhancing transmission expansions for wholesale market also reduce annual average costs
  - Transmission network must be suited to actual market design
- Regulator must adapt as quickly as possible to new role

Questions/Comments

For more information

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