Maintaining Baseload Generation Capacity

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Challenge of Baseload Energy

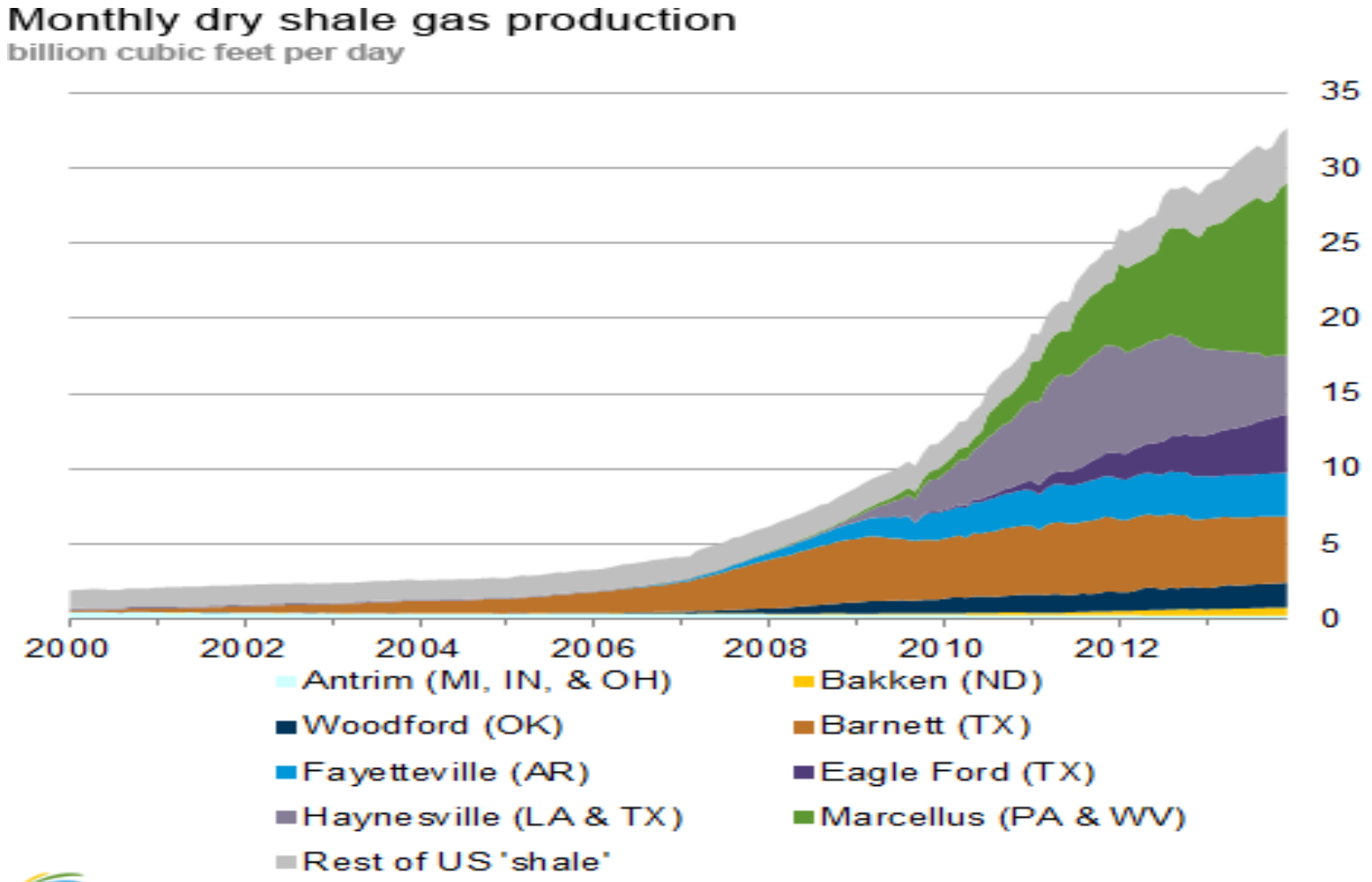
- Coal-fired and nuclear capacity is exiting or proposing to exit in all US markets
  - PJM, ISO-NE, NYISO, MISO, ERCOT, CAISO
- This pattern of exit does not appear to be occurring in other parts of the world
- Two major factors explain US experience
  - Low natural gas prices and environmental regulations favor natural gas over coal use
    - Shale gas boom in the US
  - Renewable energy goals supported state and federal government financial incentives
    - Renewables Portfolio Standard (RPS) goals

Challenge of Baseload Energy

- Different challenge for vertically-integrated utilities in non-restructured regions
- Regulator determines whether coal and nuclear capacity are needed for a reliable supply of energy at least cost to consumers
  - If so, regulator can allow recovery of total cost of generation units in regulated retail prices
- Problem not significantly different from traditional generation adequacy question in vertically-integrated regime
  - More complex with significant renewables

Explanation #1: Technical Change Renders Existing Suppliers Obsolete in Wholesale Market Regime

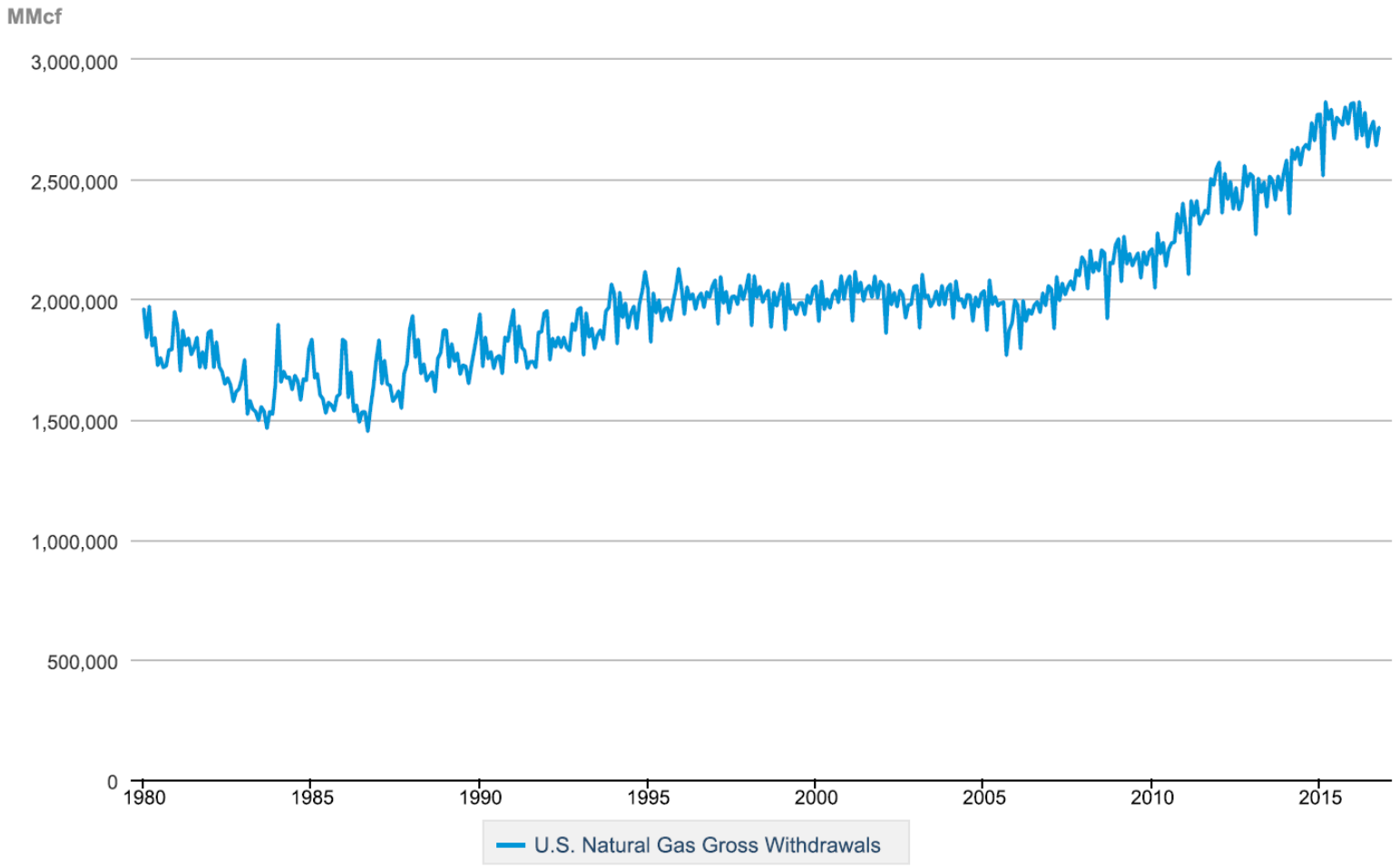
US Monthly Shale Gas Production



Source: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through February 2014 and represent EIA's official shale gas estimates, but are not survey data. State abbreviations indicate primary state(s).

Monthly U.S. Natural Gas Withdrawals

(Millions of Cubic Feet (MMcf))

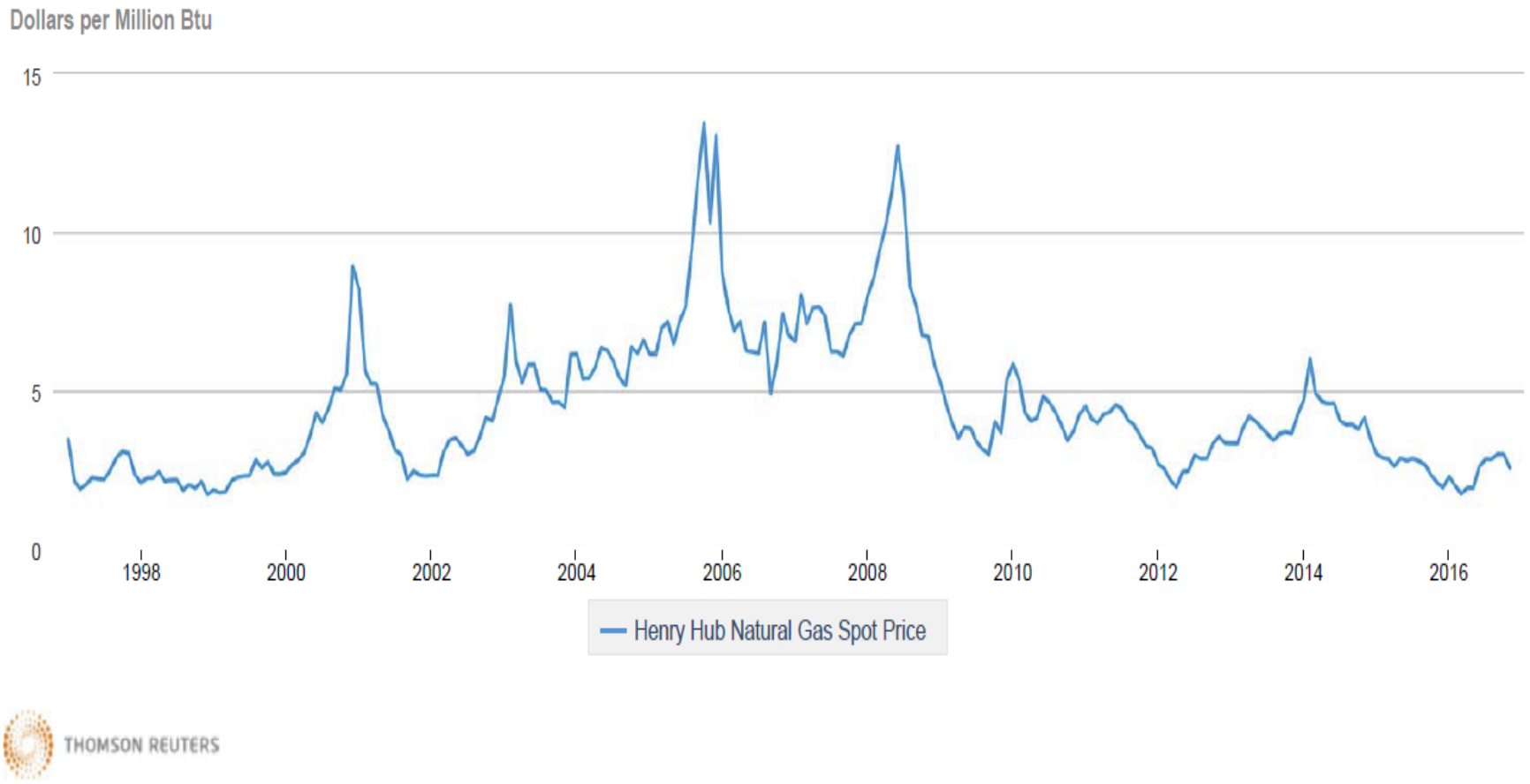


eia Source: U.S. Energy Information Administration

Source: http://www.eia.gov/dnav/ng/hist/n9010us2m.htm

Price of Natural Gas at Henry Hub

(Monthly Average Prices in $/MMBTU)



Source:http://www.eia.gov/dnav/ng/hist/rngwhhdM.htm

Major North American Shale Gas Plays

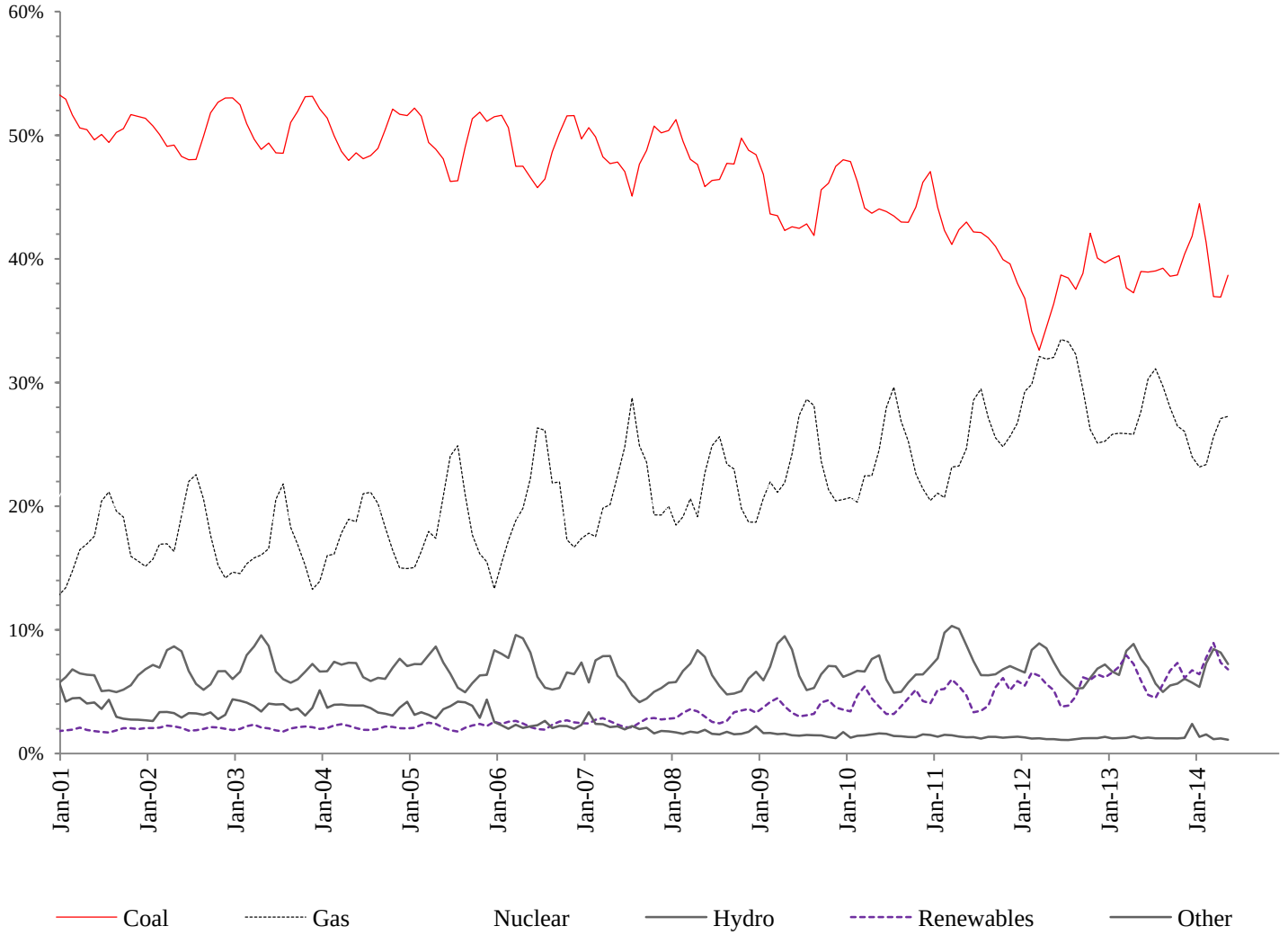
Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Updated: May 9, 2011

Shale Gas as Disruptive Innovation

- Shale gas has significantly reduced variable cost of producing baseload energy
  - Combined cycle gas turbine (CCGT)
- More stringent environmental regulations have increased cost of continuing to operate coal and nuclear generation units
- Conclusion--Retirement of coal and nuclear capacity based on unique economics and environmental regulations in the US
  - Markets with low barriers to entry and exit quickly find least cost mode of production

Increasing Role of Gas in US Power Sector

Share of Total US Generation by Input Fuel



In April 2012, Coal provided 34% and Natural Gas 32% of Total US Generation

What Explains Increasing US Gas Use?

- Economics favors natural gas-fired generation versus coal-fired generation
  - Average heat rate of typical coal-fired unit significantly larger than that for combined-cycle gas turbine (CCGT) unit
    - Heat Rate = MMBTU of input fuel per MWh of electricity produced
      - » MMBTU = millions of British Thermal Units
      - » MWh = Megawatt-hour
  - Average Heat Rate of Coal unit could be twice that of CCGT generation unit
    - Even if price of coal is less than price of natural gas, economics could favor running CCGT unit because of lower heat rate
      - » 12 MMBTU/MWh x $2/MMBTU coal = $24/MWh from coal
      - » 7 MMBTU/MWh x $3/MMBTU gas = $21/MWh from gas
      - » Variable O&M cost for coal > Variable O&M cost for gas
  - $/MW of capacity cost for coal-fired power unit greater than $/MW of capacity cost for natural gas-fired unit

Increased US Gas Use in Power Sector

- Environmental Protection Agency (EPA) rules
  - Mercury and Air Toxics Standards (MATS) for coal-fired power plants
  - Cross-State Air Pollution Rule (CSAPR)
    - Reduce SO_2, NO_x, and Particulate emissions
  - At many existing power plants substantial new capital investments are necessary to meet these standards
- Economics (low-priced natural gas) appears to dominate coal and nuclear capacity retirement decisions
  - Most of these units are very old, 40 to 60 years old
  - Most coal units have high heat rates
- Replacing these units with modern natural gas-fired units makes economic sense and has environmental benefits
  - Hedge against future carbon policy

Explanation #2: Impact of Renewables Mandates on Baseload Generation

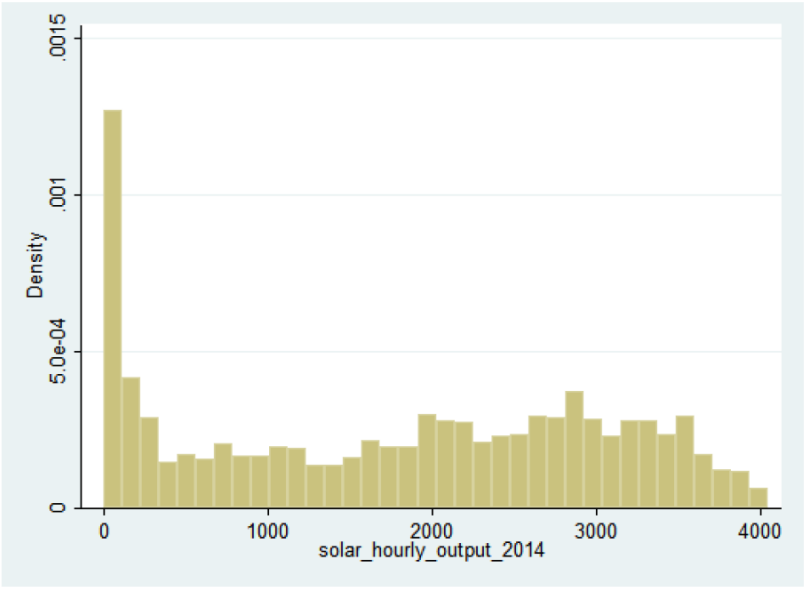
Renewable Portfolio Standards

- Majority of states have a renewables portfolio standards (RPS) that require either
  - Absolute levels of renewable generation capacity in state
  - A pre-specified share of the total energy consumed in the state must come from “qualified” renewable sources
- Under an RPS, above-market payments to renewable resource owners must be sufficient to obtain the mandated annual renewable energy share
- Renewable energy has two unique features
  - Variable cost of production is zero or close to zero
  - Intermittent--Energy can be produced only when underlying resource, primarily wind and solar, is available

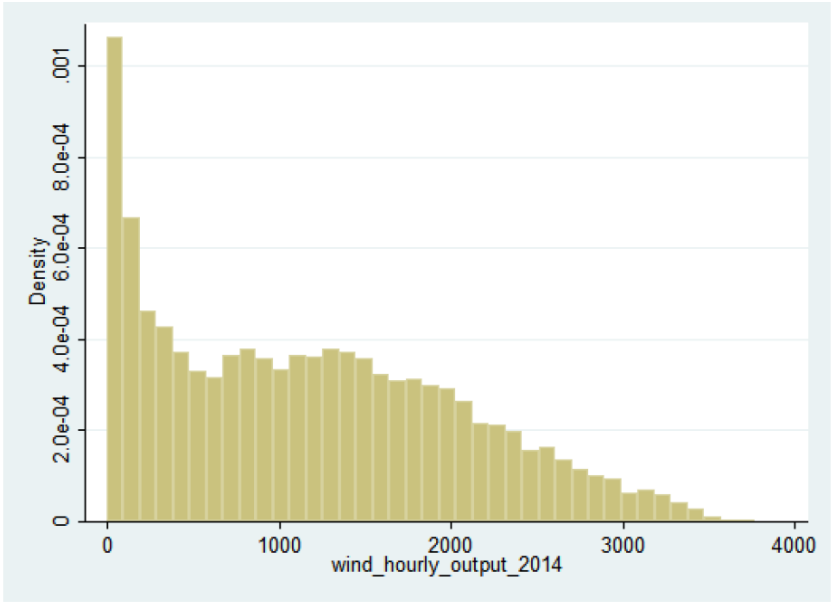
Renewable Portfolio Standards

- Renewable energy purchased at above-market prices displaces energy from conventional “dispatchable” baseload generation units
  - Less sales by conventional baseload units
  - Lower short-term prices
- Both factors reduce revenues earned by conventional baseload generation units
  - Increases likelihood of exit of conventional baseload units
- Outcome due to excess generation capacity relative to that needed to meet demand, not the existence of RPS
- Intermittency of the renewable generation units implies continued need for conventional “dispatchable generation” units

Histogram of Hourly Wind and Hourly Solar Output in CAISO

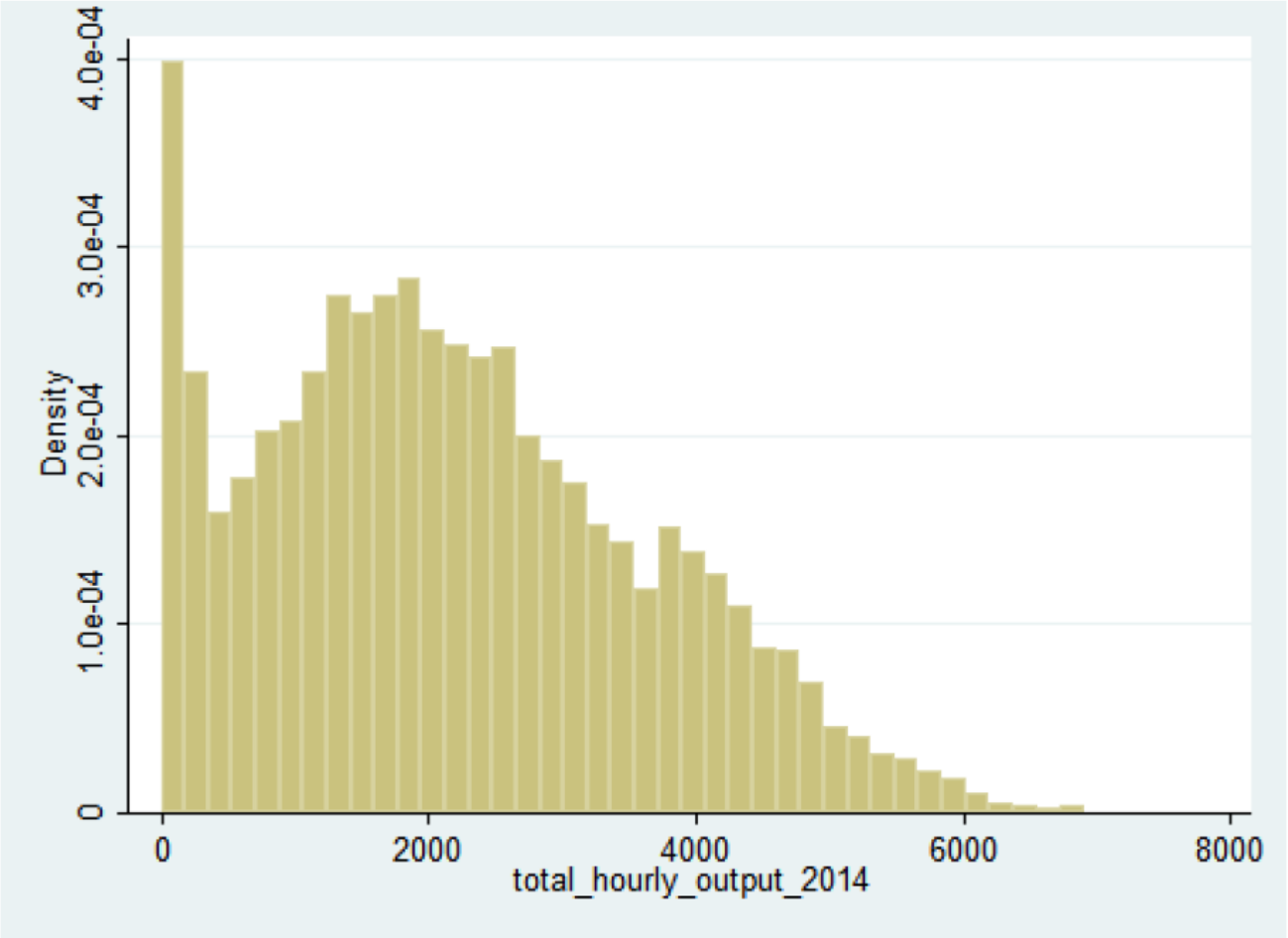


$P(\text{solar\_hourly\_output} = 0) = 0.4361$



$P(\text{wind\_hourly\_output} = 0) = 0.0345$

Histogram of Hourly Wind and Solar Output in CAISO



$$P(\text{total\_hourly\_output} = 0) = 0.0280$$

Demand for Dispatchable Energy

- Despite having more than 8,000 MW of wind and solar capacity in California, in majority of hours of year these units produce less than 2,000 MWh
  - Wolak (2016) “Level and Variability Trade-offs in Wind and Solar Investments: The Case of California,” demonstrates very high degree of positive correlation in hourly output across CA wind locations and CA solar locations
- Without significant storage, virtually all dispatchable capacity is still needed because ~3 percent of hours of year no renewable energy is produced

Obtaining Financial Viability for Baseload Generation

Value versus Price

- "[An economist is] a man who knows the price of everything, and the value of nothing"
  - With apologies to Oscar Wilde
- "Value" is a personal assessment
  - Purchase good if value greater than price
- Key issue is long-term financial viability of sufficient dispatchable generation capacity for a reliable supply of energy
- Financial viability requires
  - Price paid for energy must be sufficient to recover total cost of constructing and operating unit over useful life of unit

Shale Gas as Innovation

- If shale gas boom continues coal and nuclear generation cannot compete with CCGT units on a levelized cost basis
- Primary rationale for continued operation of coal and nuclear generation is hedge against high natural gas prices in future
- Financial sector believes shale gas boom will continue
  - Flat forward price curve for Henry Hub deliveries of natural gas out to 2020

RPS Mandates and Excess Capacity

- Despite RPS mandates, all markets still require a significant amount of dispatchable generation capacity
  - Until significant storage capacity is constructed
- Sufficient dispatchable capacity to produce energy when renewable resources are unavailable
  - Water, wind, and solar energy
- Policy Challenge—How to ensure that sufficient dispatchable generation capacity is financially viable for a reliable of energy all hours of the year

Are All Attributes of Generation Units Priced in RTO Markets?

Locational Marginal Pricing (LMP)

- All restructured US regions operate multi-settlement LMP markets
  - All relevant operating constraints are accounted for in locational marginal prices
    - Transmission, ramping, and other operating constraints
- Price characteristics of generation units needed for system operation in ancillary services
  - Regulation (AGC), Spinning and Non-Spinning Reserve
  - Mileage charges for regulation
  - Pay-for-performance prices responsiveness of unit ISO operates grid
- LMP market ideally suits to price all characteristics of generation units required by system operator
  - Add another constraint to LMP pricing problem

A Mechanism for Maintaining Sufficient Dispatchable Energy

Forward Market for Energy

- Electricity industry restructuring eliminates entity traditionally responsible for long-term resource adequacy
  - ISO operates grid
  - Generation unit owners sell wholesale energy
  - Retailers purchase wholesale energy
- State regulator is still responsible for long-term resource adequacy but it has limited tools to achieve this goal
  - Can no longer require vertically-integrated utility to construct new generation capacity and set price that allows it the opportunity to recover these costs

Forward Market for Energy

- Retirement of coal and nuclear capacity can be addressed by long-horizon forward market for energy
- Even at current natural gas prices, purchasing a fixed-price forward contract for energy from coal or nuclear capacity may be justified as a hedge against future natural gas price volatility
  - Longer duration contract allows coal and nuclear to compete against natural gas
- Forward market energy purchases can ensure sufficient dispatchable energy for markets with substantial renewable energy goals

Alternative Approach to Reliability

- Eliminate capacity payment mechanisms
  - Capacity shortfalls are not the problem, energy shortfalls are
- Implement approach based on standardized forward contracts for energy
  - Product can be traded through ISO
- Extend logic of multi-settlement market to long-horizon forward market
  - Product can clear against quantity-weighted average of locational marginal prices at all load withdrawal points in region

Alternative Approach to Reliability

- Mandate that all retailers and free consumers must purchase pre-specified fractions of realized demand at various horizons to delivery in standardized forward contract
  - 95 percent one year in advance
  - 90 percent two years in advance
  - 85 percent three years in advance
- Retailers and free consumers subject to financial penalties for under-procurement
  - No prohibition on additional bilateral trading of energy by retailers or suppliers
- Goal of mechanism is to encourage development long-horizon forward market for energy

Alternative Approach to Reliability

- Contracts used for compliance with obligation by retailer or free consumer must be held until expiration
  - Contracts used for compliance with mandate are placed in separate "compliance" account and cannot be unwound by either counterparty
  - These contracts must be held until expiration
- If regulator believes that insufficient generation capacity is being built, it can increase annual contracting percentages and length of contracting horizon
  - 98 percent one year in advance
  - 93 percent two years in advance
  - 90 percent three years in advance
  - 87 percent four years in advance
- Suppliers decide how much and what mix of generation capacity is necessary to produce contracted levels of demand
  - Provides strong incentive for market to supply this energy at least cost

Alternative Approach to Reliability

- Use firm capacity designation of generation unit from capacity market to determine amount energy a supplier can sell in forward market
  - Renewable resource owner can sell Q(Contract) ≤ Q(Firm)
  - Thermal resource owner must sell Q(Contact) ≥ Q(Firm) and Q(Contract) ≤ Capacity of Unit
- Restrictions on standardized energy contract sales by technology ensures a reliable supply of energy at a reasonable price
  - Competition among all technologies ensures reasonable prices during other system condition
  - Creates a strong incentive to manage low renewable energy production conditions
- Does not require high degree of sophistication from suppliers

Alternative Approach to Reliability

- Incentive for Supplier Behavior with Standardized Forward Contracts
- Supplier k's variable profit during hour h:
- Profit(P(h)) = (Q(h) - QC(h)) P(h)
  + PC(h)QC(h) - C(Q(h)) ,
  - Q(h) = output in hour h
  - QC(h) = forward contract obligations in hour h
  - P(h) = short-term price in hour h
  - PC(h) = forward contract price in hour h
  - C(Q) = variable cost of producing output Q
- Supplier has strong incentive to supply QC(h) at least cost

Alternative Approach to Reliability

- Suppose that supplier k is a dispatchable baseload unit and there is plenty of renewable energy during hour, so it does not sell any energy (Q(h) = 0)
- Supplier k's variable profit during hour h is:
- Profit(P(h)) = (PC(h) – P(h))QC(h)
- Supplier earns profit by selling at PC(h) and buying from market at P(h)
- To discipline incentive of renewable suppliers to exercise unilateral market power, dispatchable supplier should submit offer into short-term market at its marginal cost
  - This ensures efficient ``make versus buy'' decision by dispatchable unit to supply QC(h)

Alternative Approach to Reliability

- Load-Profile-Shaped Standardized Forward Contract
- Goal of alternative approach is to make QC(h) for supplier k as close as possible to output of supplier k in hour h under least cost dispatch of system
- Allocate more of total quarterly energy sold to higher demand hours of the day
- This provides incentive for dispatchable suppliers to submit offers for peak hours of day
  - The fact that thermal suppliers are compensated for start-up costs increases likelihood that this will occur

Advantages of Alternative Approach

- Stimulates development of liquid forward market for energy at long horizons to delivery
  - Can provide revenue stream to sustain needed dispatchable baseload energy
- Uses Firm Energy value for generation unit from Capacity Mechanism to set energy sales
  - Provides strong economic signals for efficient short-term operation of grid
  - If renewables are unavailable or attempt to raise short-term price, dispatchable generation will supply energy sold in forward contract rather than purchasing it from the short-term market at P(h)

Advantages of Alternative Approach

- Minimal regulatory intervention into market mechanisms
  - Does not specify value of capacity obligation
  - Allows suppliers to figure out least cost mix of generation capacity to meet forward energy sales
  - Eliminates need for regulated price-setting process that characterizes most US capacity markets
    - For example, “dee-mand” curve for capacity and rule that only new suppliers can submit offers
- No stranded contracts unless total system demand falls substantially
  - Retailers that lose customers have valuable contract to sell to retailers that gain customers

Conclusions

- Shale gas boom and RPS mandates both likely causes of coal and nuclear retirements
- In restructured markets, regulator no longer able to mandate long-term resource adequacy
- Mandated purchases of forward contracts for energy at various horizons to delivery can achieve this goal at least cost to consumers
  - Maximum reliance on market mechanisms to retain financial viability of sufficient dispatchable baseload capacity
  - Strong incentive for least cost provision of a reliable supply of energy all hours of the year

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