Energy Sector Modeling and Fuel Price Assumptions

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Takeaways

- Dozens of economic/energy/electric sector models are in use publicly and privately – many shapes, sizes, colors
- Models provide the statistics and the logic; users provide the assumptions – and do so freely
- Rationality lies in the mind of the forecaster
- Prices move faster than regulators, so people hedge
  - (If it's not too expensive)
  - (If the PUC is comfortable with it)
  - (If credit is sufficient)
  - (If it doesn't violate production leases)
  - (If the counterparties are there)

Energy sector modeling

- Models take economic and energy market data as inputs, and produce forecasts of future market conditions
  - Wholesale power prices
  - Capacity additions
  - Retrofits
  - Emission levels and prices

- Virtually every market player uses some form of model – from the crude to the sophisticated – to develop assumptions about future energy market conditions and perform “what-if” analyses
  - Utilities, RTOs, academics, policymakers, investment banks, consultants, industrials, etc.
- In addition to commercial firms, some academic institutions, think tanks, and consortia develop and maintain models for use in policy analysis

- Commonly referenced models include
  - National Energy Modeling System (NEMS) – open source model published by EIA and used as the basis for numerous others
  - Integrated Planning Model (IPM) – maintained by ICF and used in EPA rule-making process

Approaches to modeling

- **Engineering-economic:** meet system demand at minimal costs, with some dynamic adjustment of demand based on prices
- **Computational general equilibrium:** top-down macroeconomic assumptions drive production decisions and prices, with an iterative approach to preserving market equilibria
- **Macroeconomic:** top-down macroeconomic assumptions drive quantity decisions, such that markets aren't always in equilibrium
- **Input-output:** sector-specific analysis of production and consumption, with more detail than other macro models
- **Hybrid:** combines data from different models, either automatically and iteratively, or manually

Where do fuel price inputs come from?

- Models come "pre-stocked" with data from numerous sources
  - EIA's Annual Energy Outlook
  - Platts
  - FERC
  - NREL
  - ORNL
  - NETL
  - EPRI
  - EPA
  - NERC
  - etc…

- Model outputs are highly sensitive to, among other things…
  - Fuel price assumptions
  - Electricity price assumptions
  - Operating cost assumptions

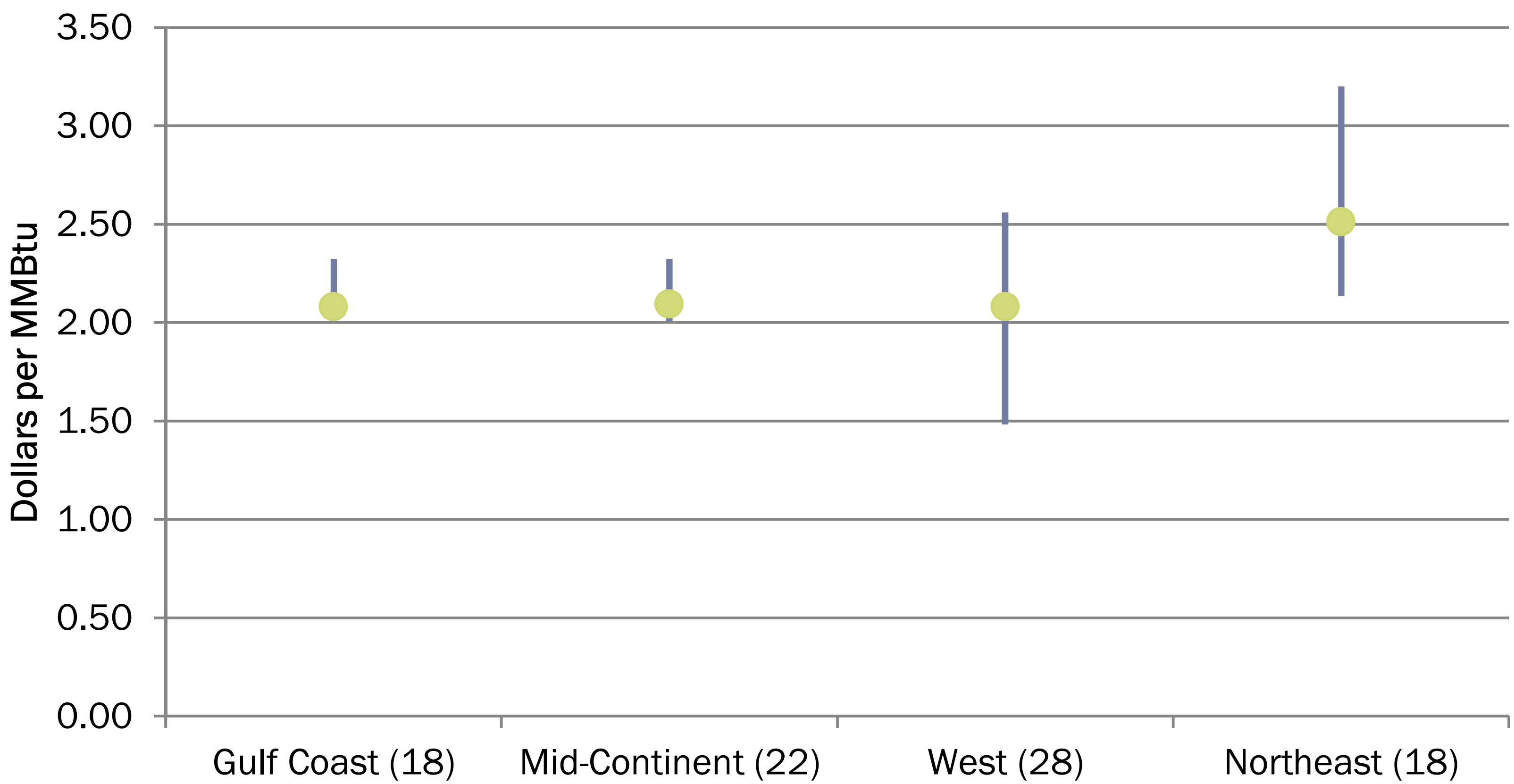
- Most models are designed to be flexible and able to incorporate user data

Sample of regulatory filings shows numerous data sources and forecasting techniques

Utility	Data Source	Starting $ coal/gas	Reference
AEP	Natural gas prices to double from 2010-2030; coal prices to rise by 1.5x. Based on **AEP proprietary analysis**, updated semi-annually	Not specified	2009 SPP & 2010 East IRPs
Connecticut DEEP	Natural gas prices based on **NYMEX Henry Hub futures** through 2021, plus a basis differential based on historical prices and NYMEX basis swaps, and an LDC charge. Oil prices based on **current forward prices.** Coal prices based on **NYMEX Central Appalachian futures** plus transportation costs	$4 / $4.10	2012 IRP Draft
Dominion	**Forward curves** for first 18 months, blended **ICF** commodity forecasts and forward prices for next 18 months, then ICF commodity price forecasts exclusively	$3.05 / $6.44	2011 IRP
Duke Energy Carolinas	Duke Energy uses **its own** fundamental price forecasts, which are updated annually	Not specified	2011 IRP
Georgia Power (Southern)	CRA	Not specified	2010 IRP
Montana-Dakota	For the base case, natural gas was priced for delivery at $5.05/mmbtu, as of August 31, 2011, for the base year 2010 and **escalated by an average of 3.5 percent.** Coal modeled at $1.50/mmbtu	$1.50 / $5.05	2011 IRP
OG&E	30-year monthly fuel forecast based on **NYMEX, EIA, PIRA, CERA, forward basis curves**	Not specified	2011 IRP
Pacificorp	**Third-party proprietary data and IPM** for fuel; MIDAS for power	None / $4.41	2011 IRP
PGE	For natural gas, combination of **forward prices and modeling** by PIRA; for coal, combination of EIA coal price forecasts and modeling by PIRA	$3.15 / $5.71	2011 IRP Update
PNM	PNM base case coal price forecasts are based on **current prices with an escalation of 2.5% per year.** Natural gas prices are based on NYMEX futures, escalated at 2.5% per year after five years to obtain a twenty-year price forecast.	$1.90 / $4.08	2011-2030 IRP
TVA	**Proprietary fuel** price assumptions; MIDAS used to generate power price forecast	Not specified	2011 IRP

Source: MJB&A analysis

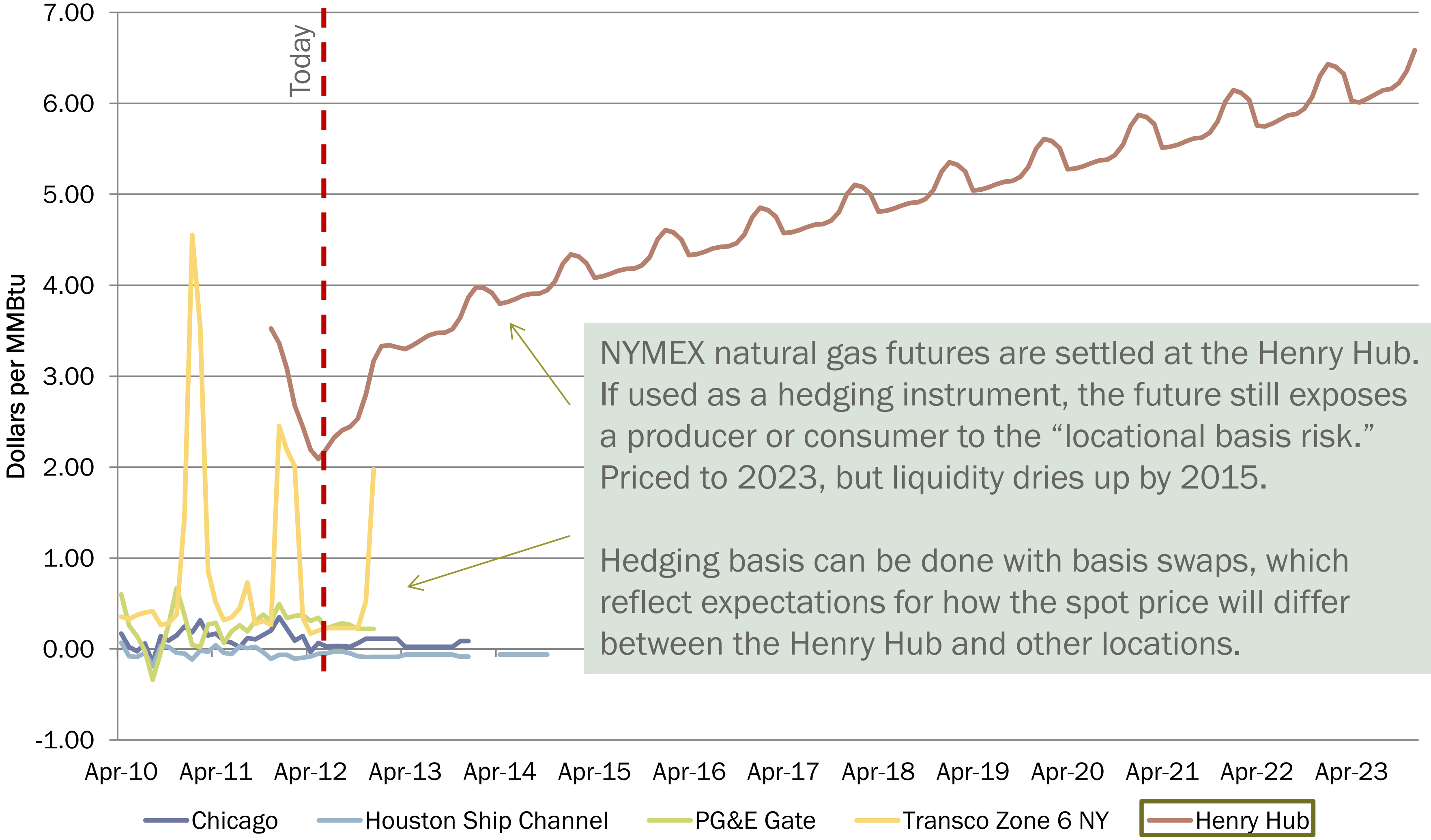
Natural gas spot prices are merely a snapshot



- Locational basis differentials lead to a range of prices in each region
- Number in parentheses indicates number of trading points sampled
- Green dot represents regional average

Source: SNL; MJB&A

NYMEX natural gas futures curve and basis swaps are used for longer term forecasting

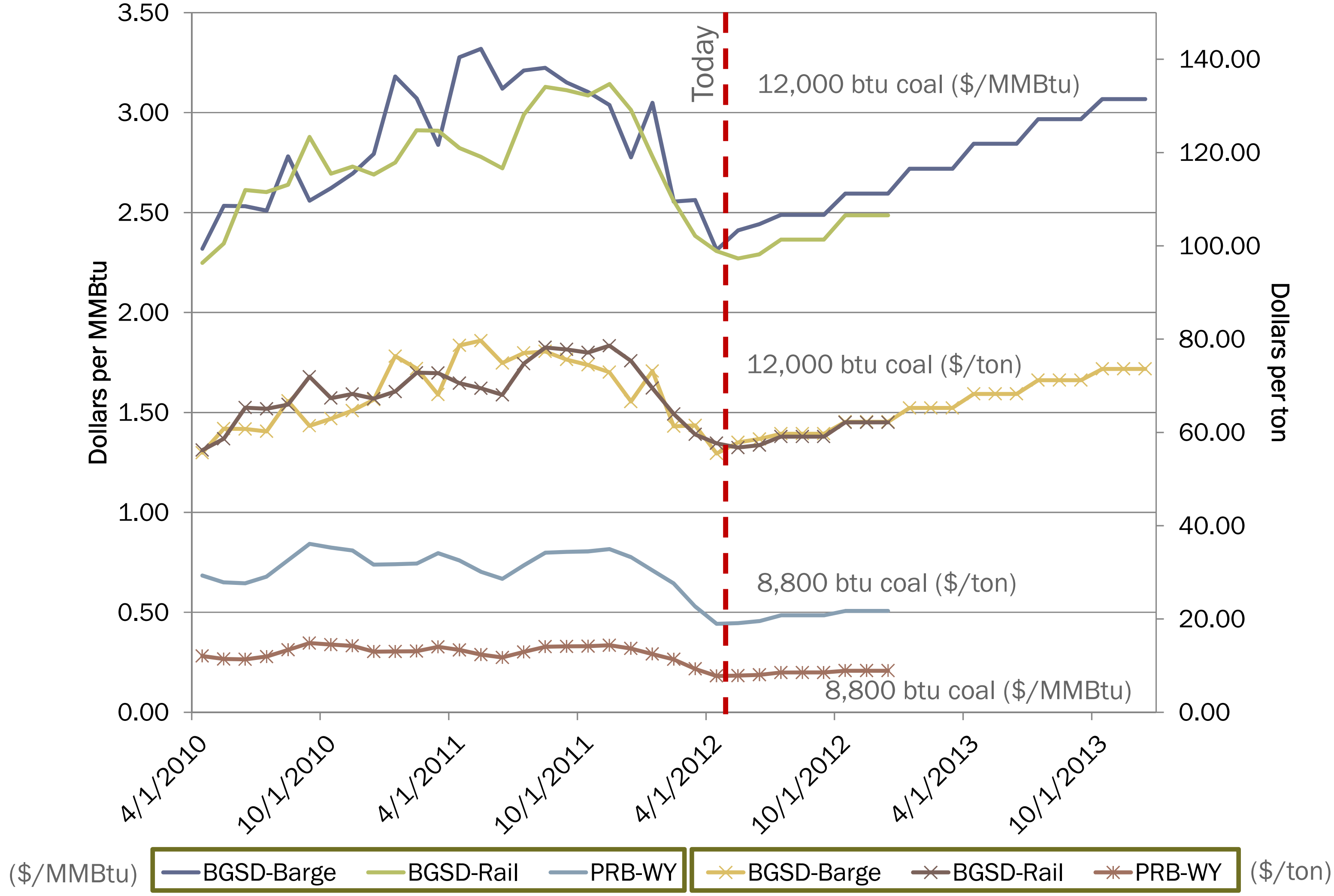


NYMEX natural gas futures are settled at the Henry Hub. If used as a hedging instrument, the future still exposes a producer or consumer to the "locational basis risk." Priced to 2023, but liquidity dries up by 2015.

Hedging basis can be done with basis swaps, which reflect expectations for how the spot price will differ between the Henry Hub and other locations.

Source: SNL; MJB&A

Coal futures prices also used in forecasting



Source: SNL; MJB&A

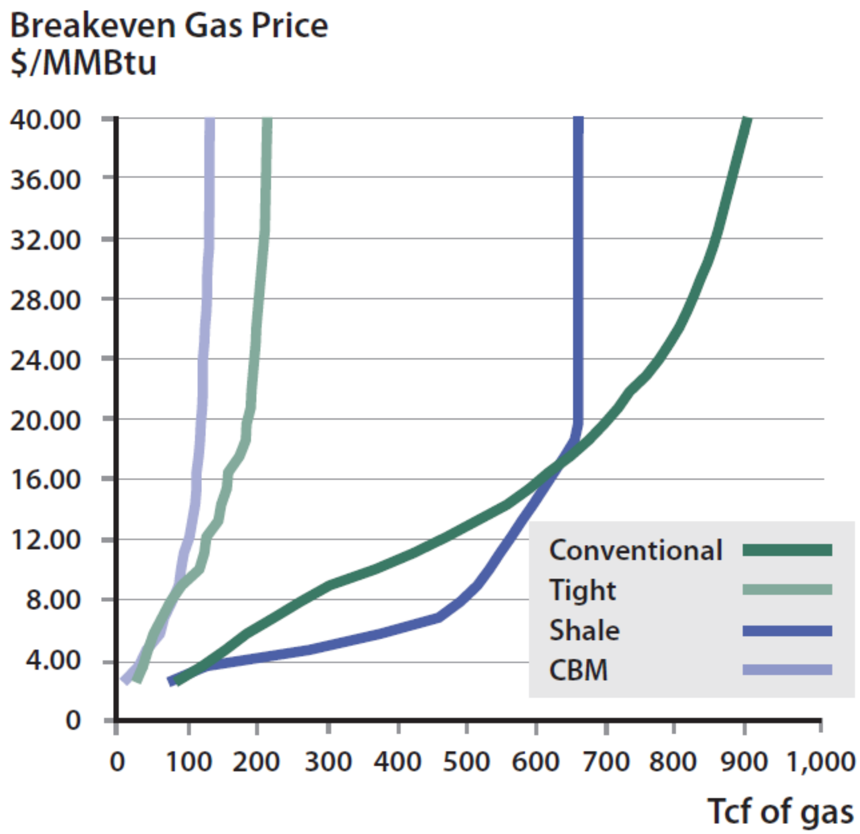
Natural gas market fundamentals have changed too quickly for the planning process

- Natural gas futures last week fell below $2 for the first time in a decade
- Demand is high, but inventories and production are higher
- Rig count falling in dry gas areas like Barnett and Haynesville, but this is not impacting production nor is it expected to
    - Continued demand for liquids expected to keep associated dry gas production high, from 3.9 Bcfd in 2011 to 17.7 Bcfd in 2030 from liquids-rich plays
    - Flaring of wet gas (100MMcfd in Bakken) may end if processing systems are built
- Revenues for producers have been supported by hedges, but we are now leaving the early shale window and hedges are coming off – what next?
    - e.g. CHK rolled off all hedges after 2011, completely unhedged for 2012
- Lease agreements (shut-in clauses) and debt covenants (must produce) may distort the equilibrium
- Industrial and electric sector demand for natural gas remains high
- As gas displaces coal, EIA projects delivered coal prices to fall into 2013 (this is not captured in futures curves)

Source: ARI; EIA

Shale gas lowers the cost curve (but all the way to $2/mmbtu?)

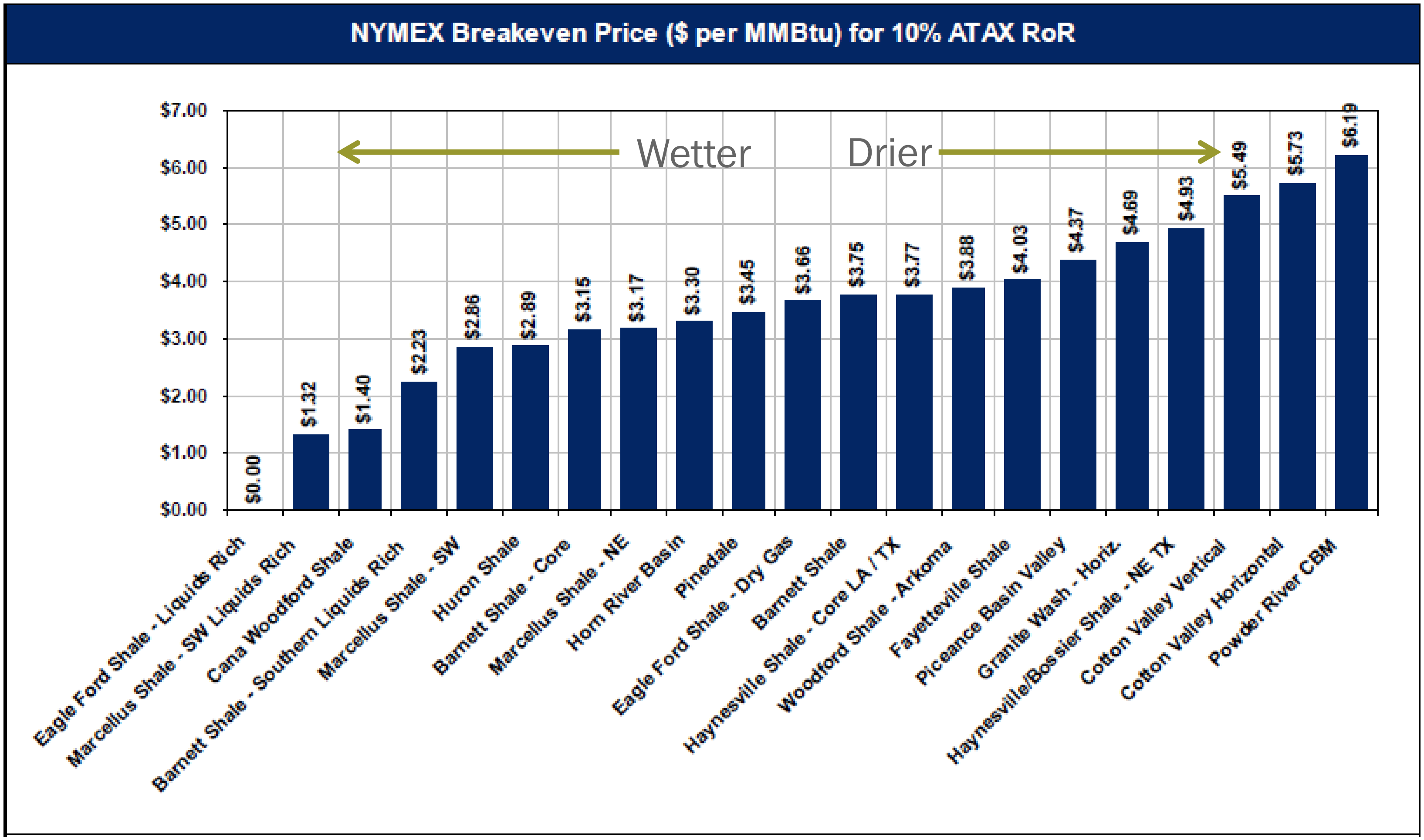
Figure 2.14b Breakdown of Mean U.S. Gas Supply Curve by Type; 2007 Cost Base



Source: MIT; ICF North American Hydrocarbon Supply Model

Source: MIT EI

NG liquids revenues are subsidizing dry gas production



Source: Credit Suisse

Swaps, collars, contracts: hedging helps

PXD Open Commodity Derivative Positions as of 3/21/2012 (includes PSE)

PIONEER NATURAL RESOURCES

Gas	Q1 2012	Q2 2012	Q3 2012	Q4 2012	2013	2014	2015
Swaps - (MMBTUPD)	186,374	275,000	275,000	275,000	112,500	50,000	-
NYMEX Price ($/MMBTU)[1]	$ 5.29	$ 4.97	$ 4.97	$ 4.97	$ 5.62	$6.05	-
Collars - (MMBTUPD)	65,000	65,000	65,000	65,000	150,000	140,000	50,000
NYMEX Call Price ($/MMBTU)[1]	$ 6.60	$ 6.60	$ 6.60	$ 6.60	$ 6.25	$ 6.44	$ 7.92
NYMEX Put Price ($/MMBTU)[1]	$ 5.00	$ 5.00	$ 5.00	$ 5.00	$ 5.00	$ 5.00	$ 5.00
Three Way Collars - (MMBTUPD)[1,2]	81,813	-	-	-	-	60,000	30,000
NYMEX Call Price ($/MMBTU)	$ 7.65	-	-	-	-	$ 7.80	$ 7.11
NYMEX Put Price ($/MMBTU)	$ 6.05	-	-	-	-	$ 5.83	$ 5.00
NYMEX Short Put Price ($/MMBTU)	$ 4.50	-	-	-	-	$ 4.42	$ 4.00
% U.S. Gas Production	~90%	~90%	~90%	~90%	~65%	~55%	~20%

Gas Basis Swaps	Q1 2012	Q2 2012	Q3 2012	Q4 2012	2013	2014	2015
Spraberry (MMBTUPD)	32,500	32,500	32,500	32,500	52,500	45,000	-
...MBTU)	$ (0.38)	$ (0.38)	$ (0.38)	$ (0.38)	$ (0.23)	$ (0.27)	-
...PD)	50,000	50,000	50,000	50,000	30,000	30,000	-
...MBTU)	$ (0.53)	$ (0.53)	$ (0.53)	$ (0.53)	$ (0.38)	$ (0.27)	-
	53,500	53,500	53,500	53,500	60,000	40,000	-
...MBTU)	$ (0.15)	$ (0.15)	$ (0.15)	$ (0.15)	$ (0.14)	$ (0.16)	-

At $2.50 NYMEX, PXD would have earned $4.55/mmbtu in Q1 2012

1) Represents the NYMEX Henry Hub index price or approximate NYMEX price based on historical differentials to the index price at the time the derivative was entered into
2) When NYMEX price is above Call price, PXD receives Call price. When NYMEX price is between Put price and Call price, PXD receives NYMEX price. When NYMEX price is between the Put price and the Short Put price, PXD receives Put price. When NYMEX price is below the Short Put price, PXD receives NYMEX price plus the difference between Short Put price and Put price

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Source: Pioneer

Appendix: Model Summaries (1)

	ADAGE	AURORAxmp	CIMS	EMA	EPPA	GCAM
Full Name	Applied Dynamic Analysis of the Global Economy	AURORAxmp	Canadian Integrated Modeling System	Electricity Markets Analysis	Emissions Predictions and Policy Analysis	Global Change Assessment Model
Administrator	RTI International	EPIS, Inc.	Simon Fraser University	RTI International	MIT	University of Maryland
What the model predicts	Macroeconomic results (GDP, welfare, output, trade, employment, energy); GHG results	Wholesale power prices, resource valuation, capacity expansion, risk modeling	Energy production and consumption, resource mix, emissions, investment, labor and fuel costs	Environmental retrofits, emissions, allowance prices, electricity prices, generation costs, new capacity, fuel consumption, interregional imports and exports	GDP, energy use, sectoral output, GHG emissions, air pollution, carbon prices	GDP, world energy and agriculture prices, energy production and trade, agriculture, land use, emissions, climate change
Key data inputs	GHG policies; macro policies	New and existing generator characteristics, retirements, fuel price projections, transmission limitations, demand projections, expansion unit characteristics	Equipment stocks, market and consumer behavior, energy demand, energy policies	Electricity supply and demand (units, load curves, capacity factors, etc.), fuel prices/supplies, emissions	Economic data; emissions data; taxes	Demographics, labor productivity, price and income elasticities, resources, technologies
Sources of inputs	GTAP/IEA; WEO; IMPLAN; AEO; RTI EMA	Not disclosed	Environment Canada, Canada's Energy Outlook, technical and market literature, EPA, behavioral literature	NEEDs, EIA demand forecasts, reserve margins, IPM O&M cost data, EIA gas and oil forecasts	GTAP dataset (Purdue University); EPA	GTAP, DOE, various scientific and technical literature
Methodology	Dynamic computable general equilibrium	Simulation model	Hybrid technology simulation model	Dynamic linear programming	Computable general equilibrium (CGE) model of the world economy	Dynamic-recursive model (economy, energy and land-use), partial equilibrium
Logic	Energy, environmental, and trade policies	Transmission constrained dispatch logic	Simulates technological evolution of fixed capital stocks and associated energy supply and demand	Determines least-cost method of meeting electricity demand. Can be linked to ADAGE	Optimization decisions of consumers and producers. Recursive and forward-looking versions available.	
Free/pay	Pay	Pay		Pay	Free for educational and research purposes only	Free
Open source?	No	No		No	Yes	Yes
Clients/who uses it	EPA, NGOs, RTI	IHS CERA, utilities, analysts	Academics, Canadian government	RTI	Academics and researchers	DOE, EPA, US Climate Change Science and Technology Programs, Energy Modeling Forum

Appendix: Model Summaries (2)

	Haiku	IGEM	IPM	MRN-NEEM	NEMS	NESSIE	NewERA
Full Name	na	Intertemporal General Equilibrium Model	Integrated Planning Model	North American Electricity and Environment Model	National Energy Modeling System	National Electric System Simulation Integrated Evaluator	na
Administrator	Resources for the Future	RFF, Harvard, Northeastern, etc.	ICF Consulting	Charles River Associates	U.S. Department of Energy - EIA	EPRI	NERA Consulting
What the model predicts	Electricity prices and demand, electric generation, fuel consumption, interregional electricity trade, generation capacity, pollution controls, emissions, allowance prices, economic surplus	Commodity prices for numerous sectors, industry output	Generation, capacity mix, capacity additions and retirements, capacity and energy prices, power production costs, fuel consumption, fuel supply and demand, fuel prices, emissions, allowance prices	Average peak and off-peak electricity price by region, emission allowance prices, coal prices, unit retirements, resource additions, unit retrofits and associated costs	Fuel prices, energy demand and consumption, generating capacity, emissions	Capacity expansion, system operations, electricity prices, emissions, social welfare	Demand and supply of goods and services, commodity prices, changes in imports/exports, gross regional product, consumption, investment, disposable income, and jobs
Key data inputs	Existing generators, fuel and resource supply, pollution controls, transmission grid, electricity consumption	Industry input-output tables, household consumption data, investment, tax rates, exports and imports, population and demographics	Existing and new unit-level data; transmission constraints; electric demand and load curves; financial outlook; fuel prices, supply curves, and transportation costs; air regulations	Existing unit-level data, new generation options, transmission constraints, environmental regulations, fuel prices and supply curves, electricity demand, reserve margin requirements	Fuel prices and supply and demand curves, production profiles, building stocks and energy consumption, existing unit-level data	Characteristics of generating technologies, such as fixed and variable costs, efficiency, availability, capacity factor, etc; market values for natural gas, other fuels, emissions allowances	Not disclosed
Sources of inputs	EIA, FERC, EPA, RFF, NERC, IPM		AEO, NERC, FERC, EIA, Global Energy, utility and RPO comments, NETL, EPRI, others	FERC Form 714, RTO forecasts, AEO 2011, EIA 816, EIA 860, EIA 767, McIlvaine, EPA, NERC ES&D Database, Energy Velocity, NREL WinDS, NRC, NYMEX	Census, BLS, EPA, IHS Global Insight, EPA, Platts, McCloskey, EIA, FERC, IEA, F.W. Dodge, EPRI, Navigant, NREL, NERC, PG&E, ICF, ORNL, others	NEMS, EPRI	Not disclosed
Methodology	Aggregates generators into model plants that are representative of generators in 21 regions to simulate electricity sector	Computable general equilibrium model	Dynamic linear programming	MRN: Dynamic computable general equilibrium NEEM: Flexible partial equilibrium MRN and NEEM submodels integrated through iterative solving process	Modular design; modules executed iteratively in a convergence equilibrium designed to simulate annual energy market equilibria	Least-cost economics, production simulation (dispatch model)	Computable general equilibrium
Logic	Deterministic, forward-looking model that finds equilibrium in electricity markets	Balances demands and supplies for products and factors of production at each point in time	Minimize NPV of total electric sector costs over the planning period	MRN: Equilibrium within which outcomes are driven by self-interested consumers and producers NEEM: Optimal system expansion	Equilibrium in which suppply equals demand		Equilibrium in which suppply equals demand. Electric sector model determines least-cost method of satisfying all constraints
Free/pay	Pay		Pay	Pay	Free but requires proprietary software to run	Internal use	Pay
Open source?	No		No	No	Source language, input files, and output files are provided, but certain portions of the model are proprietary		No
Clients/who uses it	RFF, researchers	EPA	EPA, state environmental agencies, utilities, other public and private sector clients	Government, NGOs, utilities, academia	EIA and other government entities	EPRI, EPRI members	NERA