California Energy Commission

North American Market Gas-Trade (NAMGas) Model:

Key Drivers, Structure, and Preliminary Cases

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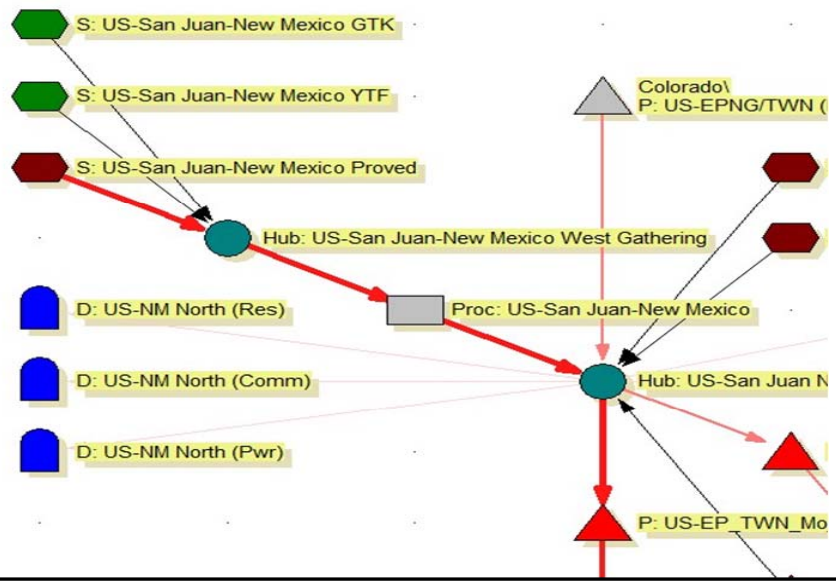
North American Market Gas Trade Model: Construction

- Started with the World Gas Trade Model (WGTM) and completed the following:
  - Reconfigured the California portion of the model to suit the Energy Commission needs
  - Removed all non-North American structure
  - Added functional nodes to account for Liquefied Natural Gas (LNG) imports and exports
  - Added nodes needed to represent natural gas demand in the transportation sector
- NAMGas Trade Model created in the MarketBuilder platform.

North American Market Gas Trade Model: Key Drivers (Supply Side)

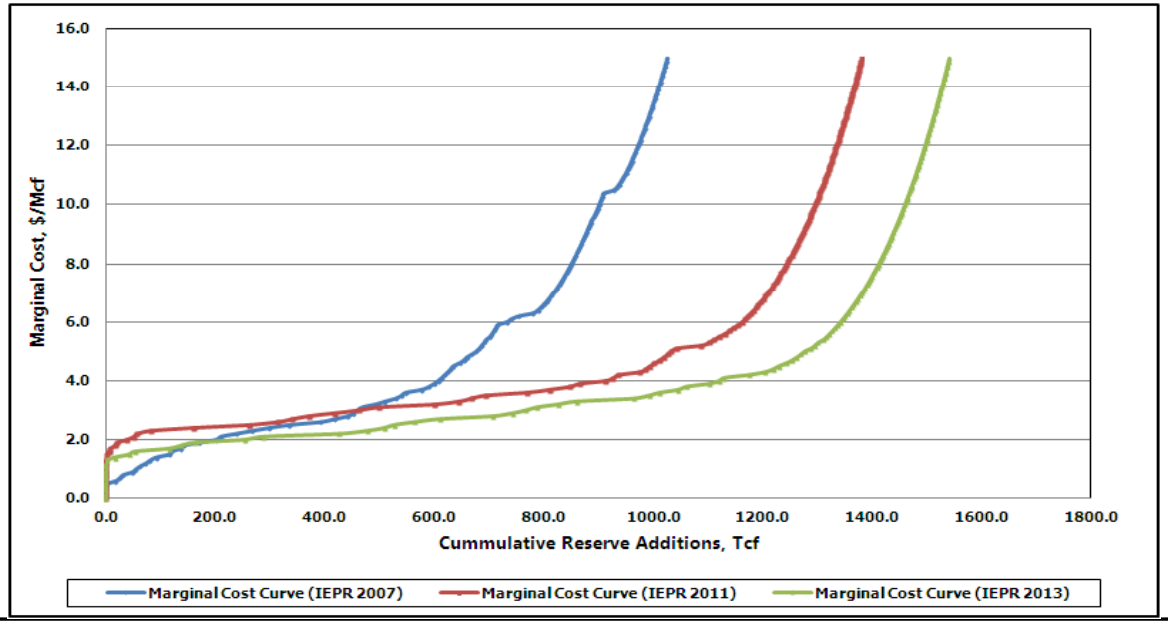
- **Resource assessments:**
  - Assessments of technically recoverable resources
    - Most important factor affecting regional trade flows and price
  - In general, price path in any long-term model should be most affected by the quantity of resources that are technically available
- **Resource costs**
  - Costs of developing resources in various regions in North America define the subset of *technically* recoverable resources which is *economically* recoverable
    - Change as price increases
  - Regional trade flows reflect the fact
    - Production generally occurs from the lower-cost resources first
  - Technology innovations forces per-unit cost lower.

North American Market Gas Trade Model: Key Drivers (Supply Side)



- **Model structure represents all production basins**
- **Green node is a depletable resource:**
  - **Requires both capital cost and O&M cost for production**
- **Brown node is a simple supply:**
  - **Requires only O&M cost for production.**

North American Market Gas Trade Model: Key Drivers (Supply Side)~US Supply Cost Curve



- **Marginal cost profile is a major input parameter for the natural gas model:**
  - **Technology is shifting the marginal cost profile**
  - **Overall, the shifting of the marginal cost supply profile results in more resources available at lower cost.**

Sources: California Energy Commission; Altos Management Partners; Baker Institute; National Petroleum Council.

North American Market Gas Trade Model: Key Drivers ~ (Demand Side)

- Development of initial (starting/reference) prices and quantities:
  - Excel-based econometric tool (Small 'm' model) uses historical data to calculate initial prices and quantities
- Initial prices and quantities uploaded to MarketBuilder-based general equilibrium model (NAMGas)
- Demand in Five Disaggregated Sectors:
  - Residential
    - Residential sector factors: recent historical demand for natural gas, population, natural gas price, income, heating oil price, and cold weather

North American Market Gas Trade Model: Key Drivers ~ (Demand Side)

- **Demand in Five Disaggregated Sectors (cont'd):**
  - **Commercial:**
    - **Commercial sector factors: recent historical demand for natural gas, income, natural gas price, population, heating oil price, and cold weather**
  - **Industrial:**
    - **Industrial sector factors: recent historical demand for natural gas, natural gas price, coal price, industrial production, and cold weather**
  - **Power Generation:**
    - **Power Generation sector factors: total electricity generation, weather, natural gas price, fuel oil price, renewable electricity generation, and coal price**

North American Market Gas Trade Model: Key Drivers ~ (Demand Side)

- **Demand in Five Disaggregated Sectors (cont'd):**
  - **Transportation:**
    - **Transportation Factors: recent historical demand for natural gas, income, natural gas price, population, heating oil price, and cold weather.**

- **General Demand-side Impacts:**
  - **High rates of demand growth tend to push the marginal source of production into higher-cost regions**
  - **This influences the flow of trade and the price.**

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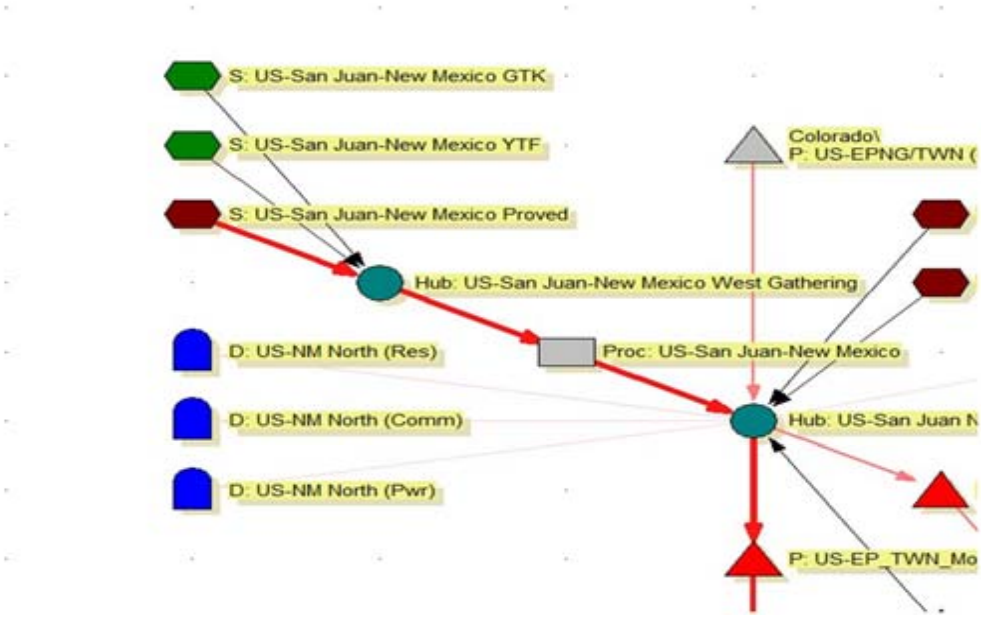
North American Market Gas Trade Model: Key Drivers ~ (Demand Side)



- **Model structure with associated data represents all demand sectors:**
  - **Blue nodes (tombstones) are elastic demand nodes**
    - **Nodes are price-responsive.**

North American Market Gas Trade Model: Key Drivers (cont'd)

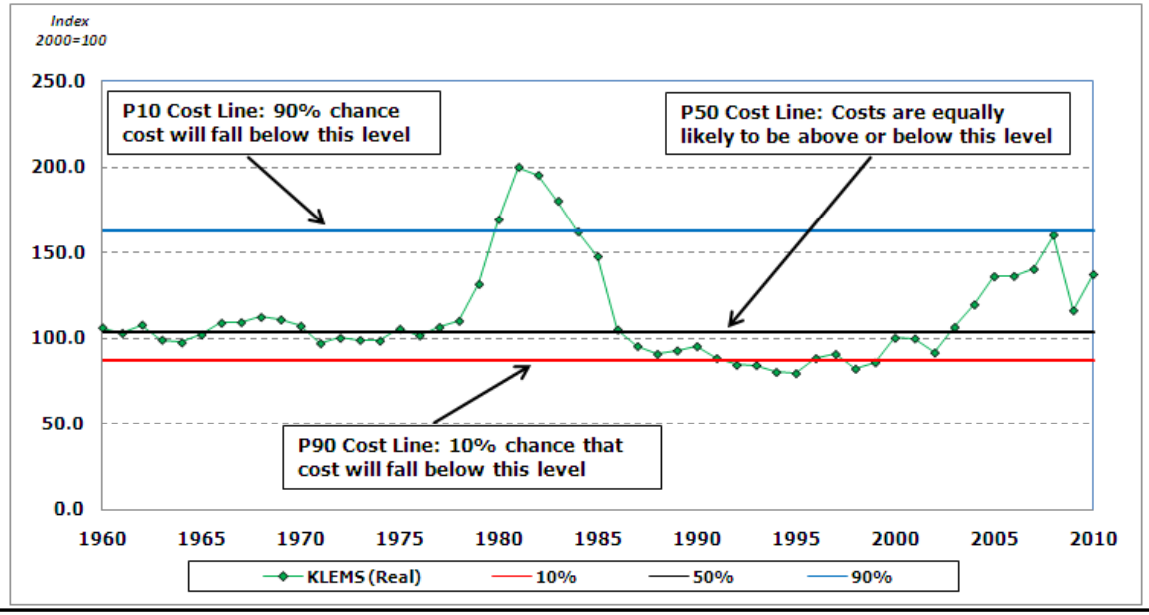
- **Gas substitutes:**
  - Assumptions about the cost of "backstop" resources define the long run ceiling on gas price
  - As this price is approached, future investments in higher cost natural gas resources are disadvantaged
- **Policy parameters:**
  - Assumptions regarding various political and regulatory constraints can have profound impacts on model outcomes
  - Policy may limit access to resources, inflate demand, or lead to accelerated adoption of backstop technologies.

North American Market Gas Trade Model: Key Drivers (cont'd)

- **Investment parameters:**
  - Fiscal terms under which resources and infrastructure can be developed influences economic viability
  - Factors such as high taxes/royalties and higher-than-normal required returns can inhibit production in those regions affected, thus shifting the flow of trade
- **Assumptions regarding timing and availability of resources and infrastructure:**
  - Constraints imposed on the availability of infrastructure (e.g., the start date and capacity of pipeline infrastructure) can have a large influence on regional pricing and flows.

North American Market Gas Trade Model: Developing a Cost Environment

Typical Cost Environment (P50): 1975, 1986, and 2003



- **Staff must simulate the cost environment for analysis:**
  - **Graph shows indexed cost between 1960 and 2010**
  - **High cost environment ~ 1979 – 1984**
  - **Low cost environment ~ 1992 – 2000.**

Sources: Baker Institute.

National Price and Supply Outlooks/Scenarios: Road Map

- Purpose of Preliminary Scenarios
- The Preliminary Scenarios
- Descriptions of the Scenarios
- General Impact of Price Changes
- Price Performance of Cases
- Supply Portfolio

National Scenarios:
Purpose of Scenarios

- **To examine price and supply in the national natural gas market:**
  - **Potential vulnerabilities to California**
  - **Potential opportunities for California**
- **To investigate natural gas price and supply uncertainty:**
  - **Plausible range of conditions developed**
- **To develop plausible outlooks of prices and supply:**
  - **The question: What if all plausible events associated with a particular outcome occurred simultaneously?**

National Scenarios:
Purpose of Cases (cont'd)

- To evaluate the impact of relevant policy drivers:
  - Implementation of Renewables Portfolio Standard (RPS)
  - Conversion of coal-fired generation
  - Environmental mitigation of shale development:
    - Water use and disposal
  - Licensing of liquefied natural gas (LNG) export capability.

National Scenarios:
What are the National Scenarios?

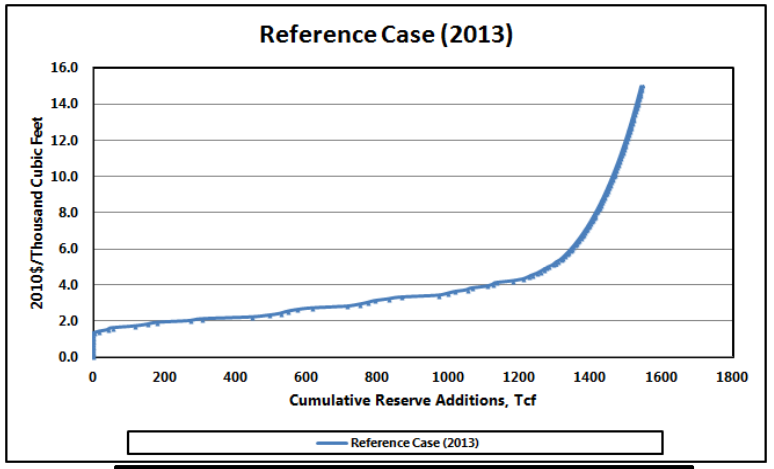
- **Staff constructed the following national outlooks:**
  - **Reference Case**
  - **High Price (Low Consumption) Case**
  - **Low Price (High Consumption) Case.**

National Scenarios:
Scenario Description (Reference Case)

- **Initial (starting) demand quantity (United States):**
  - 2011: Total ~ 22.1 Tcf; Power Gen ~ 7.5 Tcf
  - 2020: Total ~ 26.9 Tcf; Power Gen ~ 9.9 Tcf
  - 2030: Total ~ 26.2 Tcf; Power Gen ~ 10.6 Tcf
- **Estimated Elasticity:**
  - Residential, Commercial, Industrial, Power Gen, and Transportation;
  - Range of elasticity ~ 0.5298 – 1.2363
- **Coal Conversion: 30 Gigawatts starting in 2014**
- **Renewables Portfolio Standard:**
  - California meets on time
  - 5-year delay in other states.

National Scenarios:
Scenario Description (Reference Case) (cont'd)

- Proved Reserves: 325 Tcf
- Potential Reserves:
  - 1280.4 Tcf @ $5.00/Mcf
  - 1462.4 Tcf @ $10.00/Mcf
- Rate of Return:
  - Resources: 12.2% (real)
  - Pipeline Investment: 8.4% (real)
  - Income Tax Rate: 35%
  - Return on Equity: 8%
- Backstop Technology:
  - Unspecified at $9.00/Mcf
- Technology Factor:
  - 1%/year.



Aggregate Supply Cost Curve

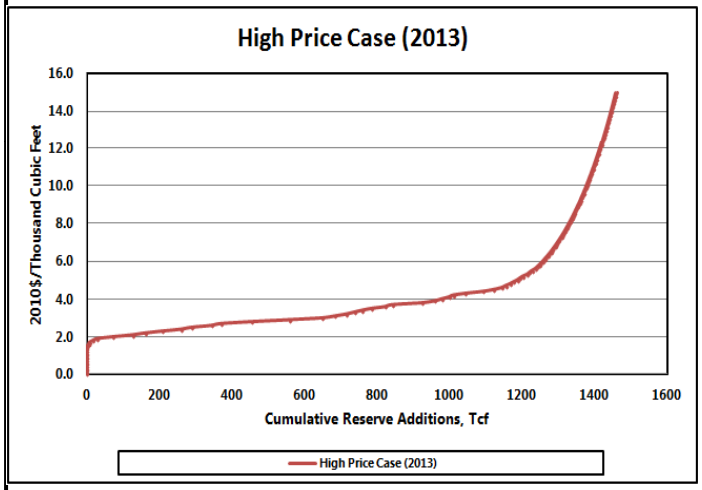
National Scenarios:
Scenario Description (High Price Case)

- Converted 80 GW of coal-fired generation
- Assumed robust economic performance, with long-term annual economic growth capped at about 3.5%
- Delayed RPS implementation by 10 years as states grapple with budgetary concerns
- Starting in 2016, assumed robust LNG export capability developed and utilized at:
  - Kitimat (Canada, Apache)
  - Sabine Pass (Cheniere), Lake Charles (BG), and Freeport
  - Cove Point .

National Scenarios:
Scenario Description (High Price Case) (cont'd)

- **Assumed added environmental compliance costs in Canada and the United States:**
  - **$0.40 / Mcf to the O&M cost of developing shale formations**
  - **$0.20 / Mcf to conventional resources**

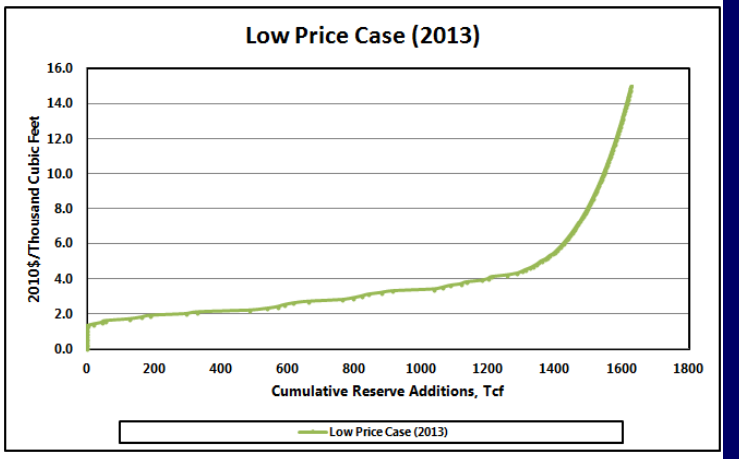
- **Removed from development potential shale resources in particular regions, such as New York and the Rocky Mountains (Colorado and Wyoming):**
  - **Altered the available gas resource and shrank resource base by about 5.5 %**
  - **Re-established merit order of resource selection.**



Aggregate Supply Cost Curve

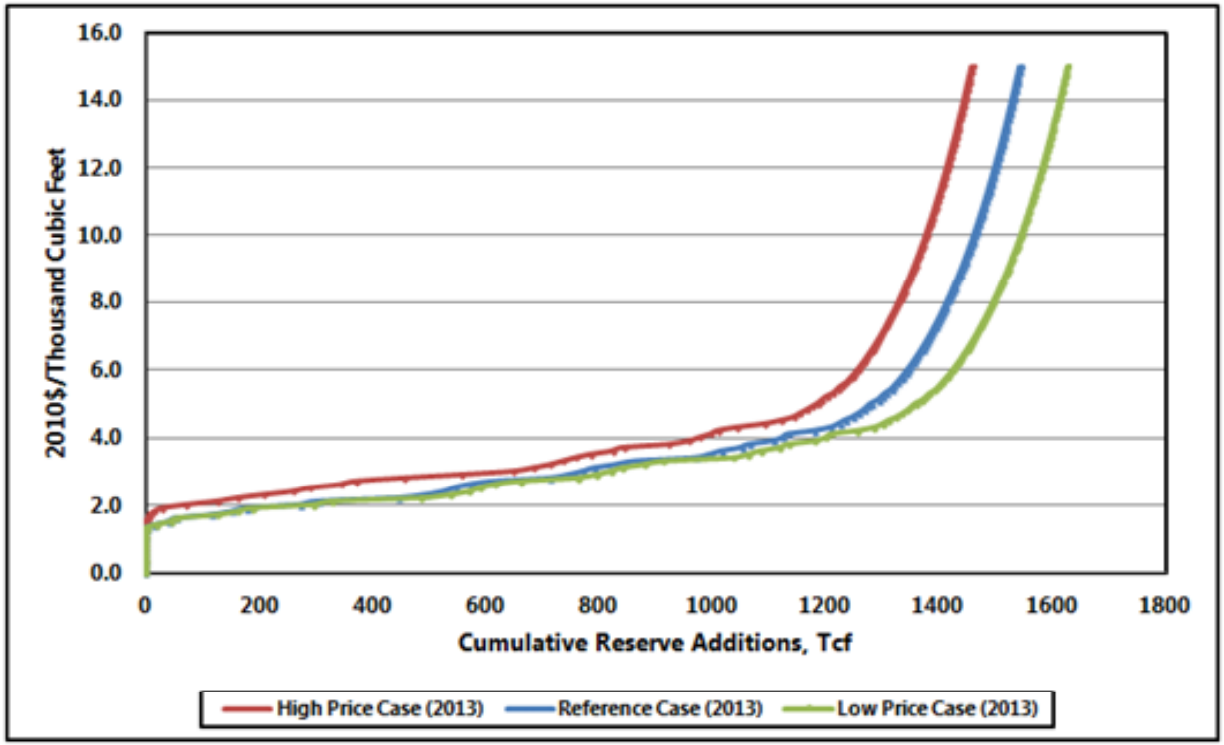
National Scenarios:
Scenario Description (Low Price Case)

- Converted 1 Gigawatt of coal-fired generation
- Assumed all states meet RPS targets on time
- Capped long-term annual economic growth capped at about 2.1%, portending weak gross domestic product growth
- Disallowed LNG exports, thus keeping North America isolated



- Assumed technology develops at a rate of 2.5%
- Assumed larger resource base
  - Increased assessment size in the Marcellus, Haynesville, and western Canadian shale formations
  - Used upper range of published data
  - Resulted in additional 5.3% rightward shift of overall supply cost curve.

National Scenarios:
Scenario Description (Supply Cost Curve Comparison)



- Individual resources turned off or turned on
- Curves shift to the right or to the left.

Sources: California Energy Commission; Altos Management Partners; Baker Institute; National Petroleum Council.

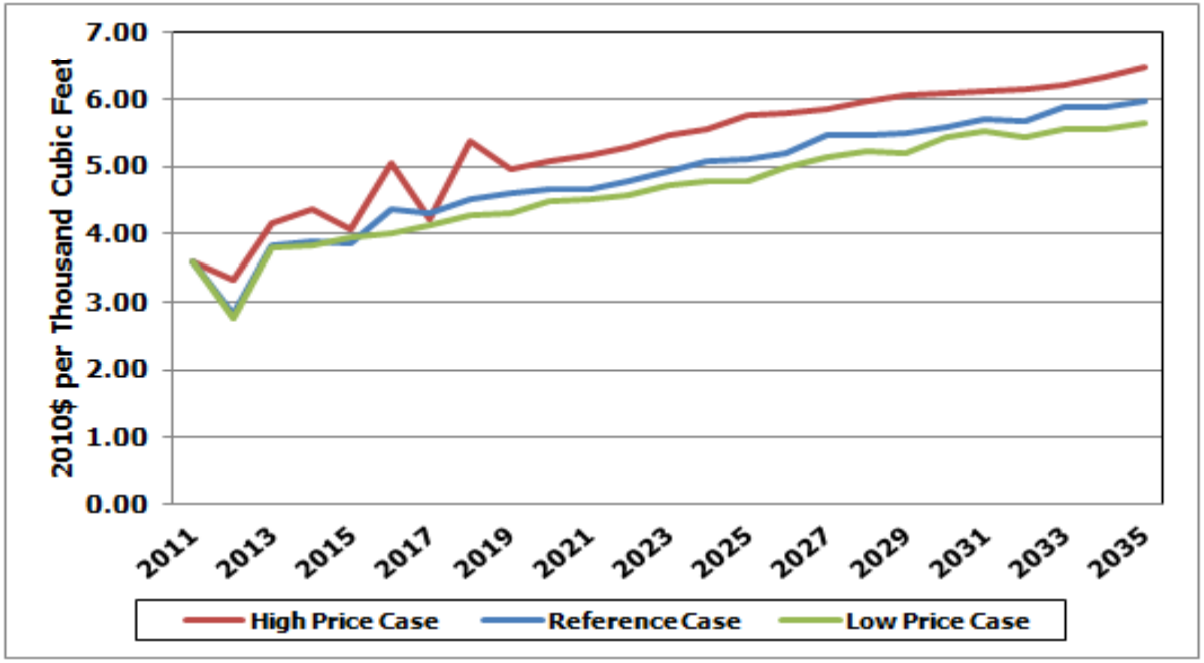
National Scenarios:
General Impacts of Price Changes

- **Price changes produce various responses:**
  - **Higher prices**
    - **Depress demand**
    - **Stimulate added supply**
  - **Lower prices**
    - **Stimulate demand**
    - **Suppress supply**
- **Usually, a combination of dual impact occurs**
- **Price *changes* also re-configure the order of economic selection and, thus, the supply portfolio:**
  - **In a dynamic market, this can affect the attractiveness of particular supply resources**
- **Question: What is the dominant effect?**

National Cases: Supply Balance

Performance of Cases: Lower 48

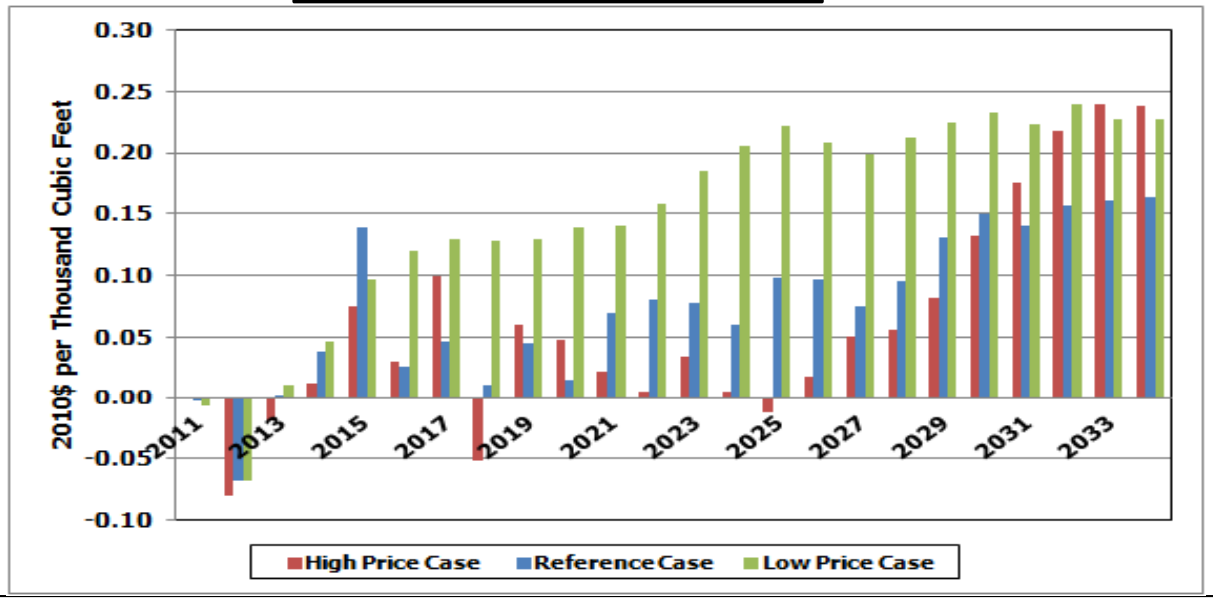
National Cases:
Price Performance of Cases (Henry Hub)



- In general, prices behave as expected:
  - High Price case produced highest prices
  - Low price case produced lowest prices
- Together, three cases produced the "zone of uncertainty."

National Cases:
Price Performance of Cases (Differentials)

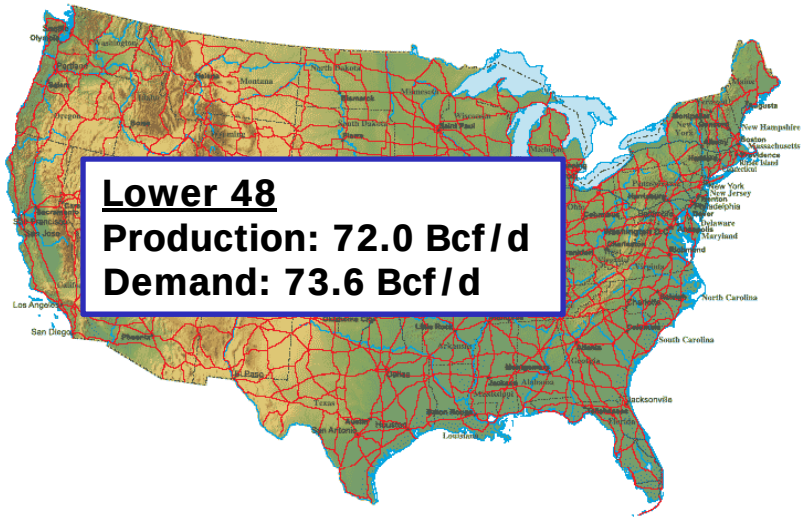
Topock - Henry Hub



- **In general, differentials turn positive after 2013:**
  - **Resource abundance more evident in the eastern US**
  - **Access to shale and 'tight' gas resources is re-ordering the supply portfolio, impacting eastern prices more than western.**

National Scenarios Cases: Supply Portfolio of Reference Case (2025)

Canadian Imports: 13.0 Bcf/d



Lower 48
Production: 72.0 Bcf/d
Demand: 73.6 Bcf/d

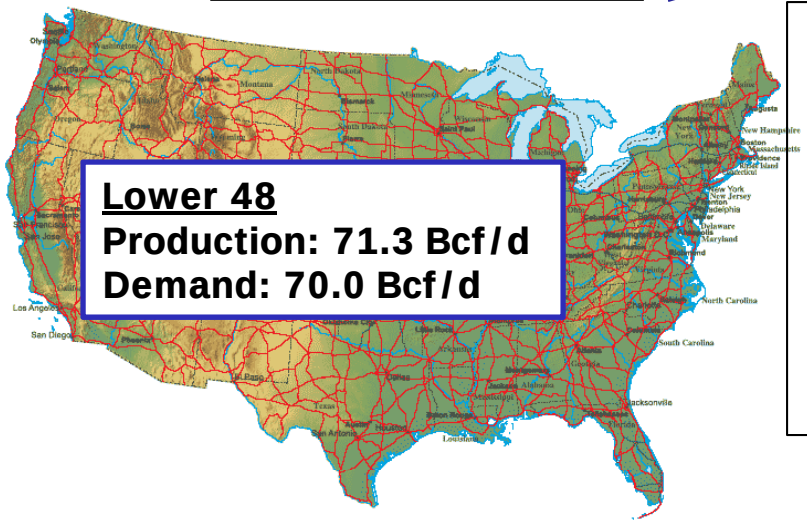
- **Two main demands: End-use and Exports**
- **Demand satisfied by:**
  - **Canadian Imports**
  - **L48 Production**
  - **LNG Imports**

Exports: 8.4 Bcf/d

LNG Imports: 0.25 Bcf/d

National Scenarios: Reconfiguration of Supply Portfolio (2025)

Canadian Imports: 11.9 Bcf/d



Lower 48
Production: 71.3 Bcf/d
Demand: 70.0 Bcf/d

Exports: 11.1 Bcf/d

LNG Imports: 0.64 Bcf/d

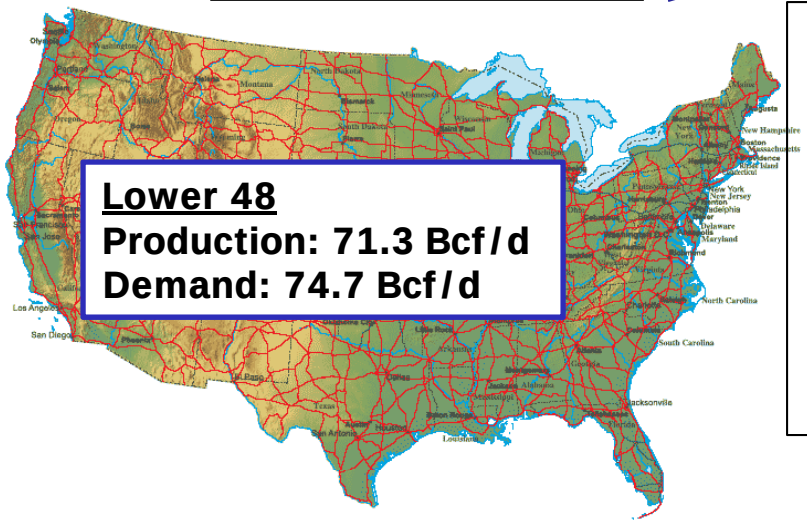
High Price Case (+12.3%)

- Two main demands: End-use (-5.5%) and Exports (+32.1%)
- Demand satisfied by:
  - Canadian Imports (-8.5%)
  - L48 Production (- 1.0%)
  - LNG Imports (+156.0%)
- Competing sources of natural gas reconfiguring the supply portfolio

( ) Percent change from reference case

National Cases: Reconfiguration of Supply Portfolio (2025)

Canadian Imports: 12.7 Bcf/d



Lower 48
Production: 71.3 Bcf/d
Demand: 74.7 Bcf/d

Exports: 6.5 Bcf/d

LNG Imports: 0.10 Bcf/d

Low Price Case (-6.8%)

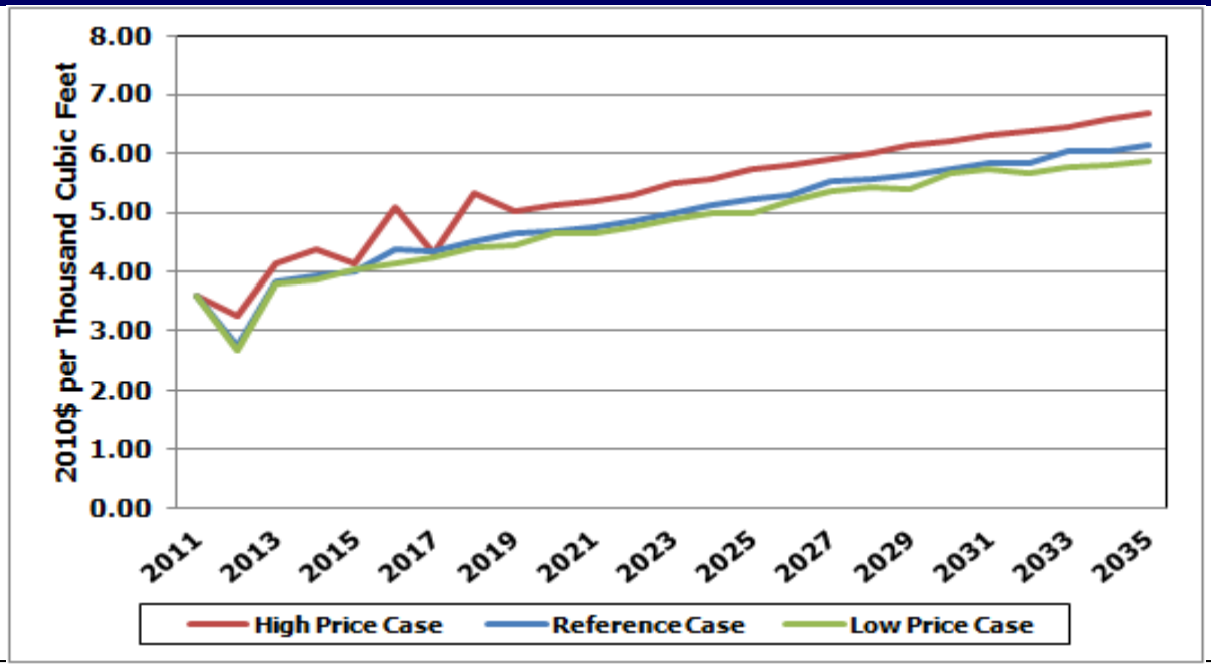
- Two main demands: End-use (+1.5%) and Exports (-22.6%)
- Demand satisfied by:
  - Canadian Imports (-2.3%)
  - L48 Production (-1.0%)
  - LNG Imports (-60.0%)
- Competing sources of natural gas reconfiguring the supply portfolio

( ) Percent change from reference case

National Cases: Supply Balance

Performance of Cases: California

National Cases:
Price Performance of Cases (Topock Hub)



- **In general, prices behave as expected:**
  - **High Price case produced highest prices**
  - **Low price case produced lowest prices**
- **Together, three cases produce "zone of uncertainty" for California.**

National Cases: California Supply Portfolio (2025)

Calif. Imports (Malin):
2.68 Bcf/d

Rocky Mountain:
1.23 Bcf/d

Southwest:
2.37 Bcf/d

Reference Case

- California Demand: End-use
- Demand satisfied by:
  - Imports (Malin)
  - Rocky Mountain Supplies
  - Southwest Supplies
  - Local Production

California
Production: 0.21 Bcf/d
Demand: 6.38 Bcf/d

( ) Percent change from reference case

National Cases: California Supply Portfolio (2025)

Calif. Imports (Malin): 2.50 Bcf/d

Rocky Mountain: 1.16 Bcf/d

Southwest: 2.38 Bcf/d

California
Production: 0.25 Bcf/d
Demand: 6.16 Bcf/d

High Price Case (+9.9%)

- California Demand: End-use (-3.4%)
- Demand satisfied by:
  - Imports (Malin) (-6.7%)
  - Rocky Mountain Supplies (-5.7%)
  - Southwest Supplies (< +1.0%)
  - Local Production (+19.0%)
- Competing sources of natural gas reconfiguring the supply portfolio

( ) Percent change from reference case

National Cases: California Supply Portfolio (2025)

Calif. Imports (Malin): 2.72 Bcf/d

Rocky Mountain: 1.22 Bcf/d

Southwest: 2.39 Bcf/d

California
Production: 0.19 Bcf/d
Demand: 6.39 Bcf/d

Low Price Case (-4.3%)

- California Demand: End-use (< +1%)
- Demand satisfied by:
  - Imports (Malin) (+1.5%)
  - Rocky Mountain Supplies (-1.0%)
  - Southwest Supplies (+1.0%)
  - Local Production (-9.5%)
- Competing sources of natural gas reconfiguring the supply portfolio

( ) Percent change from reference case

Additional Scenarios: Merging of Reserves Estimates and Cost Environment

		Reserve Estimates (RE)		
		P10: 10% chance costs reach value or higher	**P50:** Actual cost value equally likely to be higher or lower than estimate	**P90:** 90% chance costs reach value or higher
Cost Environment (CE)	**P10:** 10% chance costs reach value or higher	Reserve Estimates: Proven: 325 Tcf Potential: 1970 - 2460 Tcf** Cost Environment: Cost going forward approximates real costs in 1984 and 2008	Reserve Estimates: Proven: 325 Tcf Potential: 1543 Tcf Cost Environment: Cost going forward approximates real costs in 1984 and 2008	Reserve Estimates: Proven: 325 Tcf Cost Environment: Cost going forward approximates real costs in 1984 and 2008
	P50: Actual cost value equally likely to be higher or lower than estimate	Reserve Estimates: Proven: 325 Tcf Potential: 1970 - 2460 Tcf** Cost Environment: Cost going forward approximates real costs in 1975, 1986, and 2003	Reserve Estimates: Proven: 325 Tcf Potential: 1543 Tcf Cost Environment: Cost going forward approximates real costs in 1975, 1986, and 2003	Reserve Estimates: Proven: 325 Tcf Cost Environment: Cost going forward approximates real costs in 1975, 1986, and 2003
	P90: 90% chance costs reach value or higher	Reserve Estimates: Proven: 325 Tcf Potential: 1970 - 2460 Tcf** Cost Environment: Cost going forward approximates real costs between 1991 and 1999	Reserve Estimates: Proven: 325 Tcf Potential: 1543 Tcf Cost Environment: Cost going forward approximates real costs between 1991 and 1999	Reserve Estimates: Proven: 325 Tcf Cost Environment: Cost going forward approximates real costs between 1991 and 1999

**Gross approximation assuming a log-normal distribution

- **Additional scenarios result from the combination of the cost environment and the reserve estimates**
- **Extreme high-price will pull toward the upper right cell; Extreme low-price will pull toward lower left cell.**

Sources: California Energy Commission, EIA, and Baker Institute

National Scenarios:
Conclusions

- Plausible national scenarios produce a range of price and supply outcomes
- Price changes can reconfigure the supply portfolio
- To integrate renewables into the generation supply portfolio, California needs a robust natural gas supply base
- The switch from coal-fired generation may lead to higher natural gas demand
- Plausible national scenarios produce a “Zone of Uncertainty”
- The abundance of shale resources keeps the “Zone of Uncertainty” relatively narrow.