Proposed Modeling Scenarios

Staff Workshop

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Purposes for Which Natural Gas Market Assessments Are Used

Natural Gas Market Assessments and Forecasts support:

- Energy policy making and program implementation activities
- Relative economics of alternative electricity resource choices, such as
  - energy efficiency programs and standards
  - distributed generation choices (e.g., photovoltaics, combined heat and power)
  - new central station generation
- Energy costs for households and businesses
- Environmental impacts of natural gas market activity
- Electricity demand assessments
- Wholesale electricity and natural gas market procurement, including hedging
- Natural gas infrastructure requirements assessments

Electricity Analysis Office
Natural Gas Unit

Long-range assessments of the demand for natural gas evaluate drivers of:

- end use gas demand
- gas demand to serve grid-delivered end use electric generation
- mix of electric generation resources (e.g., renewables, coal) which substitute for gas-fired generation (either utilization or construction)

and are affected by:

- world, national, regional and state energy and environmental policies
- economic choices utilities make for generation capacity expansion

Modeling the World Gas Market

World Gas Trade Model - simplified

- general equilibrium model iterates world-wide regional natural gas demand & supplies, “investing” in new pipelines, if economic
- perfect foresight in making return-on-investment decisions
- resulting prices are those that would have to be sustained to make investments economic (under the assumed future conditions)

Thousands of assumptions are made about future conditions of complex, interacting key drivers

Provide insights on potential market outcomes under different plausible future conditions

WGTM Reference Case

Econometric approach: equations that well explain past gas market activities are enlisted to predict the future

- Many assumptions for WGTM independent input variables re: U.S. energy activities come from EIA Annual Energy Outlook 2010 Reference Case output
- Therefore, WGTM Reference Case is conditional wrt some AEO 2010 Reference Case underlying conditions/assumptions, e.g.,

EIA AEO acknowledges that inherent uncertainties require Reference Case results not to be viewed in isolation

- alternate market projections must be reviewed to gain perspective on how variations in key assumptions can lead to different outlooks for energy markets

Proposed Scope and Design of Natural Gas Market Assessment

- Focus assessment on cases helpful to decisionmakers, rather than having a single point forecast be the primary product
- The "business as usual" Reference Case only a starting point: reflects expert opinion and current perception of current conditions
- Many future potential changes cannot be predicted accurately or even probabilistically, but are deeply uncertain
- Alternative cases are needed for additional insights, especially about potential future structural changes to the market conditions or regulations
- Staff requests parties comments on the proposed alternative cases' topic question, structure, and assumptions

Proposed Alternate Cases

Cases A & B are designed to explore California's potential vulnerabilities, or opportunities, across a plausible range of conditions that could drive future wholesale gas market prices

- A: High Gas Price Case - assumes a plausible combination US-policy-driven and market conditions that would lead to higher national wholesale gas demand and higher gas prices

- B: Low Gas Price Case - assumes a plausible combination of US-policy-driven and market conditions that would lead to lower national wholesale gas demand and lower gas prices

[see accompanying charts for more detailed description]

Proposed Alternative Cases (cont'd)

Cases C & E are designed to explore California's potential vulnerabilities, or opportunities, across a plausible range of conditions that could drive future California gas demand, costs, and infrastructure additions

- C: High CA Gas Demand Case – assumes a plausible combination of CA-policy-driven conditions that would lead to high gas demand
- E: Low CA Gas Demand Case – assumes a plausible combination of CA-policy-driven conditions that would lead to low gas demand

Each of the above cases will have a stressed sensitivity case for snapshot years that also assumes occasional low hydroelectricity conditions, high summer, low winter temperatures, and robust economic conditions (Cases D & F)

[see accompanying charts for more detailed description]

Proposed Alternate Cases (cont'd)

Cases G & H are policy-relevant sensitivities designed to guard against one-side biases

Explore key uncertainties testing the claim that shale gas is a "game changer" for the U.S. gas market

- G: Shale Environmental Mitigation Sensitivity Case – assumes plausible combination of higher environmental mitigation costs or constraints on shale gas production

Explore potential market impacts of pipeline pressure limitations on transportation capacity

- H: Reduced Pipeline Pressure Case – assumes reduced pipeline pressures/capacities associated with new public safety limitations

[see accompanying charts for more detailed description]

Uncertainty Analysis Helps Decisionmakers

Policy decisions often seek to strike a balance between competing objectives

Decisions carry risk because the future is highly uncertain

- Accurate probability of complex future outcomes unachievable
- Even knowing what factors matter, and to what degree, is a challenge
- Consequences of actions based on one forecast are uncertain—another future can happen instead

Moderating the risks of decisionmaking requires understanding the ranges of forecasts and their consequences

Prudently selecting forecasts can moderate the risks of potential consequences of a specific decision

- Decisionmaker’s risk tolerance is important

"Road Map" to Natural Gas Demand-Related Assmptions for Staff's Proposed Natural Gas Market Assessment; For Discussion at April 19, *2011 IEPR* staff workshop

		A	B	C	D	E	F	G	H	Reference Case
		Reference Case and Scenarios								Case not question-focused
		Focus on national drivers that lead to*		Focus on CA drivers that lead to @				Single-variable Sensitivity+	Single-variable Sensitivity#	
Case No:		A	B	C	D	E	F	G	H	Reference Case
Below are Key Drivers for Which Assumptions are Selected and Combined to Create the Cases in Each Column		High Gas Price Case (output price is high, not input)	Low Gas Price Case (output price is low, not input)	High CA Gas Demand Case (output demand is high, not input)	Stressed **High** CA Demand Case (higher econ/demo; lower temps, hydro-generation)	Low CA Gas Demand Case (output demand is low, not input)	Stressed **Low** CA Demand Case (higher econ/demo; higher temps, hydro-generation)	Increased Environmental Mitigation Cost for Drilling and Production Case	Reduced Pipeline Pressure Case	**Rice University CA-specific Constrained Reference Case**
Economy/ Demographics	GDP	Reference Case Values	Slower GDP and Manufacturing Output	Higher GDP growth	Higher GDP growth	Lower GDP growth	Lower GDP growth	Reference Case Values	Reference Case Values	**IMF through 2015; after GDP grows using relation between US and UK historical growth at different per capita income levels, converging across countries over time**
	Population	Reference Case Values	Reference Case Values	Higher CA Population Growth	Higher CA Population Growth	Lower CA Population Growth	Lower CA Population Growth	Reference Case Values	Reference Case Values	**UN median case 2008 Revision avg growth to 2050 = 0.703% http://esa.un.org/unpd/wpp2008/all-wpp-indicators_components.htm**
	Personal Income									
Weather	Temperature - degree days	Reference Case Values	Reference Case Values	Reference Case Values	Colder winter and hotter summer than in Reference Case	Reference Case Values	Warmer winter and cooler summer than in Reference Case	Reference Case Values	Use extreme weather so can see how lower capacity affects system at limits	**Average 1989 to 2009 NOAA Recorded by state**
Electricity, Natural Gas and Fuel Prices	Initial Electricity price by sector and elasticities	Reference Case Values	Reduce the coefficient on gas' share of electricity demand	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	**elasticity of higher electricity demand = 1.089**
	Initial gas price by sector and elasticities	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	**own price elasticity for NG is -0.442**
	Cross-price elasticities for substitute fuels (e.g., oil)	Reference Case Values OR Reverse the sign on Renewables	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	**oil = 0.238 & coal = 0.108 & Renewables = -0.189**
Precipitation	Amount of Hydroelectric generation	Reference Case Values	Reference Case Values	Reference Case Values	Low Hydro increases CA gas demand by 15%	Reference Case Values	High Hydro reduces CA gas demand by 12%	Reference Case Values	Reference Case Values	**No Explicit Precip Assumption other than renewables INCLUDING conv hydro and use of CA/US historical relationship between renewables and total electricity generation**
GHG and Energy Policy Incentives & Constraints (These drivers affect gas demand via their effects on end use gas demand, end use electricity demand, and/or electricity supply alternatives).	GHG Regulations	GHG and other EPA regs further push out coal	More Nukes or CCS allow Reduction in Gas Burn	Reference Case Values	Reference Case Values	Carbon adder on CA gas consumption?	Carbon adder on CA gas consumption?	Reference Case Values	Reference Case Values	**None but gas-fired gen grows as much as if GHG were in place**
	Energy Efficiency	Reference Case Values	High EE reduces electricity and gas demand growth by half	Only half of load reduction desired by EE is achieved	Only half of load reduction desired by EE is achieved	EE reduces CA demand growth to 1% -- reality check with DAO	EE reduces CA demand growth to 1% -- reality check with DAO	Reference Case Values	Reference Case Values	**US load grows at 1.12% compared to EIA Fig 69 3-yr rollng avg in same range; CA grows at 1.61%**
	Central Station Renewable Generation	50% fewer Renewables	Grow Renewables Excl Conv Hydro to 20% of US Demand	Assume CA gets only to 25% Renewables	Assume CA gets only to 25% Renewables	Assume CA gets to 50% Renewables	Assume CA gets to 50% Renewables	Reference Case Values	Reference Case Values	**Renewables Excl Conv Hydro becomes 12.5% of U.S. portfolio by 2040 and 44% of CA (reality check against CA gas burn)**
	Combined Heat & Power	Reference Case Values	Impact depends on assumed fuel source and efficiency	Impact depends on assumed fuel source and efficiency	Impact depends on assumed fuel source and efficiency	Impact depends on assumed fuel source and efficiency	Impact depends on assumed fuel source and efficiency	Reference Case Values	Reference Case Values	**AEO 2010 shows CHP purch and own use but not by generation fuel/not explicitly broken out in RWGTM**
	Distributed Generation	Reference Case Values	Impact depends on assumed fuel source and efficiency	Impact depends on assumed fuel source and efficiency	Impact depends on assumed fuel source and efficiency	Impact depends on assumed fuel source and efficiency	Impact depends on assumed fuel source and efficiency	Reference Case Values	Reference Case Values	**all initially as assumed in AEO 2010 reference case (Zero DG in AEO 2010)/not explicitly broken out in RWGTM**
	Transportation Electricity/NG Use	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	**AEO 2010 shows electricity demand for transportation in CA of 0.49 Gwh growing at 4.1%/not explicitly broken out in RWGTM**
	Other	Go to top of 95% conf interval on all demand coefficients	Go to bottom of 95% conf interval on all demand coefficients	n/a	n/a	n/a	n/a	n/a	n/a	**N/A**
Environmental Protection and Public Safety	Environmental Compliance Costs	PCB ANPR requires major U.S. pipeline replacement and/or impose adder such as proposed in PA ($0.40 to $0.80 per MMBtu)	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Could add PA Compliance Charge ($0.40 to $0.80 per MMBtu) to O&M Cost	Reference Case Values	**includes Marcellus NY moratorium + limits on Montana Front Range + no OCS expansion**
	Public Safety Compliance costs	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	could either add cost to PG&E backbone OR reduce capacity	**None**
Supply	Technology	Slow the technology growth factor ... by half?	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	**Learning factor rate: approx. 1%/yr improvement**
	Production Cost	Could shift supply curves leftward to reduce supply available as public concern limits drilling	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Reference Case Values	Could shift supply curves leftward to reduce supply available as public concern limits drilling	Reference Case Values	**RWGTM Supply Curves**

* Explore California's potential vulnerabilities, or opportunities, across a plausible range of conditions that could drive future wholesale market gas prices

@ Explore California's potential vulnerabilities, or opportunities, across a plausible range of conditions that could drive future California gas demand, costs, and infrastructure additions

\+ Explore potential effects on natural gas price and supply of uncertainties related to possible constaints/environmental mitigatiion costs assigned to shale gas development.

\# Explore potential effects on supply adequacy/price of uncertainties related to pressure reductions in gas pipelines.

Reference Case

Below are Key Drivers for Which Assumptions are Selected and Combined to Create the Cases in Each Column		**Rice University CA-specific Constrained Reference Case**
Economy/ Demographics	GDP	**IMF through 2015; after GDP grows using relation between US and UK historical growth at different per capita income levels, converging across countries over time**
	Population	**UN median case 2008 Revision avg growth to 2050 = 0.703% http://esa.un.org/unpd/wpp2008/all-wpp-indicators_components.htm**
	Personal Income	
Weather	Temperature - degree days	**Average 1989 to 2009 NOAA Recorded by state**
Electiricty, Natural Gas and Fuel Prices	Initial Electricity price by sector and elasticities	**elasticity of higher electricity demand = 1.089**
	Initial gas price by sector and elasticities	**own price elasticity for NG is -0.442**
	Cross-price elasticities for substitute fuels (e.g., oil)	**oil = 0.238 & coal = 0.108 & Renewables = -0.189**
Precipitation	Amount of Hydroelectric generation	**No Explicit Precip Assumption other than renewables INCLUDING conv hydro and use of CA/US historical relationship between renewables and total electricity generation**
GHG and Energy Policy Incentives & Constraints (These drivers affect gas demand via their effects on end use gas demand, end use electricity demand, and/or electricity supply alternatives).	GHG Regulations	**None but gas-fired gen grows as much as if GHG were in place**
	Energy Efficiency	**US load grows at 1.12% compared to EIA Fig 69 3-yr rollng avg in same range; CA grows at 1.61%**
	Central Station Renewable Generation	**Renewables Excl Conv Hydro becomes 12.5% of U.S. portfolio by 2040 and 44% of CA (reality check against CA gas burn)**
	Combined Heat & Power	**AEO 2010 shows CHP purch and own use but not by generation fuel/not explicitly broken out in RWGTM**
	Distributed Generation	**all initially as assumed in AEO 2010 reference case (Zero DG in AEO 2010)/not explicitly broken out in RWGTM**
	Transportation Electricity/NG Use	**AEO 2010 shows electricity demand for transportation in CA of 0.49 Gwh growing at 4.1%/not explicitly broken out in RWGTM**
	Other	**N/A**
Environmental Protection and Public Safety	Environmental Compliance Costs	**includes Marcellus NY moratorium + limits on Montana Front Range + no OCS expansion**
	Public Safety Compliance costs	**None**
Supply	Technology	**Learning factor rate: approx. 1%/yr improvement**
	Production Cost	**RWGTM Supply Curves**

High Price Case

Below are Key Drivers for Which Assumptions are Selected and Combined to Create the Cases in Each Column		High Gas Price Case (output price is high, not input)	Rice University CA-specific Constrained Reference Case
Economy/ Demographics	GDP	Reference Case Values	IMF through 2015; after GDP grows using relation between US and UK historical growth at different per capita income levels, converging across countries over time
	Population	Reference Case Values	UN median case 2008 Revision avg growth to 2050 = 0.703% http://esa.un.org/unpd/wpp2008/all-wpp-indicators_components.htm
	Personal Income		
Weather	Temperature - degree days	Reference Case Values	Average 1989 to 2009 NOAA Recorded by state
Electiricty, Natural Gas and Fuel Prices	Initial Electricity price by sector and elasticities	Reference Case Values	elasticity of higher electricity demand = 1.089
	Initial gas price by sector and elasticities	Reference Case Values	own price elasticity for NG is -0.442
	Cross-price elasticities for substitute fuels (e.g., oil)	Reference Case Values OR Reverse the sign on Renewables	oil = 0.238 & coal = 0.108 & Renewables = -0.189
Precipitation	Amount of Hydroelectric generation	Reference Case Values	No Explicit Precip Assumption other than renewables INCLUDING conv hydro and use of CA/US historical relationship between renewables and total electricity generation
GHG and Energy Policy Incentives & Constraints (These drivers affect gas demand via their effects on end use gas demand, end use electricity demand, and/or electricity supply alternatives).	GHG Regulations	GHG and other EPA regs further push out coal	None but gas-fired gen grows as much as if GHG were in place
	Energy Efficiency	Reference Case Values	US load grows at 1.12% compared to EIA Fig 69 3-yr rollng avg in same range; CA grows at 1.61%
	Central Station Renewable Generation	50% fewer Renewables	Renewables Excl Conv Hydro becomes 12.5% of U.S. portfolio by 2040 and 44% of CA (reality check against CA gas burn)
	Combined Heat & Power	Reference Case Values	AEO 2010 shows CHP purch and own use but not by generation fuel/not explicitly broken out in RWGTM
	Distributed Generation	Reference Case Values	all initially as assumed in AEO 2010 reference case (Zero DG in AEO 2010)/not explicitly broken out in RWGTM
	Transportation Electricity/NG Use	Reference Case Values	AEO 2010 shows electricity demand for transportation in CA of 0.49 Gwh growing at 4.1%/not explicitly broken out in RWGTM
	Other	Go to top of 95% conf interval on all demand coefficients	N/A
Environmental Protection and Public Safety	Environmental Compliance Costs	PCB ANPR requires major U.S. pipeline replacement and/or impose adder such as proposed in PA ($0.40 to $0.80 per MMBtu)	includes Marcellus NY moratorium + limits on Montana Front Range + no OCS expansion
	Public Safety Compliance costs	Reference Case Values	None
Supply	Technology	Slow the technology growth factor … by half?	Learning factor rate: approx. 1%/yr improvement
	Production Cost	Could shift supply curves leftward to reduce supply available as public concern limits drilling	RWGTM Supply Curves

Low Price Case

Below are Key Drivers for Which Assumptions are Selected and Combined to Create the Cases in Each Column		Low Gas Price Case (output price is low, not input)	**Rice University CA-specific Constrained Reference Case**
Economy/ Demographics	GDP	Slower GDP and Manufacturing Output	**IMF through 2015; after GDP grows using relation between US and UK historical growth at different per capita income levels, converging across countries over time**
	Population	Reference Case Values	**UN median case 2008 Revision avg growth to 2050 = 0.703% http://esa.un.org/unpd/wpp2008/all-wpp-indicators_components.htm**
	Personal Income		
Weather	Temperature - degree days	Reference Case Values	**Average 1989 to 2009 NOAA Recorded by state**
Electiricty, Natural Gas and Fuel Prices	Initial Electricity price by sector and elasticities	Reduce the coefficient on gas' share of electricity demand	**elasticity of higher electricity demand = 1.089**
	Initial gas price by sector and elasticities	Reference Case Values	**own price elasticity for NG is -0.442**
	Cross-price elasticities for substitute fuels (e.g., oil)	Reference Case Values	**oil = 0.238 & coal = 0.108 & Renewables = -0.189**
Precipitation	Amount of Hydroelectric generation	Reference Case Values	**No Explicit Precip Assumption other than renewables INCLUDING conv hydro and use of CA/US historical relationship between renewables and total electricity generation**
GHG and Energy Policy Incentives & Constraints (These drivers affect gas demand via their effects on end use gas demand, end use electricity demand, and/or electricity supply alternatives).	GHG Regulations	More Nukes or CCS allow Reduction in Gas Burn	**None but gas-fired gen grows as much as if GHG were in place**
	Energy Efficiency	High EE reduces electricity and gas demand growth by half	**US load grows at 1.12% compared to EIA Fig 69 3-yr rollng avg in same range; CA grows at 1.61%**
	Central Station Renewable Generation	Grow Renewables Excl Conv Hydro to 20% of US Demand	**Renewables Excl Conv Hydro becomes 12.5% of U.S. portfolio by 2040 and 44% of CA (reality check against CA gas burn)**
	Combined Heat & Power	Impact depends on assumed fuel source and efficiency	**AEO 2010 shows CHP purch and own use but not by generation fuel/not explicitly broken out in RWGTM**
	Distributed Generation	Impact depends on assumed fuel source and efficiency	**all initially as assumed in AEO 2010 reference case (Zero DG in AEO 2010)/not explicitly broken out in RWGTM**
	Transportation Electricity/NG Use	Reference Case Values	**AEO 2010 shows electricity demand for transportation in CA of 0.49 Gwh growing at 4.1%/not explicitly broken out in RWGTM**
	Other	Go to bottom of 95% conf interval on all demand coefficients	**N/A**
Environ mental Protecti on and Public Safety	Environmental Compliance Costs	Reference Case Values	**includes Marcellus NY moratorium + limits on Montana Front Range + no OCS expansion**
	Public Safety Compliance costs	Reference Case Values	**None**
Supply	Technology	Reference Case Values	**Learning factor rate: approx. 1%/yr improvement**
	Production Cost	Reference Case Values	**RWGTM Supply Curves**

High CA Gas Demand

Below are Key Drivers for Which Assumptions are Selected and Combined to Create the Cases in Each Column		High CA Gas Demand Case (output demand is high, not input)	**Rice University CA-specific Constrained Reference Case**
Economy/ Demographics	GDP	Higher GDP growth	**IMF through 2015; after GDP grows using relation between US and UK historical growth at different per capita income levels, converging across countries over time**
	Population	Higher CA Population Growth	**UN median case 2008 Revision avg growth to 2050 = 0.703% http://esa.un.org/unpd/wpp2008/all-wpp-indicators_components.htm**
	Personal Income		
Weather	Temperature - degree days	Reference Case Values	**Average 1989 to 2009 NOAA Recorded by state**
Electiricty, Natural Gas and Fuel Prices	Initial Electricity price by sector and elasticities	Reference Case Values	**elasticity of higher electricity demand = 1.089**
	Initial gas price by sector and elasticities	Reference Case Values	**own price elasticity for NG is -0.442**
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Precipitation	Amount of Hydroelectric generation	Reference Case Values	**No Explicit Precip Assumption other than renewables INCLUDING conv hydro and use of CA/US historical relationship between renewables and total electricity generation**
GHG and Energy Policy Incentives & Constraints (These drivers affect gas demand via their effects on end use gas demand, end use electricity demand, and/or electricity supply alternatives).	GHG Regulations	Reference Case Values	**None but gas-fired gen grows as much as if GHG were in place**
	Energy Efficiency	Only half of load reduction desired by EE is achieved	**US load grows at 1.12% compared to EIA Fig 69 3-yr rollng avg in same range; CA grows at 1.61%**
	Central Station Renewable Generation	Assume CA gets only to 25% Renewables	**Renewables Excl Conv Hydro becomes 12.5% of U.S. portfolio by 2040 and 44% of CA (reality check against CA gas burn)**
	Combined Heat & Power	Impact depends on assumed fuel source and efficiency	**AEO 2010 shows CHP purch and own use but not by generation fuel/not explicitly broken out in RWGTM**
	Distributed Generation	Impact depends on assumed fuel source and efficiency	**all initially as assumed in AEO 2010 reference case (Zero DG in AEO 2010)/not explicitly broken out in RWGTM**
	Transportation Electricity/NG Use	Reference Case Values	**AEO 2010 shows electricity demand for transportation in CA of 0.49 Gwh growing at 4.1%/not explicitly broken out in RWGTM**
	Other	n/a	**N/A**
Environ mental Protecti on and Public Safety	Environmental Compliance Costs	Reference Case Values	**includes Marcellus NY moratorium + limits on Montana Front Range + no OCS expansion**
	Public Safety Compliance costs	Reference Case Values	**None**
Supply	Technology	Reference Case Values	**Learning factor rate: approx. 1%/yr improvement**
	Production Cost	Reference Case Values	**RWGTM Supply Curves**

Low CA Gas Demand

Below are Key Drivers for Which Assumptions are Selected and Combined to Create the Cases in Each Column		Low CA Gas Demand Case (output demand is low, not input)	**Rice University CA-specific Constrained Reference Case**
Economy/ Demographics	GDP	Lower GDP growth	**IMF through 2015; after GDP grows using relation between US and UK historical growth at different per capita income levels, converging across countries over time**
	Population	Lower CA Population Growth	**UN median case 2008 Revision avg growth to 2050 = 0.703% http://esa.un.org/unpd/wpp2008/all-wpp-indicators_components.htm**
	Personal Income		
Weather	Temperature - degree days	Reference Case Values	**Average 1989 to 2009 NOAA Recorded by state**
Electiricty, Natural Gas and Fuel Prices	Initial Electricity price by sector and elasticities	Reference Case Values	**elasticity of higher electricity demand = 1.089**
	Initial gas price by sector and elasticities	Reference Case Values	**own price elasticity for NG is -0.442**
	Cross-price elasticities for substitute fuels (e.g., oil)	Reference Case Values	**oil = 0.238 & coal = 0.108 & Renewables = -0.189**
Precipitation	Amount of Hydroelectric generation	Reference Case Values	**No Explicit Precip Assumption other than renewables INCLUDING conv hydro and use of CA/US historical relationship between renewables and total electricity generation**
GHG and Energy Policy Incentives & Constraints (These drivers affect gas demand via their effects on end use gas demand, end use electricity demand, and/or electricity supply alternatives).	GHG Regulations	Carbon adder on CA gas consumption?	**None but gas-fired gen grows as much as if GHG were in place**
	Energy Efficiency	EE reduces CA demand growth to 1% -- reality check with DAO	**US load grows at 1.12% compared to EIA Fig 69 3-yr rollng avg in same range; CA grows at 1.61%**
	Central Station Renewable Generation	Assume CA gets to 50% Renewables	**Renewables Excl Conv Hydro becomes 12.5% of U.S. portfolio by 2040 and 44% of CA (reality check against CA gas burn)**
	Combined Heat & Power	Impact depends on assumed fuel source and efficiency	**AEO 2010 shows CHP purch and own use but not by generation fuel/not explicitly broken out in RWGTM**
	Distributed Generation	Impact depends on assumed fuel source and efficiency	**all initially as assumed in AEO 2010 reference case (Zero DG in AEO 2010)/not explicitly broken out in RWGTM**
	Transportation Electricity/NG Use	Reference Case Values	**AEO 2010 shows electricity demand for transportation in CA of 0.49 Gwh growing at 4.1%/not explicitly broken out in RWGTM**
	Other	n/a	**N/A**
Environ mental Protecti on and Public Safety	Environmental Compliance Costs	Reference Case Values	**includes Marcellus NY moratorium + limits on Montana Front Range + no OCS expansion**
	Public Safety Compliance costs	Reference Case Values	**None**
Supply	Technology	Reference Case Values	**Learning factor rate: approx. 1%/yr improvement**
	Production Cost	Reference Case Values	**RWGTM Supply Curves**

Stressed CA High Gas Demand

Below are Key Drivers for Which Assumptions are Selected and Combined to Create the Cases in Each Column		Stressed **High** CA Demand Case (higher econ/demo; lower temps, hydro-generation)	**Rice University CA-specific Constrained Reference Case**
Economy/ Demographics	GDP	Higher GDP growth	**IMF through 2015; after GDP grows using relation between US and UK historical growth at different per capita income levels, converging across countries over time**
	Population	Higher CA Population Growth	**UN median case 2008 Revision avg growth to 2050 = 0.703% http://esa.un.org/unpd/wpp2008/all-wpp-indicators_components.htm**
	Personal Income		
Weather	Temperature - degree days	Colder winter and hotter summer than in Reference Case	**Average 1989 to 2009 NOAA Recorded by state**
Electiricty, Natural Gas and Fuel Prices	Initial Electricity price by sector and elasticities	Reference Case Values	**elasticity of higher electricity demand = 1.089**
	Initial gas price by sector and elasticities	Reference Case Values	**own price elasticity for NG is -0.442**
	Cross-price elasticities for substitute fuels (e.g., oil)	Reference Case Values	**oil = 0.238 & coal = 0.108 & Renewables = -0.189**
Precipitation	Amount of Hydroelectric generation	Low Hydro increases CA gas demand by 15%	**No Explicit Precip Assumption other than renewables INCLUDING conv hydro and use of CA/US historical relationship between renewables and total electricity generation**
GHG and Energy Policy Incentives & Constraints (These drivers affect gas demand via their effects on end use gas demand, end use electricity demand, and/or electricity supply alternatives).	GHG Regulations	Reference Case Values	**None but gas-fired gen grows as much as if GHG were in place**
	Energy Efficiency	Only half of load reduction desired by EE is achieved	**US load grows at 1.12% compared to EIA Fig 69 3-yr rollng avg in same range; CA grows at 1.61%**
	Central Station Renewable Generation	Assume CA gets only to 25% Renewables	**Renewables Excl Conv Hydro becomes 12.5% of U.S. portfolio by 2040 and 44% of CA (reality check against CA gas burn)**
	Combined Heat & Power	Impact depends on assumed fuel source and efficiency	**AEO 2010 shows CHP purch and own use but not by generation fuel/not explicitly broken out in RWGTM**
	Distributed Generation	Impact depends on assumed fuel source and efficiency	**all initially as assumed in AEO 2010 reference case (Zero DG in AEO 2010)/not explicitly broken out in RWGTM**
	Transportation Electricity/NG Use	Reference Case Values	**AEO 2010 shows electricity demand for transportation in CA of 0.49 Gwh growing at 4.1%/not explicitly broken out in RWGTM**
	Other	n/a	**N/A**
Environ mental Protecti on and Public Safety	Environmental Compliance Costs	Reference Case Values	**includes Marcellus NY moratorium + limits on Montana Front Range + no OCS expansion**
	Public Safety Compliance costs	Reference Case Values	**None**
Supply	Technology	Reference Case Values	**Learning factor rate: approx. 1%/yr improvement**
	Production Cost	Reference Case Values	**RWGTM Supply Curves**

Stressed CA Low Gas Demand

Below are Key Drivers for Which Assumptions are Selected and Combined to Create the Cases in Each Column		Stressed **Low** CA Demand Case (higher econ/demo; higher temps, hydro-generation)	**Rice University CA-specific Constrained Reference Case**
Economy/ Demographics	GDP	Lower GDP growth	**IMF through 2015; after GDP grows using relation between US and UK historical growth at different per capita income levels, converging across countries over time**
	Population	Lower CA Population Growth	**UN median case 2008 Revision avg growth to 2050 = 0.703% http://esa.un.org/unpd/wpp2008/all-wpp-indicators_components.htm**
	Personal Income		
Weather	Temperature - degree days	Warmer winter and cooler summer than in Reference Case	**Average 1989 to 2009 NOAA Recorded by state**
Electricty, Natural Gas and Fuel Prices	Initial Electricity price by sector and elasticities	Reference Case Values	**elasticity of higher electricity demand = 1.089**
	Initial gas price by sector and elasticities	Reference Case Values	**own price elasticity for NG is -0.442**
	Cross-price elasticities for substitute fuels (e.g., oil)	Reference Case Values	**oil = 0.238 & coal = 0.108 & Renewables = -0.189**
Precipitation	Amount of Hydroelectric generation	High Hydro reduces CA gas demand by 12%	**No Explicit Precip Assumption other than renewables INCLUDING conv hydro and use of CA/US historical relationship between renewables and total electricity generation**
GHG and Energy Policy Incentives & Constraints (These drivers affect gas demand via their effects on end use gas demand, end use electricity demand, and/or electricity supply alternatives).	GHG Regulations	Carbon adder on CA gas consumption?	**None but gas-fired gen grows as much as if GHG were in place**
	Energy Efficiency	EE reduces CA demand growth to 1% -- reality check with DAO	**US load grows at 1.12% compared to EIA Fig 69 3-yr rollng avg in same range; CA grows at 1.61%**
	Central Station Renewable Generation	Assume CA gets to 50% Renewables	**Renewables Excl Conv Hydro becomes 12.5% of U.S. portfolio by 2040 and 44% of CA (reality check against CA gas burn)**
	Combined Heat & Power	Impact depends on assumed fuel source and efficiency	**AEO 2010 shows CHP purch and own use but not by generation fuel/not explicitly broken out in RWGTM**
	Distributed Generation	Impact depends on assumed fuel source and efficiency	**all initially as assumed in AEO 2010 reference case (Zero DG in AEO 2010)/not explicitly broken out in RWGTM**
	Transportation Electricity/NG Use	Reference Case Values	**AEO 2010 shows electricity demand for transportation in CA of 0.49 Gwh growing at 4.1%/not explicitly broken out in RWGTM**
	Other	n/a	**N/A**
Environ mental Protecti on and Public Safety	Environmental Compliance Costs	Reference Case Values	**includes Marcellus NY moratorium + limits on Montana Front Range + no OCS expansion**
	Public Safety Compliance costs	Reference Case Values	**None**
Supply	Technology	Reference Case Values	**Learning factor rate: approx. 1%/yr improvement**
	Production Cost	Reference Case Values	**RWGTM Supply Curves**

Increased Environmental Mitigation Costs
Single Variable Sensitivity

Below are Key Drivers for Which Assumptions are Selected and Combined to Create the Cases in Each Column		Increased Environmental Mitigation Cost for Drilling and Production Case	**Rice University CA-specific Constrained Reference Case**
Economy/ Demographics	GDP	Reference Case Values	**IMF through 2015; after GDP grows using relation between US and UK historical growth at different per capita income levels, converging across countries over time**
	Population	Reference Case Values	**UN median case 2008 Revision avg growth to 2050 = 0.703% http://esa.un.org/unpd/wpp2008/all-wpp-indicators_components.htm**
	Personal Income		
Weather	Temperature - degree days	Reference Case Values	**Average 1989 to 2009 NOAA Recorded by state**
Electiricty, Natural Gas and Fuel Prices	Initial Electricity price by sector and elasticities	Reference Case Values	**elasticity of higher electricity demand = 1.089**
	Initial gas price by sector and elasticities	Reference Case Values	**own price elasticity for NG is -0.442**
	Cross-price elasticities for substitute fuels (e.g., oil)	Reference Case Values	**oil = 0.238 & coal = 0.108 & Renewables = -0.189**
Precipitation	Amount of Hydroelectric generation	Reference Case Values	**No Explicit Precip Assumption other than renewables INCLUDING conv hydro and use of CA/US historical relationship between renewables and total electricity generation**
GHG and Energy Policy Incentives & Constraints (These drivers affect gas demand via their effects on end use gas demand, end use electricity demand, and/or electricity supply alternatives).	GHG Regulations	Reference Case Values	**None but gas-fired gen grows as much as if GHG were in place**
	Energy Efficiency	Reference Case Values	**US load grows at 1.12% compared to EIA Fig 69 3-yr rollng avg in same range; CA grows at 1.61%**
	Central Station Renewable Generation	Reference Case Values	**Renewables Excl Conv Hydro becomes 12.5% of U.S. portfolio by 2040 and 44% of CA (reality check against CA gas burn)**
	Combined Heat & Power	Reference Case Values	**AEO 2010 shows CHP purch and own use but not by generation fuel/not explicitly broken out in RWGTM**
	Distributed Generation	Reference Case Values	**all initially as assumed in AEO 2010 reference case (Zero DG in AEO 2010)/not explicitly broken out in RWGTM**
	Transportation Electricity/NG Use	Reference Case Values	**AEO 2010 shows electricity demand for transportation in CA of 0.49 Gwh growing at 4.1%/not explicitly broken out in RWGTM**
	Other	n/a	**N/A**
Environ mental Protecti on and Public Safety	Environmental Compliance Costs	Could add PA Compliance Charge ($0.40 to $0.80 per MMBtu) to O&M Cost	**includes Marcellus NY moratorium + limits on Montana Front Range + no OCS expansion**
	Public Safety Compliance costs	Reference Case Values	**None**
Supply	Technology	Reference Case Values	**Learning factor rate: approx. 1%/yr improvement**
	Production Cost	Could shift supply curves leftward to reduce supply available as public concern limits drilling	**RWGTM Supply Curves**

Reduced Pipeline Pressure
Single Variable Sensitivity

Below are Key Drivers for Which Assumptions are Selected and Combined to		Reduced Pipeline Pressure Case	**Rice University CA-specific Constrained Reference Case**
Economy/ Demographics	GDP	Reference Case Values	**IMF through 2015; after GDP grows using relation between US and UK historical growth at different per capita income levels, converging across countries over time**
	Population	Reference Case Values	**UN median case 2008 Revision avg growth to 2050 = 0.703% http://esa.un.org/unpd/wpp2008/all-wpp-indicators_components.htm**
	Personal Income		
Weather	Temperature - degree days	Use extreme weather so can see how lower capacity affects system at limits	**Average 1989 to 2009 NOAA Recorded by state**
Electricity, Natural Gas and Fuel Prices	Initial Electricity price by sector and elasticities	Reference Case Values	**elasticity of higher electricity demand = 1.089**
	Initial gas price by sector and elasticities	Reference Case Values	**own price elasticity for NG is -0.442**
	Cross-price elasticities for substitute fuels (e.g., oil)	Reference Case Values	**oil = 0.238 & coal = 0.108 & Renewables = -0.189**
Precipitation	Amount of Hydroelectric generation	Reference Case Values	**No Explicit Precip Assumption other than renewables INCLUDING conv hydro and use of CA/US historical relationship between renewables and total electricity generation**
GHG and Energy Policy Incentives & Constraints (These drivers affect gas demand via their effects on end use gas demand, end use electricity demand, and/or electricity supply alternatives).	GHG Regulations	Reference Case Values	**None but gas-fired gen grows as much as if GHG were in place**
	Energy Efficiency	Reference Case Values	**US load grows at 1.12% compared to EIA Fig 69 3-yr rollng avg in same range; CA grows at 1.61%**
	Central Station Renewable Generation	Reference Case Values	**Renewables Excl Conv Hydro becomes 12.5% of U.S. portfolio by 2040 and 44% of CA (reality check against CA gas burn)**
	Combined Heat & Power	Reference Case Values	**AEO 2010 shows CHP purch and own use but not by generation fuel/not explicitly broken out in RWGTM**
	Distributed Generation	Reference Case Values	**all initially as assumed in AEO 2010 reference case (Zero DG in AEO 2010)/not explicitly broken out in RWGTM**
	Transportation Electricity/NG Use	Reference Case Values	**AEO 2010 shows electricity demand for transportation in CA of 0.49 Gwh growing at 4.1%/not explicitly broken out in RWGTM**
	Other	n/a	**N/A**
Environmental Protection and Public Safety	Environmental Compliance Costs	Reference Case Values	**includes Marcellus NY moratorium + limits on Montana Front Range + no OCS expansion**
	Public Safety Compliance costs	could either add cost to PG&E backbone OR reduce capacity	**None**
Supply	Technology	Reference Case Values	**Learning factor rate: approx. 1%/yr improvement**
	Production Cost	Reference Case Values	**RWGTM Supply Curves**