LONG-TERM ASSESSMENT OF NATURAL GAS INFRASTRUCTURE TO SERVE ELECTRIC GENERATION NEEDS WITHIN ERCOT

Prepared for

The Electric Reliability Council of Texas

JUNE 2013

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1.0 Introduction

Low natural gas prices in conjunction with environmental regulations are driving retirements of coal-fired generation capacity and a shift towards more natural gas fired generation capacity. As the dependence on natural gas as a fuel for electric generation grows, there is a need to understand the ability of the natural gas infrastructure to reliably serve electric generation needs.

The Electric Reliability Council of Texas (ERCOT) commissioned Black & Veatch to perform a Gas Curtailment Risk Study in 2012[1] to evaluate the risk of natural gas supply disruptions to electric generating stations within the ERCOT administered portion of Texas over one, five and ten year periods. The study was intended to increase ERCOT's understanding of the risks of generation loss from gas supply curtailment in the future and to consider potential mitigation measures that ERCOT can pursue to reduce risks arising from these curtailments.

The current study has been commissioned by ERCOT to assess the long-term ability of the natural gas infrastructure to serve electric generation needs within the ERCOT service region between 2020 and 2030. Both studies are part of a larger long-term transmission planning effort undertaken by ERCOT and funded by the Department of Energy.[2]

2.0 Scope of Work

In this study, Black & Veatch reviews current and projected natural gas fired generation and the sufficiency of natural gas infrastructure to support power generation needs in ERCOT. Scenario analysis of extreme supply and demand scenarios are analyzed to assess the ability of the natural gas infrastructure to serve electric generation demand under more stressed market conditions. Black & Veatch also reviews potential locational constraints in adding natural gas infrastructure needed to support electric generation needs. The scope of this study is:

A. Review of current natural gas-fired electric generation with ERCOT and current natural gas infrastructure supporting power generation needs within ERCOT
B. Review of projected natural gas demand for electric generation in 2020-2030
C. Assessment of sufficiency of natural gas infrastructure to serve electric generation needs
D. Identification of locational constraints in adding natural gas infrastructure needed to support electric generation needs

[1] *Gas Curtailment Risk Study*, Prepared for ERCOT by Black & Veatch, March 2012.
[2] *ERCOT Interconnection Long-Term Transmission Analysis*, *2012-2032*, ERCOT, Summer 2013.

3.0 Study Approach & Assumptions

3.1 FUNDAMENTAL MODEL

Black & Veatch utilized a fundamental market model[3] as a basis to analyze the ERCOT and surrounding regions' natural gas market infrastructure. The network model nodes represent production regions, pipelines, storage facilities, and end-use customer groups. The fundamental model balances supply and demand from all the regions to find equilibrium prices and quantities that maximize producer profit and minimize consumer cost. Black & Veatch supports the fundamental model with a detailed database of proprietary and public sources that was modified to support the assumptions and scenarios for this study.

One of the challenges of understanding the risk of gas curtailment to electric generators within ERCOT is to determine the demand placed on the pipelines serving these electric generators by other sources – residential, commercial, and industrial demand within ERCOT's region as well as demand from outside ERCOT's region that are served by the same pipelines. By representing the entire natural gas infrastructure within North America, the fundamental model offers an efficient and effective methodology to model the impact of the total demand on the pipeline network from other sources within and outside of ERCOT's region. The fundamental model captures both interstate and intrastate pipeline segments.

Black & Veatch utilized the fundamental model to assess the constraints within the natural gas infrastructure, in responding to demand from the electric generation sector within ERCOT under the different defined scenarios. For each scenario, a corresponding estimate of demand, supply and any applicable scenario-specific infrastructure constraints were defined.

3.2 KEY ASSUMPTIONS

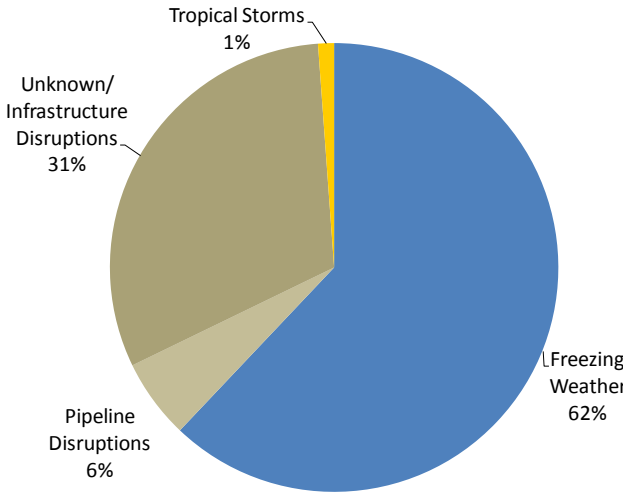
Black & Veatch utilized inputs from ERCOT's Long-Term Transmission Analysis[4] to establish electric generation assumptions within ERCOT. At ERCOT's request, Black & Veatch utilized assumptions and outputs of the Business as Usual with All Tech Scenario, developed to be consistent with EIA's Annual Energy Outlook, and designed to simulate today's market conditions, extended 20 years into the future. For all other remaining North American markets, Black & Veatch utilized its 2013 Energy Market Perspective ("EMP") to derive assumptions on electric generation. EMP is a proprietary, integrated view of natural gas and power markets across North America, and the northern portion of Baja California, Mexico, that is electrically interconnected to the U.S. In order to arrive at this market view, Black & Veatch draws on a number of commercial data sources and supplements them with our own view on several key market drivers, for example, power plant capital costs, environmental and regulatory policy, fuel basin exploration and development costs, and gas pipeline expansion.

[3] RBAC, Inc.'s GPCM® Natural Gas Market Forecasting System
[4] *ERCOT Interconnection Long-Term Transmission Analysis*, *2012-2032*, ERCOT, Summer 2013.

3.3 SCENARIOS EXAMINED

Black & Veatch analyzed the sufficiency of natural gas infrastructure serving ERCOT's electric generation needs under a Base Case as well as different supply-demand scenarios. The scenarios examined were based on an examination of historical records of gas supply curtailment during Black & Veatch's Gas Curtailment Risk Study for ERCOT from sources including ERCOT, the National Energy Technology Laboratory ("NETL") and the Railroad Commission of Texas ("TRRC"). As shown in Figure 1 , the leading cause of historical gas supply curtailment incidents identified was freezing weather, with pipeline/infrastructure disruptions and tropical cyclones being inferred as having caused the other historical incidents of curtailment reviewed.

Figure 1: Historical Texas Gas Supply Curtailment Events



This study, therefore, examines the ability of the natural gas infrastructure to support electric generation needs within the ERCOT service region under extreme scenarios driven by these identified causes[5]:

- Cold weather
- Pipeline disruptions
- Tropical storms

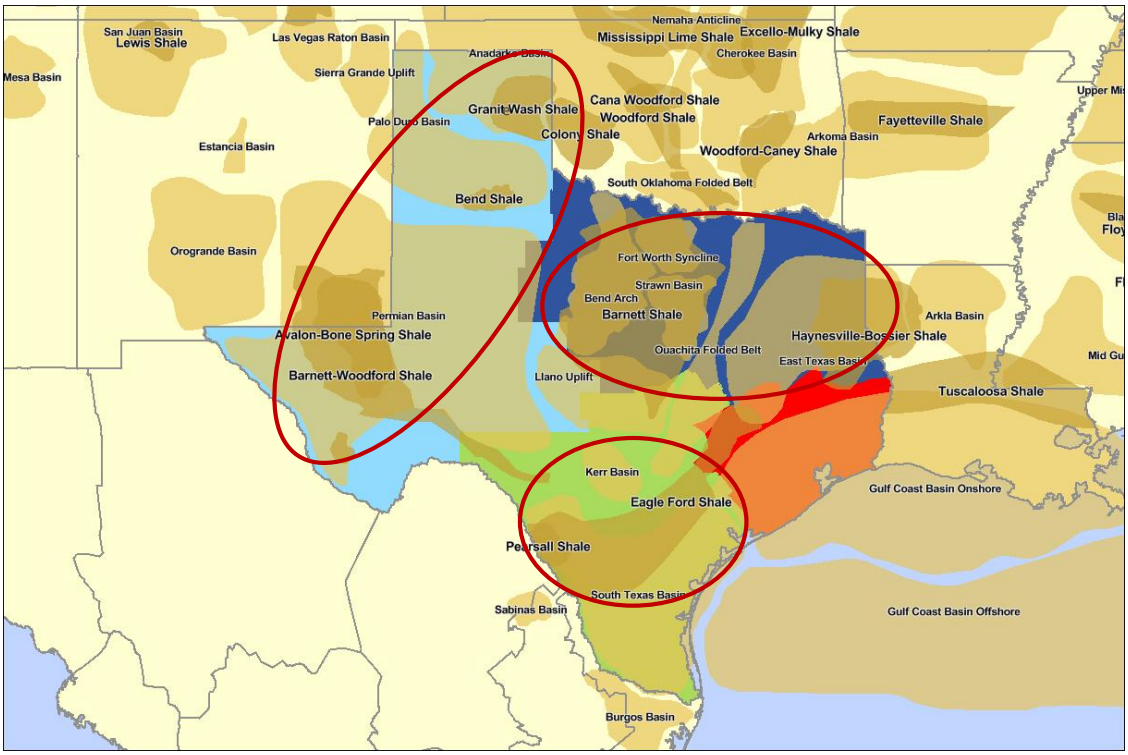
[5] In addition to these scenarios, we also examined additional export demand from incremental LNG exports and pipeline exports to Mexico as a way of demonstrating the pipeline utilization and price impacts from these emerging demand sources. The results from these scenarios are included as an Appendix to the study.

4.0 Key Observations and Conclusions

Texas Enjoys Well Developed Natural Gas Infrastructure & Robust Production Growth Forecasts

Texas is a major natural gas producing state with production from conventional resources as well as unconventional natural gas resources from the Barnett Shale in the North, Granite Wash in the Panhandle region and Eagle Ford Shale in the South as shown in Figure 2. Pipelines located in the South zone of ERCOT also provide access to offshore Gulf of Mexico ("GOM") production.

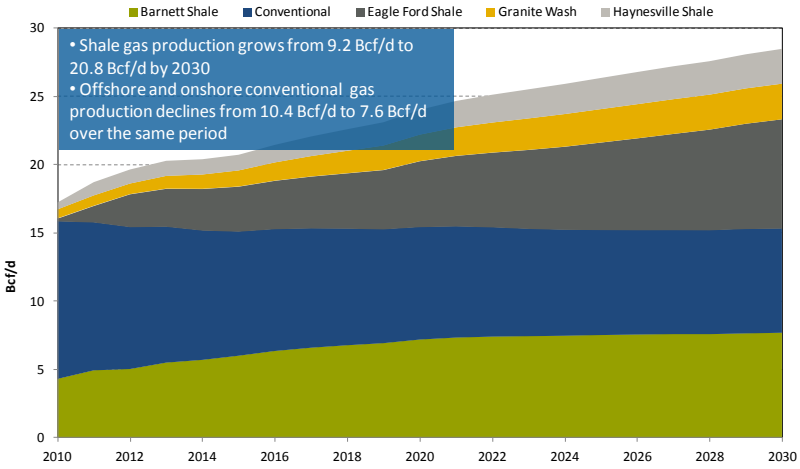
Figure 2: Texas Natural Gas Production Basins



Natural gas production in Texas is expected to grow by 8.5 billion cubic feet per day ("Bcf/d"), as shown in Figure 3 with growth in unconventional production expected to offset declines in conventional production. Multiple interstate and intrastate pipelines traverse Texas designed to move gas from production areas to consuming areas both within and outside Texas. Approximately 600 Bcf of natural gas storage capacity is located throughout the state to help manage seasonal demand fluctuations. The existing natural gas infrastructure is sufficient to meet the current needs from the power sector as evidenced by the relative stability of regional natural gas prices. For example, over the past three years, natural gas prices across Texas have averaged $0.04/MMBtu below Henry Hub, a pricing point in Louisiana that is considered as reflecting overall natural gas market conditions in the U.S.

Shale gas production has created supply sources in regions that have historically been consuming markets and altered traditional pipeline flows. Emerging Marcellus and Utica Shale production growth in Pennsylvania and Ohio has reduced the demand for interstate natural gas pipeline flows from Texas to Northeast and Southeast markets. Reduced pipeline flows out of Texas are expected to make more interstate pipeline capacity available to the Texas market while reducing pipeline constraints.

Figure 3: Texas Natural Gas Production by Region



Natural Gas Fired Generation Capacity is Expected to Increase in ERCOT as well as Lower-48

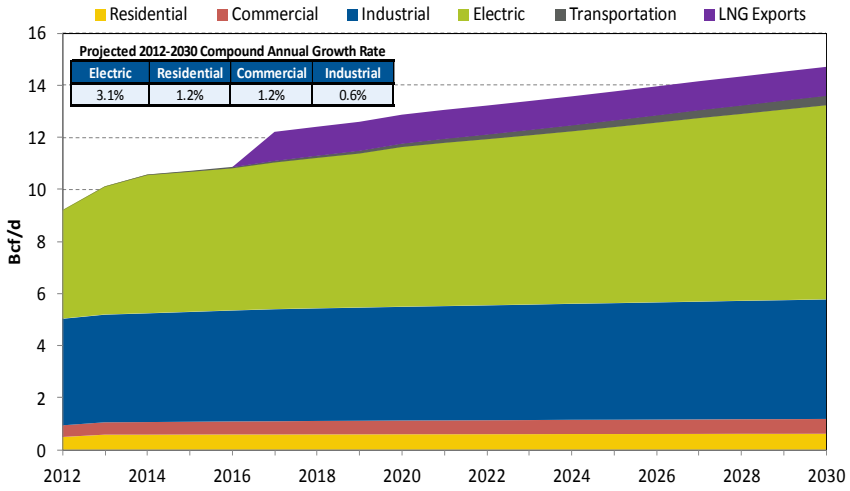
The study period between 2020 and 2030 is marked by expectations of significant growth in the use of natural gas for electric generation in North America driven by environmental policies and resulting coal-fired electric generation plant retirements and the cost competitiveness of natural gas technology compared to other fuel sources on a fixed and variable cost basis. ERCOT currently has 75,000 MW of total generation capacity, 43,000 MW of which is gas-fired generation capacity located in North, South, West and Houston zones. ERCOT's Long-Term Transmission Analysis indicates that total generation capacity within ERCOT is expected to increase to 92,000 MW by 2030 with gas-fired generation capacity additions within ERCOT expected to exceed 17,000 MW by 2030.

Lower-48 natural gas-fired generation capacity is expected to grow to represent 170,000 MW of the 290,000 MW of net generation capacity additions by 2030. This strong trend towards additional natural gas-fired generation capacity within ERCOT as well as the Lower-48 as a whole is expected to create new demand for natural gas and place greater strain on natural gas infrastructure.

Natural Gas Demand Growth in Texas is Expected to be Driven by Consumption from the Power Sector

Black & Veatch projects a moderate growth rate of 1.2% in residential and commercial demand for natural gas within Texas from 2013 through 2030. Industrial demand for natural gas is meanwhile expected to grow from 4.1 Bcf/d in 2013 to 4.6 Bcf/d by 2030 driven by low, competitive gas prices.

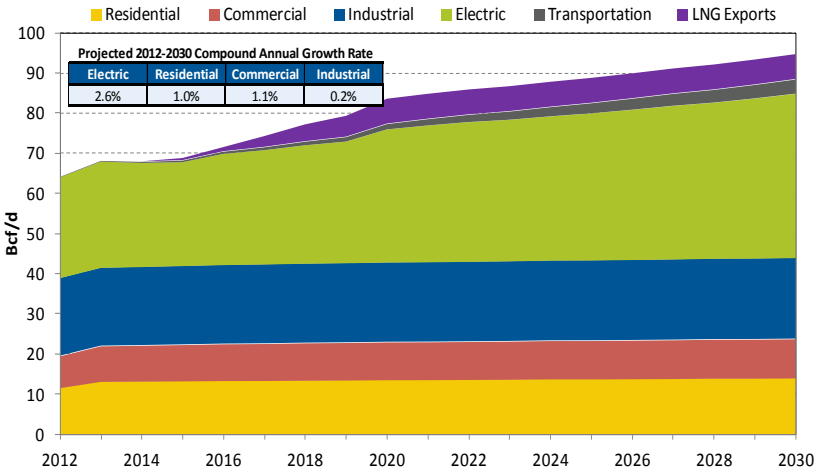
Figure 4: Texas Natural Gas Demand



Given modest demand growth in residential, commercial and industrial demand, electric generation is expected to be the biggest driver of natural gas demand growth, by far, both within Texas and the U.S. as a whole. Figure 5 shows that the projected increase in natural gas demand for electric generation within Texas from 4.2 Bcf/d in 2012 to 7.4 Bcf/d in 2030, at an annual growth rate of 3.1%. Power generation demand is expected to comprise 49% of total natural gas demand by 2030 within Texas.

A similar trend is projected for the Lower-48 as a whole with retirement of coal-fired generation capacity in the Midwest and in PJM creating key drivers for growth of natural gas demand for power generation as natural gas fired capacity helps meet load requirements in these regions. Figure 5 shows that the projected increase in natural gas demand for electric generation in the Lower 48 is expected to grow from 26.5 Bcf/d in 2013 to 41 Bcf/d in 2030, at an annual growth rate of 2.6%. Power generation demand is expected to comprise 44% of total natural gas demand by 2030 in the Lower-48.

Figure 5: U.S. Lower 48 Natural Gas Demand



Natural Gas Infrastructure is Sufficient to Support Electric Generation in ERCOT during the Period of 2020 through 2030 under Base Case Conditions

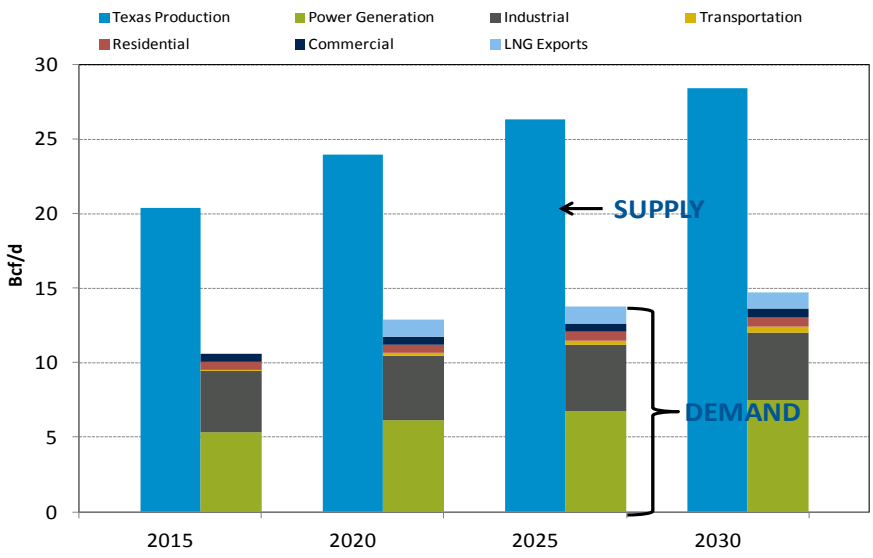
Black & Veatch's analysis shows that all four transmission zones in ERCOT will have access to sufficient natural gas infrastructure to meet their power generation needs under the Base Case scenario. Total natural gas production in Texas is projected to grow from 20 Bcf/d in 2013 to 28 Bcf/d in 2030, led by the fast growth from the Eagle Ford Shale in the South and steady output from the Barnett and Bossier Shales in the North. In aggregate, the South, West, and North transmission zones are expected to be able to export 12 Bcf/d of natural gas to Mexico, the Houston zone and downstream markets in the U.S. Southeast and Florida. Figure 6 illustrates regional production and total demand (including demand from all sectors and LNG export terminals) in ERCOT from 2015 to 2030.

Regional production in the South zone is expected to grow and indicate excess natural gas supplies of 5 Bcf/d by 2030 that can be exported via pipelines to Mexico and the Houston zone.

Similarly, the North and West zones have excess supply of 4 Bcf/d and 3 Bcf/d, respectively, by 2030.

Demand in the Houston zone relies upon imports from outside the zone. However, it has a total pipeline capacity of 6 Bcf/d from the South and 3 Bcf/d from the North, which far exceeds its 4.2 Bcf/d of local demand.

Figure 6: Projected Texas Supply and Demand Balance



Natural Gas Infrastructure is Sufficient to Support Electric Generation in ERCOT during the Period of 2020 through 2030 under Stress Scenarios

Black & Veatch tested the flexibility and adequacy of the natural gas infrastructure in Texas with extreme weather and supply conditions. Two extreme cold weather scenarios were examined to replicate low probability but plausible conditions: Cold Texas which examined the impact of extreme cold weather in Texas alone, and Cold Texas and Outside, which examined the impact of extreme cold weather in Texas as well as markets in the U.S. Northeast, Southeast and Midwest.

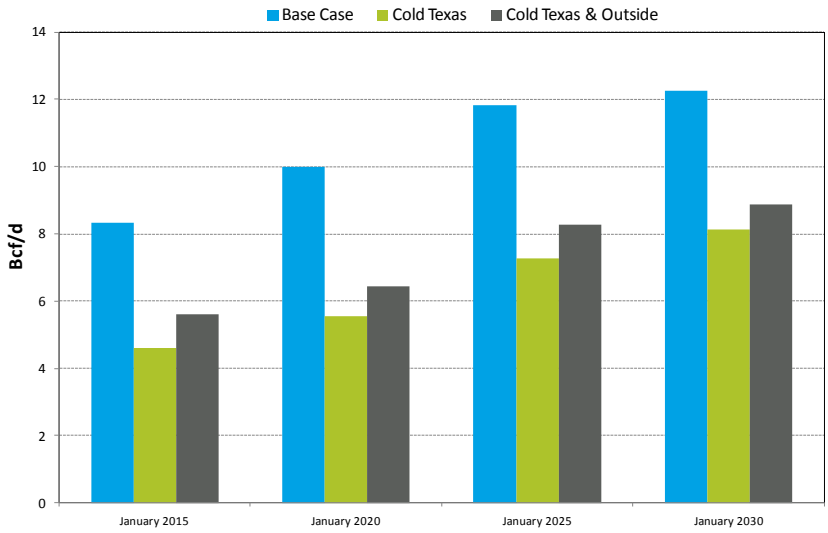
The extreme cold weather considered for each scenario assumed the cold end of average daily winter temperatures corresponding to the 95th percentile for each region; i.e., there is only a 5% probability that the temperature in the region will be lower than the assumed extreme cold temperature. For each scenario examined, a corresponding assumption on the increased demand for natural gas for heating purposes was developed based on historical data. The impact of freezing weather of simultaneously reducing natural gas supply due to production well freeze offs was also incorporated.

The Cold Texas scenario is designed to explore an extremely cold January that could cause residential, commercial and power sectors' demand for natural gas for heating within Texas to increase while natural gas supply simultaneously decreases due to production well freeze offs. The net impact on the Texas natural gas market in the Cold Texas scenario is 6 Bcf/d of combined demand increase and supply reduction.

The Cold Texas and Cold Outside scenario with cold weather within Texas accompanied by cold weather in the U.S. Southeast, Northeast and Mid-Continent results in competing demand for natural gas within Texas as well as markets downstream of Texas. In all, a net incremental demand of 10 Bcf/d for natural gas due to colder weather was assumed in this stress scenario.

The assessment examined the supply-demand balance within these extreme cold weather scenarios. The supply-demand balance indicated that even under the extreme cold weather scenarios, the projected supply in Texas exceeds regional demand for natural gas throughout the study period. Texas continues to export gas to other markets under the extreme cold weather scenarios, albeit at reduced levels as shown in Figure 7.

Figure 7: Projected Net Pipeline Exports from Texas



Market price responses offer another indicator of tightness in the natural gas market. An increase in overall price level is an indicator that more expensive supply is needed to meet the level of demand experienced in the market. An equally important indicator of regional constraint is basis, which is defined as the difference between regional natural gas prices and prices at the Henry Hub in Louisiana. When regional basis is high and separates from other markets, it provides an indication of constraints in the local market.

Under the Cold Texas scenario, overall price levels as well as basis in the Texas market rise. However, the increases in absolute price and basis are modest, indicating that the natural gas infrastructure is able to respond to and serve the incremental demand assumed.

Under the Cold Texas and Outside scenario, significant price impacts are observed across the U.S. while regional basis in Texas remains low indicating that Texas experiences relatively lower constraints in meeting the additional demand associated with the extreme cold weather scenario.

The next stress scenario examined the risk of disruption of natural gas supply to electric generators within ERCOT's service region caused by production shut-ins in the Gulf of Mexico driven by tropical cyclones. Historical data for the period 1981-2011 covering a total of 111 tropical cyclones, 25 of which made landfall in Texas was utilized to establish the level of production shut-in at 46% of the total Gulf of Mexico offshore production corresponding to a 95th percentile of risk (i.e., there is only a 5% chance of cyclone related production shut-ins impacting more than 46% of the offshore GOM production).

The primary result of the assessment is that there is minimal disruption of gas supply within Texas because much of Texas demand is served by local onshore production. Offshore production comprises only 2%-4% of total production in Texas. The loss of this production does not constrain access to supply for Texas consumers.

The study also examined the ability of the natural gas infrastructure to serve electric generators when pipeline disruptions occur. Based on the results of a survey of electric generators conducted as part of Black & Veatch's previous study for ERCOT, twenty-four electric generators are served by the Kinder Morgan Tejas Pipeline, which serves the largest number of electric generation facilities within ERCOT's service region. Our analysis reduced the capacity on this pipeline by 40% to examine the flexibility in the natural gas pipeline grid as well as in the electric generators' supply portfolios in the absence of this capacity.

Redundancy in the natural gas pipeline grid and in the transportation alternatives available to electric generators lead to increased utilization of other pipelines (primarily, Kinder Morgan Texas Pipeline in the scenario analyzed) that serve the gas demand of the customers stranded by failure of the original pipeline. Curtailment of natural gas supply was not observed in this scenario within the study period.

The study reveals that natural gas infrastructure, as represented within the fundamental model, appears to be adequate and does not act as a constraint during the stress scenarios examined. It should be noted however that localized and isolated incidents of constraints can occur on occasion at the utility or pipeline level. Although fundamental analysis indicates seamless transition in the market, it should be recognized that commercial arrangements and market inefficiencies could create challenges in the short-term to practically achieving these transitions.

Siting any New Natural Gas Infrastructure Needed will Involve Addressing Air Quality and Water Availability & Use Issues

Although no immediate constraints were identified in this study, increased production from Eagle Ford Shale in the ERCOT South zone as well as projections for strong demand growth in the ERCOT Houston zone are expected to drive higher pipeline utilization in these zones. This could create potential for increased constraints beyond the study period that may require additional natural gas infrastructure build.

At least three government agencies make authoritative decisions that affect development permits for natural gas infrastructure - Railroad Commission of Texas ("TRRC"), Texas Commission on Environmental Quality ("TCEQ") and the U.S. Environmental Protection Agency ("EPA"). At least two other government agencies can influence permit decisions affecting water or land use - Texas Water Development Board ("TWDB") and Texas Parks and Wildlife Department ("TPWD").

The main areas that need to be addressed to facilitate siting any new natural gas infrastructure needed are air quality, water availability and use and, to a lesser degree, endangered species. Air quality related to natural gas development is an issue for the Dallas, Houston and San Antonio regions with gas flaring becoming an emerging issue in the Eagle Ford region. Water availability has been recognized as an issue in the Dallas and San Antonio regions, so drought remains a concern. Endangered species (both plants and animals) are recognized by EPA/TPWD in all development areas.

Successful siting of any new natural gas infrastructure needed is expected to involve addressing these concerns. Texas has historically presented a conducive environment for the siting of energy infrastructure and this is expected to continue during the study period.