A State-Level Capacity Utilization Analysis of the U.S. Natural Gas Transmission Pipeline System and Risk Management for a Gas-Fueled Nation

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Summary:

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KEY INSIGHTS

1. Natural gas inflow and outflow capacity is constrained in some states. A lack of pipeline capacity puts some consumers at risk for supply shortages. Meanwhile, a lack of outflow lines limits production potential in new-to-market large producers such as Pennsylvania.

2. Laws and regulations play a large role in shaping energy infrastructure. The FERC approval process for new pipelines should be updated to more efficiently meet market supply and demand needs. Additionally, state energy plans may be causing some states to become overly reliant on natural gas to meet emission reduction targets.

3. Pipeline age poses a large risk to natural gas transportation. Age of manufacture was related to 3 of the 4 top causes of accidents in transmission lines between 2010 and 2018. The average year of manufacture for pipelines that experienced accidents was 1965. 60% of all interstate pipeline mileage in the U.S. was installed before 1970.

Introduction

The U.S. natural gas supply and demand market has changed drastically since the turn of the century. On the production side, horizontal drilling and hydraulic fracturing have enabled large-scale shale gas production. Capitalizing on these reserves, areas that were not previously large producers have become major suppliers. Pennsylvania, formerly a net importer of natural gas, is now second only to Texas in dry natural gas production. Geographical demand patterns are also evolving. As states like California and Florida implement policy plans to aggressively reduce emissions, in-state coal-fired power plants are rapidly being replaced with natural gas-fired plants. Many states are becoming heavily reliant on natural gas. Florida generated 62% of its electricity from natural gas in 2015, a figure that continues to increase. In 2016 Florida was the 4th largest consumer of natural gas even though it only produced very small quantities.

States with high consumption and low production demand high import volumes. Meanwhile, new large producers are demanding increased export capacity to supply the nation's growing need for fuel. Has the U.S. transmission pipeline network, largely constructed over 50 years ago, adapted to new patterns in production and consumption? Are certain states experiencing supply or demand constraints? The analysis in this thesis aims to answer these questions by calculating pipeline utilization rates. High utilization rates indicate bottlenecks in the transmission system, where certain states likely saw supply shortages or limits on production. The analysis reveals that some states do have insufficient inflow or outflow pipeline capacity that must be addressed to meet the growing demand.

New pipeline projects are proposed by companies and approved by the Federal Energy Regulatory Commission (FERC). Is this process appropriately allocating new pipeline capacity? A look at approved capacity between 2011 – 2018 reveals that it is not.

Additionally, does the age of the pipeline network pose a risk for accidents? An examination of PHMSA accident data from 2010 to today shows that 3 out of the 4 top causes of accidents are related to age.

U.S. Natural Gas Market Trends & Outlook

Data from the U.S. Energy Information Administration was analyzed in order to examine trends in recent production and consumption history. Dry natural gas production for each state was plotted for 2011 – 2016. Similarly, dry natural gas consumption, including pipeline deliveries and pipeline usage, was plotted over the same time range. This time range was chosen because the data collection method and geographical area definitions remained consistent for these years.

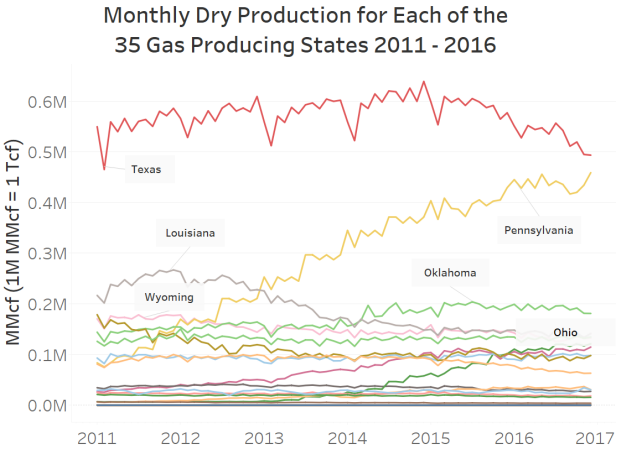

Figure 1: Monthly Natural Gas Production Volumes for U.S. States

Production volumes revealed large growth in the Marcellus shale region, especially Pennsylvania and Ohio. Growth in consumption volumes was less dramatic. Still, 41 states consumed more natural gas by the end of 2016 than at the start of 2011.

The EIA projects that natural gas production in the U.S. will grow by 30% from 2017 to 2050. The agency cites growth in shale gas, namely from plays in the northeast, as the main driver in production growth. Regarding consumption, the EIA forecasts less extreme but steady growth fueled by demand in the industrial and electric sectors. Pipeline capacity will need to scale with growing transportation demand.

Pipeline Capacity Utilization Results

In order to evaluate the current state of the pipeline system, utilization rates were calculated for natural gas inflow and outflow pipelines in each state. Each of the 48 continental U.S. states was treated as an individual entity regarding production and

consumption. Import and export volumes for each state were defined as the amount of consumption unmet by production and the amount of production in excess of consumption respectively.

State Natural Gas Import Volume Calculation:

$$IF\ Consumption\ >\ Production$$
$$THEN\ Natural\ Gas\ Import\ Volume$$
$$=\ Natural\ Gas\ Consumption\ Volume$$
$$-\ Natural\ Gas\ Production\ Volume$$
$$ELSE\ Natural\ Gas\ Import\ Volume\ =\ 0$$

State Natural Gas Export Volume Calculation:

$$IF\ Production\ >\ Consumption$$
$$THEN\ Natural\ Gas\ Export\ Volume$$
$$=\ Natural\ Gas\ Production\ Volume$$
$$-\ Natural\ Gas\ Consumption\ Volume$$
$$ELSE\ Natural\ Gas\ Export\ Volume\ =\ 0$$

This is a simple analysis that relies on several assumptions:

- All natural gas that is produced in a state is also processed in a state.
- Only processed natural gas is transported in the transmission pipeline system.
- All natural gas can be transported via any available pipeline. Variability in natural gas composition and limitations due to pipeline quality specifications are ignored.
- Natural gas crosses state borders only once.
- States are treated only as origin points or final destinations. Natural gas volumes that flow through a state are ignored.

Taking the above assumptions into consideration, the capacity analysis presented in this paper is expected to be conservative. In reality, pipeline routes are complex, gas may cross the same state boundary more than once, not all pipeline specifications are consistent, and additional volumes must flow through the pipelines for intermediate transportation purposes where the gas is neither produced nor consumed in that state. Despite the assumptions, the model yields telling results. Historically high inflow capacity utilizations calculated in the northeast during winter months coincide with real-world natural gas shortages. Relatively high export capacity utilizations in Pennsylvania match up with reported halts in state production for some wells.
The images below show the maximum monthly capacity utilization rates for both natural gas imports and exports.

Imports:

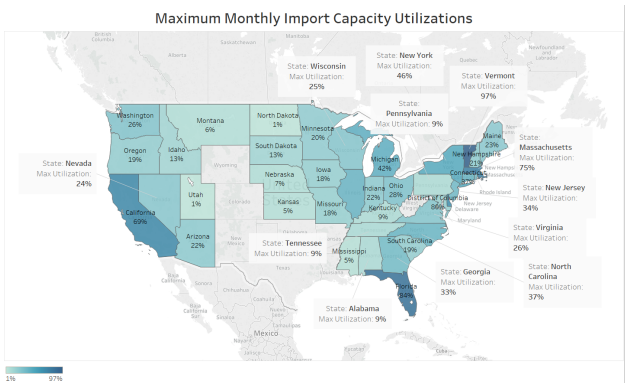

Figure 2: Maximum Monthly Import Capacity Utilizations in the Continental U.S.

Vermont had the highest maximum monthly import capacity utilization at 97%. Vermont banned hydraulic fracturing in 2012, and the state has only one pipeline for deliveries. Yet natural gas consumption in Vermont grew 40% from 2011 – 2016. Residents in the state that do not have access to natural gas distribution rely on truck deliveries of propane for fuel. Although the state has banned fracking and is against pipelines construction, Vermont still relies on fossil fuels. Florida and California also show in dark blue on the map. Their maximum import capacity utilizations were 84% and 69% respectively. Both Florida and California rely on natural gas for over 50% of their state electricity generation. Florida, a state that certainly has access to sunshine, historically only allowed utility companies to sell solar energy. The first exception was made in 2017. It seems the state is filling the demand for renewable energy with natural gas. California is following a similar trend, aggressively replacing coal-fired power plants with natural gas. California has relied on underground storage to mitigate natural gas supply risks. The state's largest storage site, Aliso Canyon, had a total capacity of 86 Bcf. The site stored 63% of Southern California's natural gas. In October of 2015 a leak was detected at this facility. By the time it was stopped in October of 2015, the costs had risen to over $1 billion and surrounding communities had to be evacuated. Long-term health effects in local residents are still being evaluated. While many states oppose natural gas pipeline construction, the alternatives may be even more dangerous. A study regarding petroleum transportation by truck and rail found that truck transportation is about 20 times more likely to result in an accident, and rail is twice as likely.

Exports:

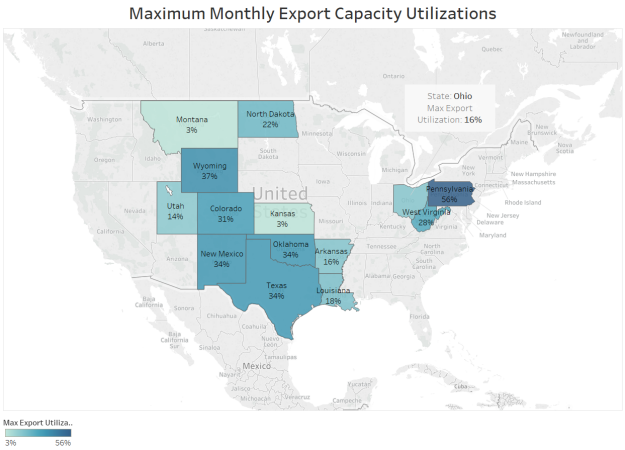

Figure 3: Maximum Monthly Export Capacity Utilizations in the Continental U.S.

The maximum monthly export capacity utlization occurred in Pennsylvania with a rate of 56%. This was unsurprising, due to the old infrastructure in the region and recent dramatic growth in Marcellus shale. New outflow pipelines are required in Pennsylvania in order to accommodate expected growth in production. Already, some wells have ceased production due to a lack of capacity.

Updates Called for in the Pipeline Planning Process, Investments in Maintenance Critical

New pipeline projects are proposed by operating companies and approved by FERC. In this paper, future planned pipeline capacity was evaluated by plotting FERC approved capacity for each state from 2011 – 2018. It was found that most of the proposed capacity was for the Southwest. 20,680 MMcf / day was planned for Texas, and 11,559 MMcf / day was planned for Louisiana. In comparison, only 3,463 MMcf / day was proposed for Pennsylvania, 680 MMcf / day was planned for Florida, and no new capacity was proposed for Vermont or California. Capacity planning seemed to take a backwards view, favoring historically large producers. This makes sense given that a “market need” for pipelines is usually justified through individual contracts between suppliers and customers. The lack of pipeline proposals in areas projected to experience the largest growth highlights the need for more comprehensive industry planning and a more critical review process by FERC.

Capacity constraints are one risk to the natural gas supply chain, aging infrastructure is another. Accident data from PHMSA for 2010 – present was analyzed to determine the importance of age as a cause of accidents. The pipelines in the accident records were manufactured between 1910 – 2015. The average year of manufacture for pipelines experiencing accidents was 1965. 3 out of the 4 most prevalent causes of accidents were related to age, including equipment failure, corrosion failure, and material failure.

Conclusions

A review of relevant literature confirms that both production and consumption of natural gas are extremely likely to continue to grow in the U.S. Production is expected to grow most dramatically in the northeast. The current system already shows inadequacies in capacity availability in certain states. A 30% growth in production is likely to strain the system even further. Some states oppose pipelines for environmental reasons, but pipeline alternatives may be even more risky. Updates to the pipeline proposal and approval process are needed in order to efficiently allocate new capacity. Maintenance investments are needed to protect old pipelines from corrosion, which can lead to accidents.

Safe pipelines have the ability to foster America’s energy independence and provide residents with low-cost reliable fuel. Yet, the newfound accessibility of natural gas in the U.S. poses a danger for overreliance on one type of fuel. Rather than seeking short-term wins in prices and emissions reductions by importing large quantities of natural gas, states should seek a more balanced energy portfolio that includes long-term renewable energy infrastructure.