RISK MANAGEMENT AS U.S. NATURAL GAS TRANSPORTATION EXPLODES

BY LAUREN SITTLER

MASTER OF ENGINEERING IN SUPPLY CHAIN MANAGEMENT

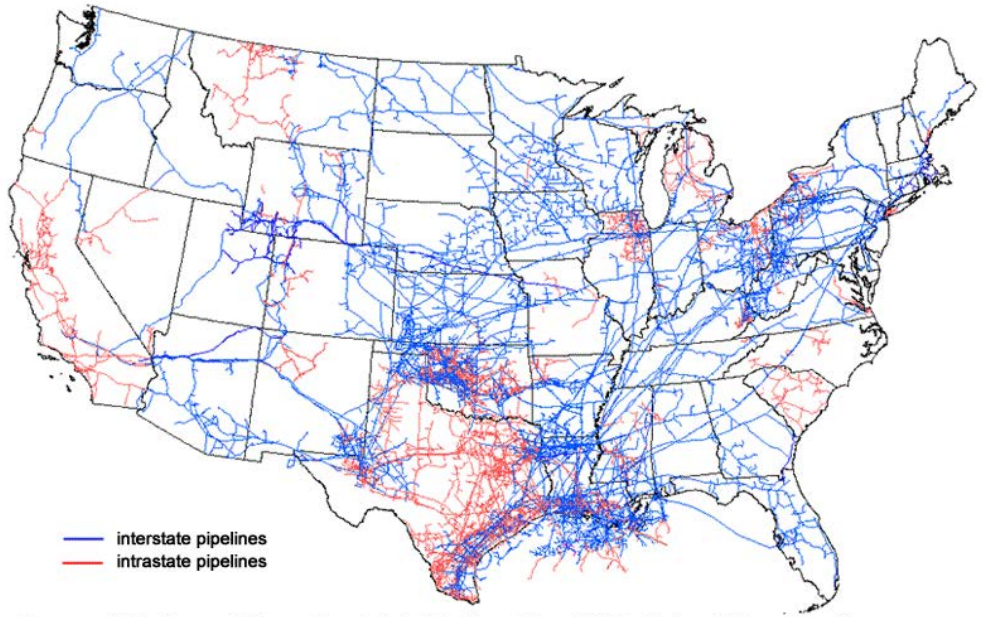
MAY 22, 2018

AGENDA

- Introduction
- Literature Review
  - Natural Gas Market Outlook in the U.S.
  - The Natural Gas Supply Chain
  - The Current Transmission System
  - The Approval Process for New Pipelines
  - Why Pipelines are Needed
- Analysis Goals & Results
  - Pipeline Inflow & Outflow Capacity Utilization
  - Adequacy of the FERC Approval Process
  - Age as a Risk Factor
- Recommendations
- Appendix: Methodology Details

PROJECT PURPOSE

Map of U.S. interstate and intrastate natural gas pipelines



Source: U.S. Energy Information Administration, *About U.S. Natural Gas Pipelines*

- Is pipeline capacity constrained?
- Is the FERC approval process for new pipelines efficient allocating capacity where it is needed?
- Are old pipelines a risk for accidents?

PROJECT MOTIVATION

60% of all U.S. transmission pipelines installed before 1970

Shifting patterns in production and consumption

New projects proposed by individual companies – does that lead to an efficient network overall?

MY BACKGROUND

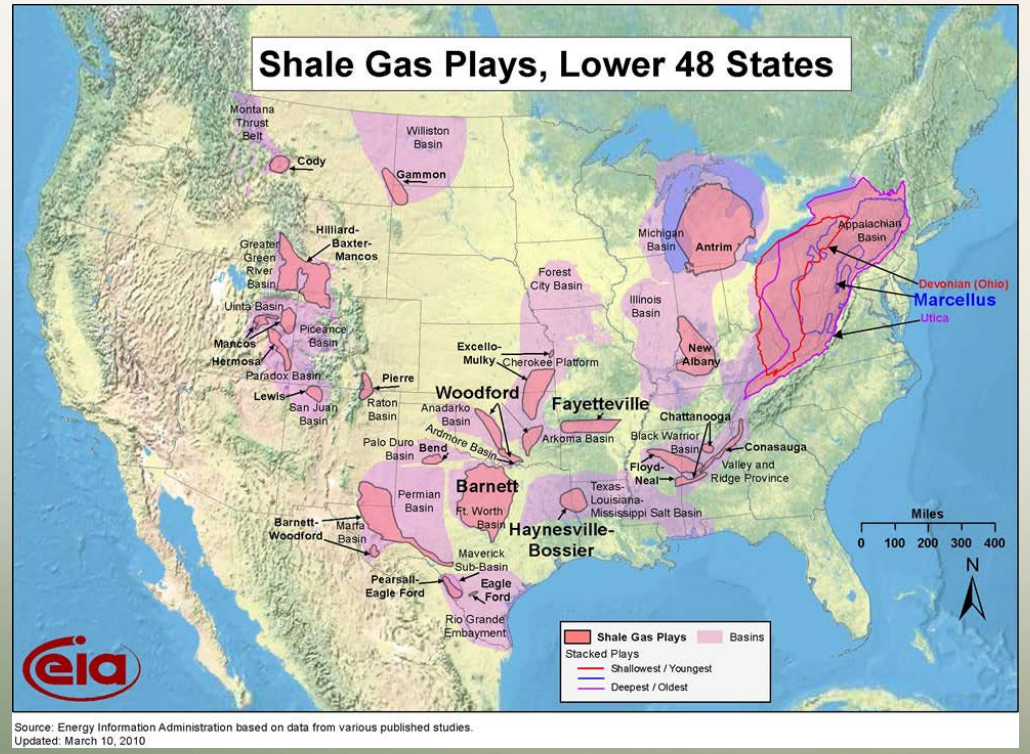
B.S. Chemical Engineering

3 yrs. Process Engineer

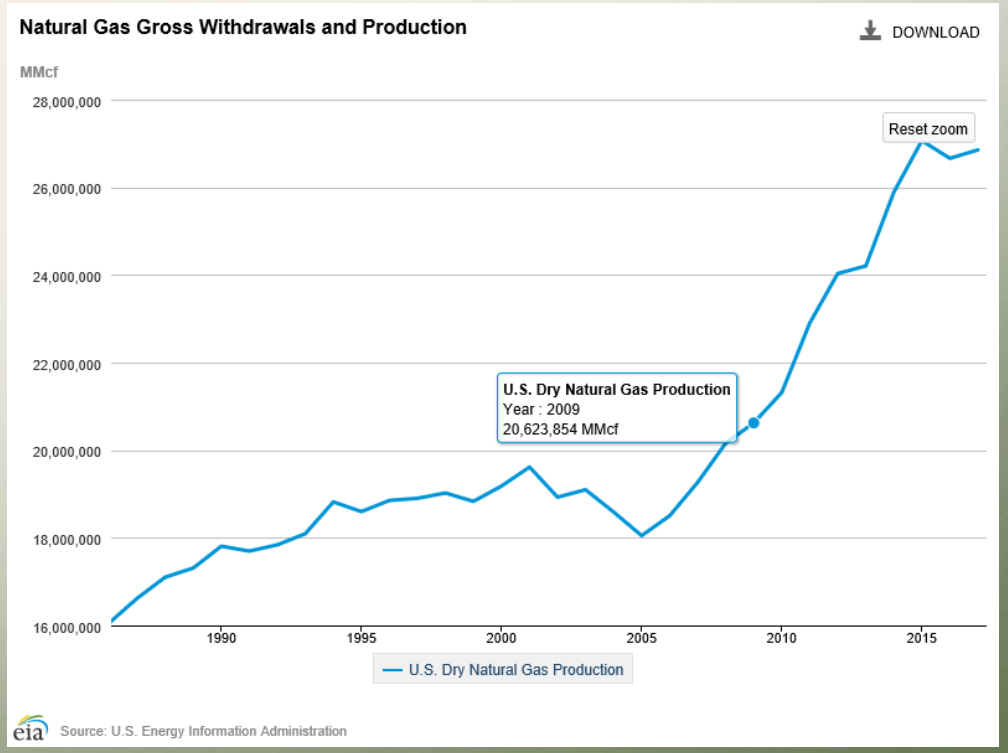
AGENDA

- Introduction
- Literature Review
  - Natural Gas Market Outlook in the U.S.
  - The Natural Gas Supply Chain
  - The Current Transmission System
  - The Approval Process for New Pipelines
  - Why Pipelines are Needed
- Analysis Goals & Results
  - Pipeline Inflow & Outflow Capacity Utilization
  - Adequacy of the FERC Approval Process
  - Age as a Risk Factor
- Recommendations
- Appendix: Methodology Details

U.S. NATURAL GAS PRODUCTION

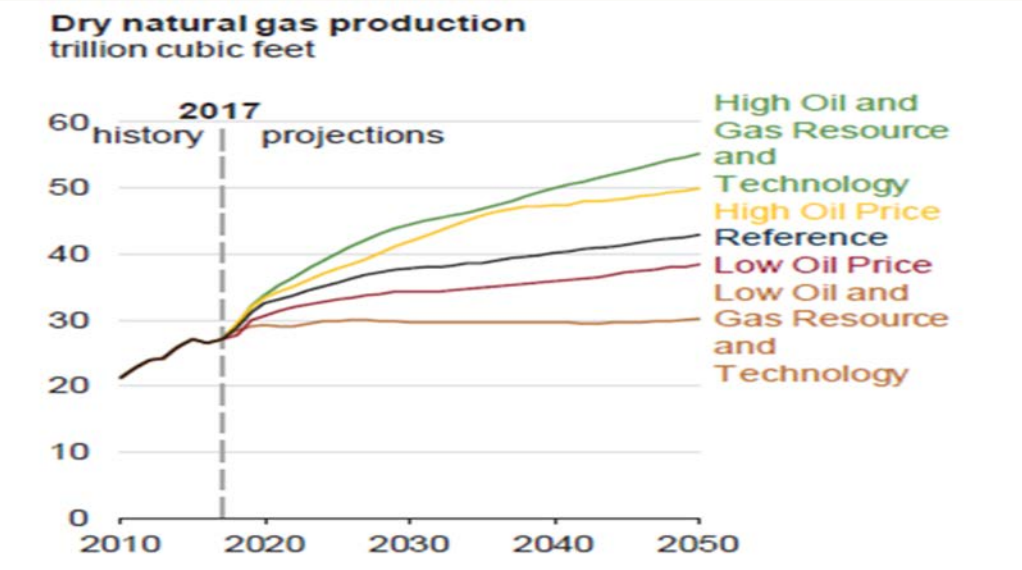


Source: Energy Information Administration based on data from various published studies.
Updated: March 10, 2010

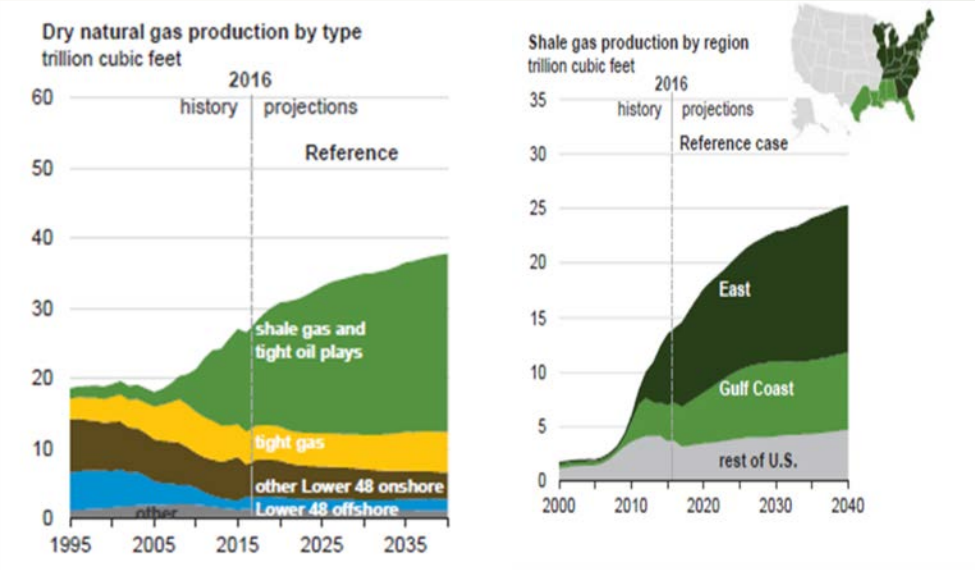


LITERATURE REVIEW – NATURAL GAS PRODUCTION FORECAST

NATURAL GAS PRODUCTION IS PROJECTED TO GROW 30%

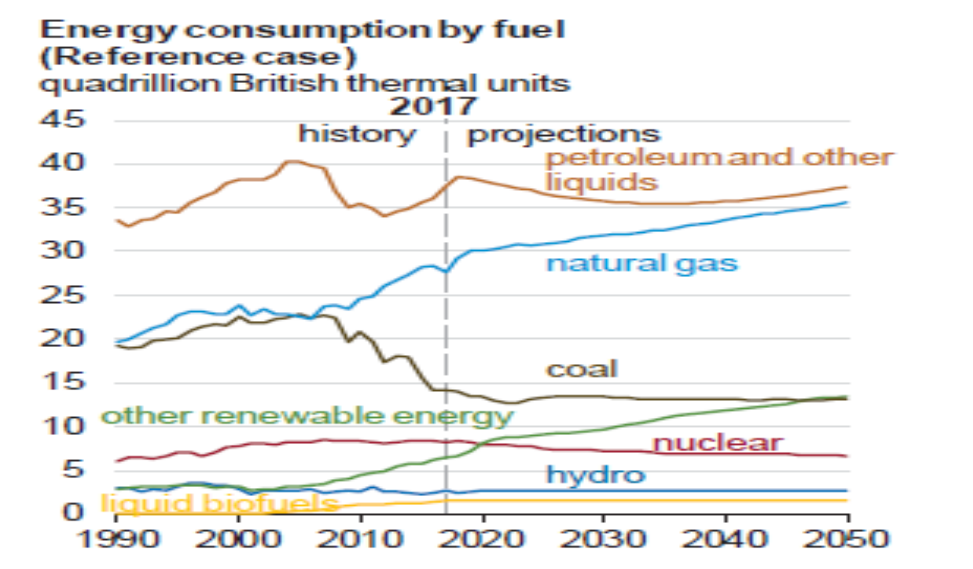


WITH SHALE GAS PRODUCTION IN THE EAST DRIVING GROWTH

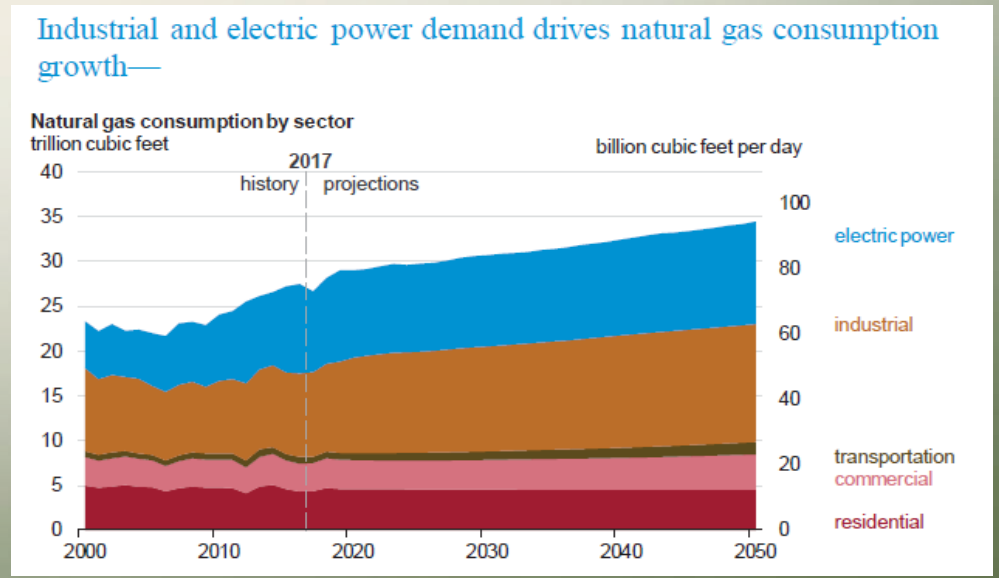


LITERATURE REVIEW – NATURAL GAS CONSUMPTION FORECAST

CONSUMPTION IS ALSO EXPECTED TO GROW – (ACTUAL RATE NOT GIVEN)



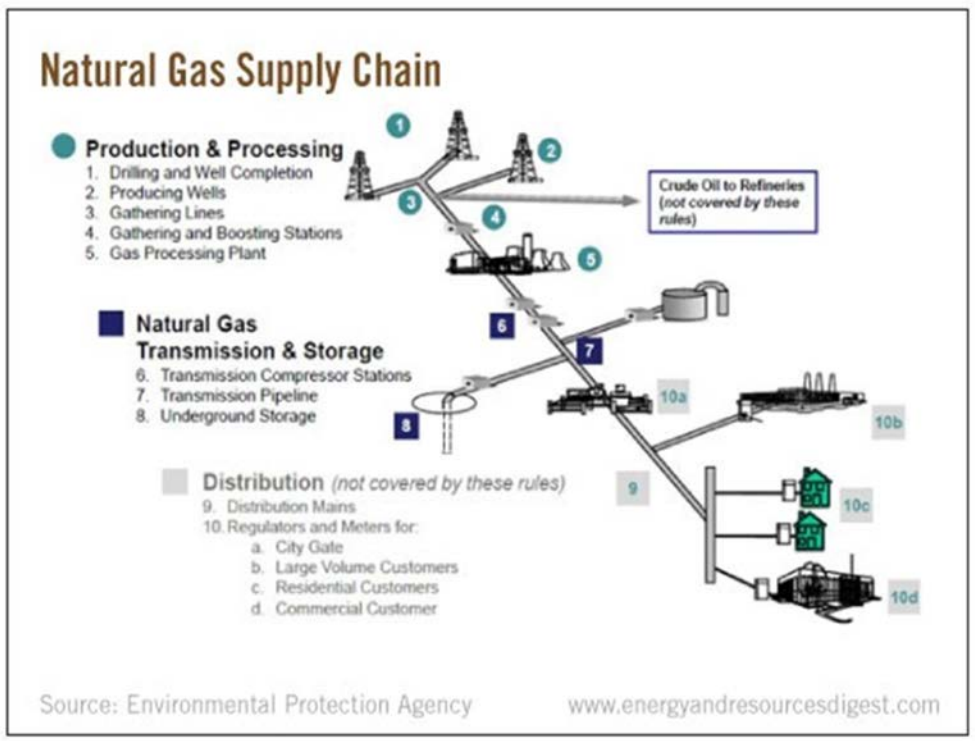
GROWTH IS DRIVEN BY DEMAND IN INDUSTRIAL & ELECTRIC POWER USE



AGENDA

- Introduction
- Literature Review
  - Natural Gas Market Outlook in the U.S.
  - The Natural Gas Supply Chain
  - The Current Transmission System
  - The Approval Process for New Pipelines
  - Why Pipelines are Needed
- Analysis Goals & Results
  - Pipeline Inflow & Outflow Capacity Utilization
  - Adequacy of the FERC Approval Process
  - Age as a Risk Factor
- Recommendations
- Appendix: Methodology Details

LITERATURE REVIEW – THE NATURAL GAS SUPPLY CHAIN



- Upstream – geological exploration, drilling
- Midstream – processing (methane is separated from heavier hydrocarbons)
- Downstream – further processing (petrochemical) distribution

LITERATURE REVIEW – THE NATURAL GAS PIPELINE SYSTEM

Upstream

- Gathering Lines
- Small Diameter 2-8 in
- Low Pressure

Midstream

- Transmission Lines
- Large Diameter 6-48 in
- 200 – 1500 psi

Downstream

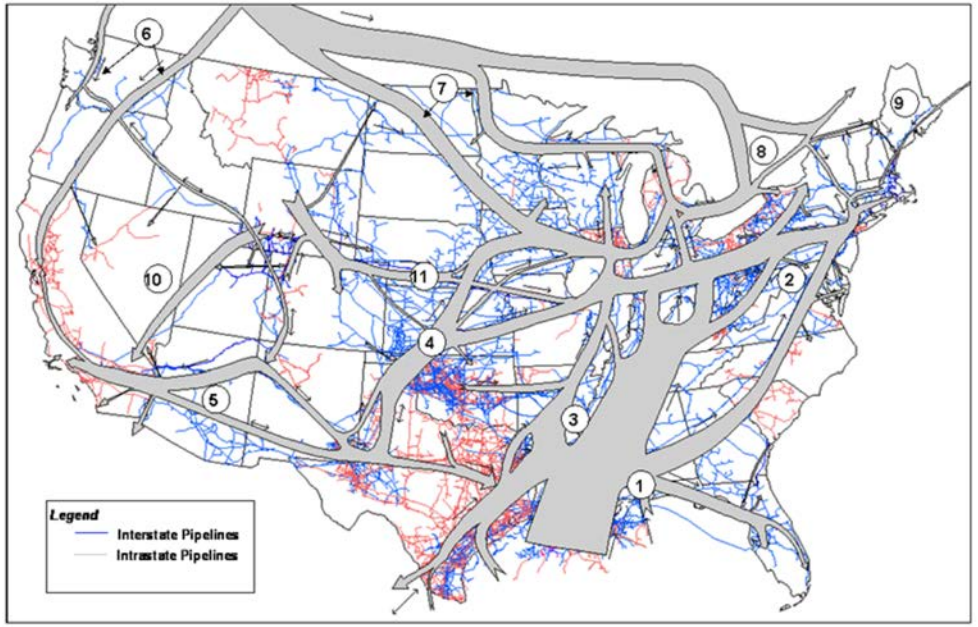
- Distribution Lines
- Low pressure lines that deliver gas to customers

AGENDA

- Introduction
- Literature Review
  - Natural Gas Market Outlook in the U.S.
  - The Natural Gas Supply Chain
  - The Current Transmission System
  - The Approval Process for New Pipelines
  - Why Pipelines are Needed
- Analysis Goals & Results
  - Pipeline Inflow & Outflow Capacity Utilization
  - Adequacy of the FERC Approval Process
  - Age as a Risk Factor
- Recommendations
- Appendix: Methodology Details

LITERATURE REVIEW – THE NATURAL GAS TRANSMISSION SYSTEM

- Major Transportation Corridors
- Corridors from the Southwest
  - Southwest – Southeast
  - Southwest – Northeast
  - Southwest – Midwest
  - Southwest Panhandle – Midwest
  - Southwest – Western
- Corridors from Canada
  - Canada – Western
  - Canada – Midwest
- Canada – Northeast
  - Eastern Offshore Canada – Northeast
- Corridors from the Rocky Mountain Area
  - Rocky Mountains – Western
  - Rocky Mountains - Midwest



Source: Energy Information Administration, Office of Oil and Gas, Natural Gas Division, GasTran Gas Transportation Information System.

The EIA has determined that the informational map displays here do not raise security concerns, based on the application of the Federal Geographic Data Committee's *Guidelines for Providing Appropriate Access to Geospatial Data in Response to Security Concerns*.

AGENDA

- Introduction
- Literature Review
  - Natural Gas Market Outlook in the U.S.
  - The Natural Gas Supply Chain
  - The Current Transmission System
  - The Approval Process for New Pipelines
  - Why Pipelines are Needed
- Analysis Goals & Results
  - Pipeline Inflow & Outflow Capacity Utilization
  - Adequacy of the FERC Approval Process
  - Age as a Risk Factor
- Recommendations
- Appendix: Methodology Details

LITERATURE REVIEW – THE FERC APPROVAL PROCESS FOR NEW PIPELINES

Pipeline Operating Company Submits Application

- Expected Costs
- Geological & Engineering Studies
- Rate Data for Pipeline Operation
- Environmental Studies
- Impact Analysis on Surrounding Communities

FERC Reviews the Market Need

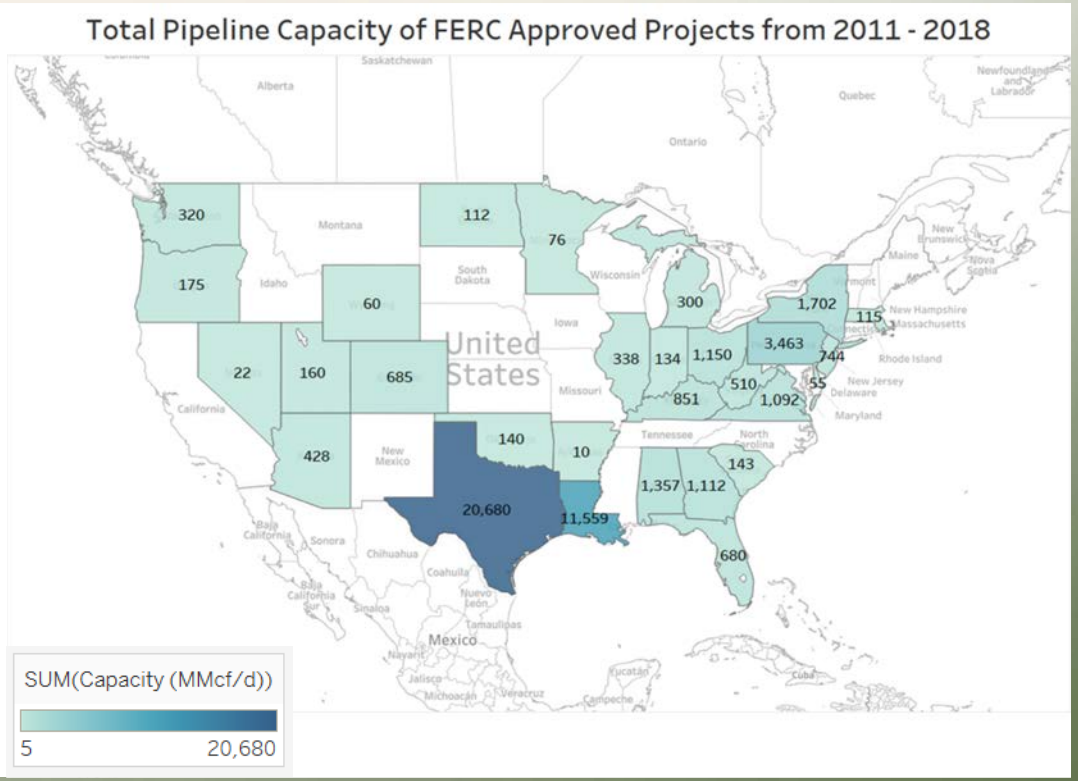
- Historically has relied largely on pre-established contracts between a pipeline operator & a prospective customer to indicate market need

FERC Issues a Certificate of Public Convenience & Necessity

- Pipeline Company is granted Eminent Domain
- Construction can begin
- Company must make regular reports to FERC on their project status as well as changes to initial

LITERATURE REVIEW – FERC APPROVED PIPELINE CAPACITY

- Out of the 400 pipeline applications that have been filed since 1999, only 2 have been rejected.
- Most of the approved capacity was planned for Texas and Louisiana.
- There was no approved capacity in California and minimal in New England.



AGENDA

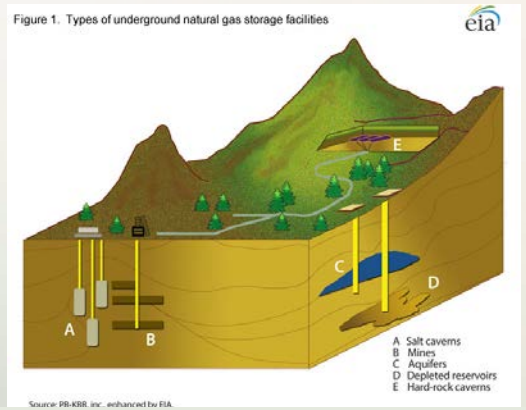
- Introduction
- Literature Review
  - Natural Gas Market Outlook in the U.S.
  - The Natural Gas Supply Chain
  - The Current Transmission System
  - The Approval Process for New Pipelines
  - Why Pipelines are Needed
- Analysis Goals & Results
  - Pipeline Inflow & Outflow Capacity Utilization
  - Adequacy of the FERC Approval Process
  - Age as a Risk Factor
- Recommendations
- Appendix: Methodology Details

LITERATURE REVIEW – PIPELINE SAFETY VS. OTHER TRANSPORTATION MODES

Table 6: Comparative Statistics for Petroleum Incident Rates: Onshore Transmission Pipelines vs. Road and Railway (2005-09)

Mode	Avg. Billions Ton-Miles Shipment Per Year	Avg. Incidents Per Year	Incidents Per Billion Ton-Miles
Road*	34.8	695.2	19.95
Railway*	23.9	49.6	2.08
Hazardous Liquid Pipeline	584.1	339.6	0.58
Natural Gas Pipeline	338.5	299.2	0.89

STORAGE IS ALSO PROBLEMATIC



- > 1/5 of the 15,000 active underground storage wells are at risk for serious leaks. These wells comprise 51% of the country's total working capacity, median age of 74 years.
- Some states, such as Florida have geologies that do not support natural gas storage.

- Aliso Canyon Injection storage capacity of 86 Bcf. Stored 63 percent of Southern California's natural gas.
- Leak detected in October 2015, stopped in February of 2016.
- Cost $1 billion, released over 100,000 metric tons of methane.
- Residents had high levels of uranium, lithium, and styrene.

AGENDA

- Introduction
- Literature Review
  - Natural Gas Market Outlook in the U.S.
  - The Natural Gas Supply Chain
  - The Current Transmission System
  - The Approval Process for New Pipelines
  - Why Pipelines are Needed
- Analysis Goals & Results
  - Pipeline Inflow & Outflow Capacity Utilization
  - Adequacy of the FERC Approval Process
  - Age as a Risk Factor
- Recommendations
- Appendix: Methodology Details

ANALYSIS GOALS

Calculate transmission pipeline utilization rates by state on a volume basis

- Inflow / Inflow Capacity
- Outflow / Outflow Capacity

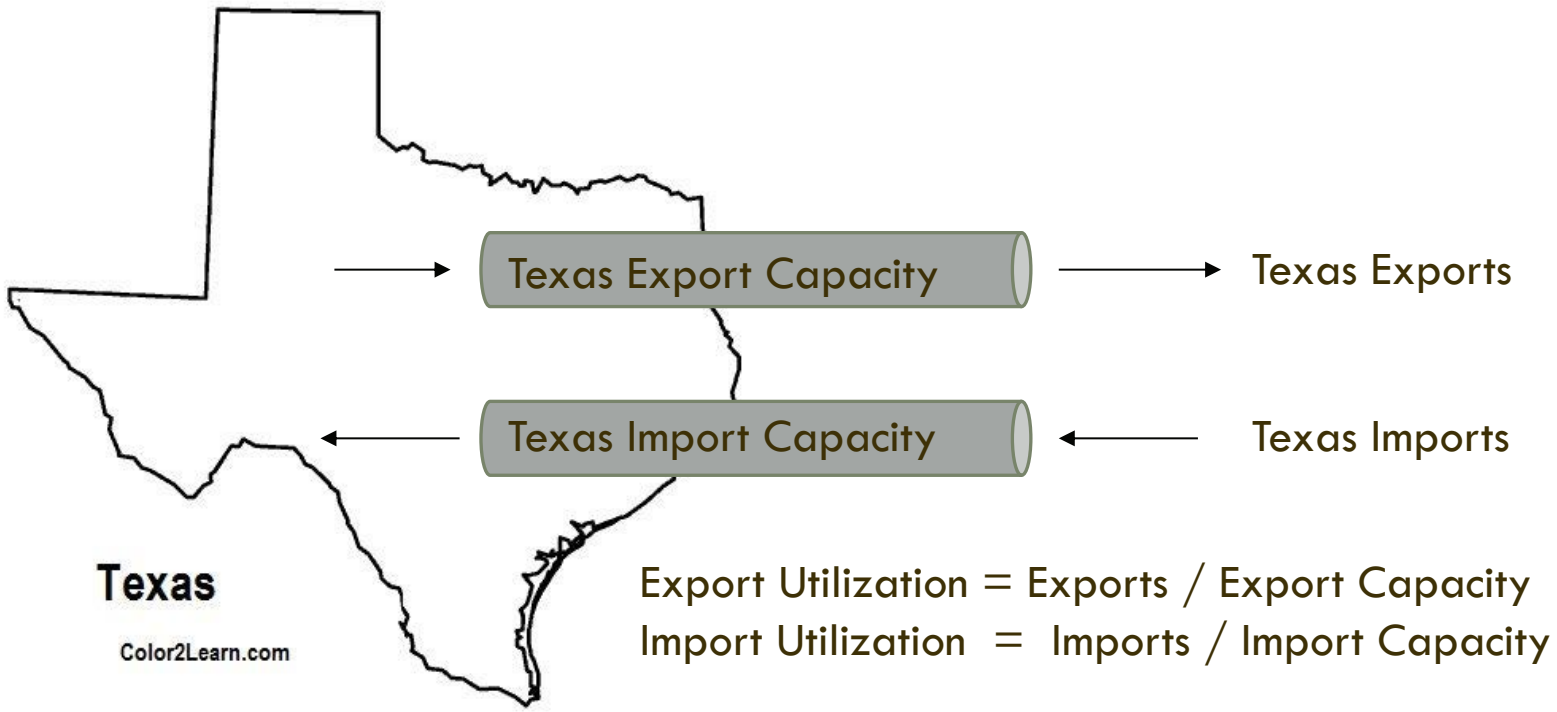
Evaluate whether new capacity is being added in the right places

Consider age as a risk factor for accidents

AGENDA

- Introduction
- Literature Review
  - Natural Gas Market Outlook in the U.S.
  - The Natural Gas Supply Chain
  - The Current Transmission System
  - The Approval Process for New Pipelines
  - Why Pipelines are Needed
- Analysis Goals & Results
  - Pipeline Inflow & Outflow Capacity Utilization
  - Adequacy of the FERC Approval Process
  - Age as a Risk Factor
- Recommendations
- Appendix: Methodology Details

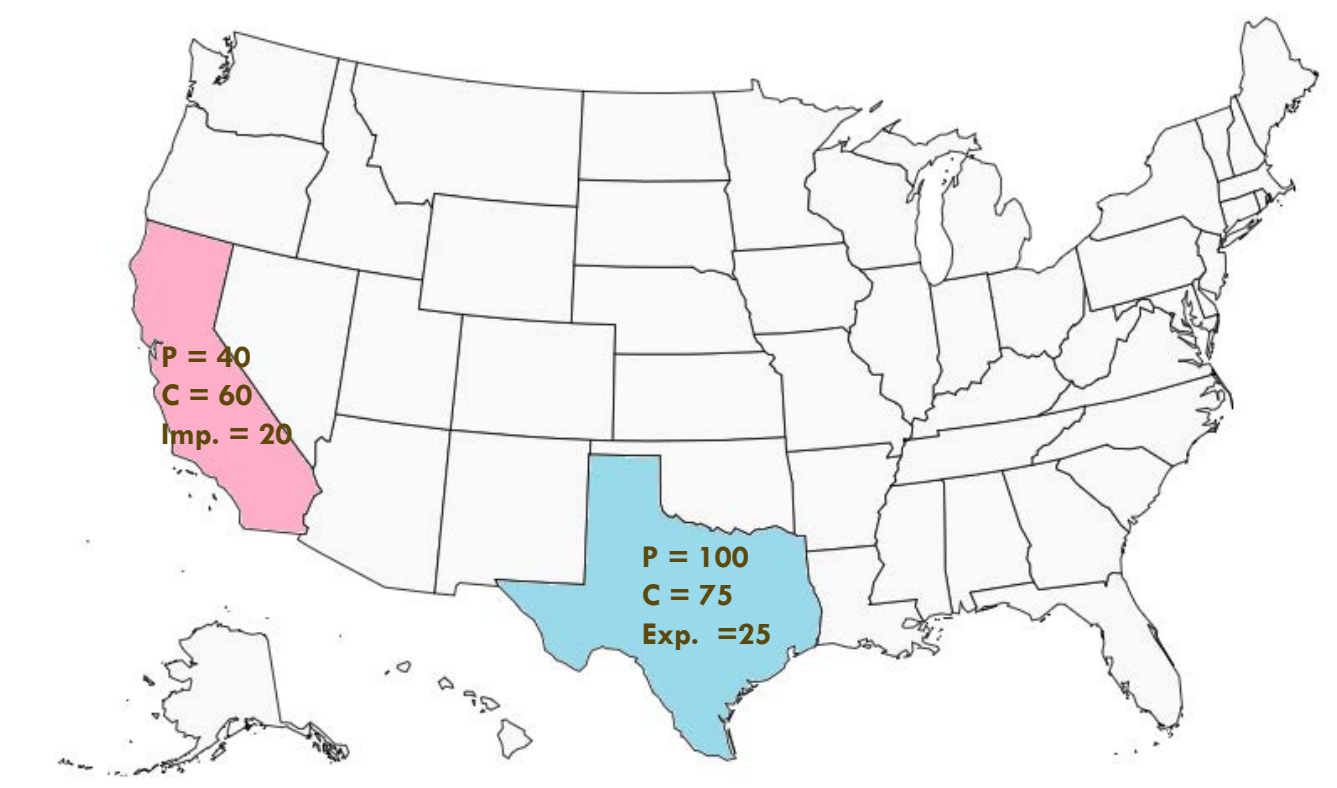
PIPELINE IMPORTS & EXPORTS



Export Utilization = Exports / Export Capacity

Import Utilization = Imports / Import Capacity

METHODOLOGY – IMPORTS & EXPORTS



METHODOLOGY – DATA SOURCES

- U.S. Energy Information Administration Website
- Production
  - Dry Production
- Consumption
  - Volumes Delivered to Consumers
  - Pipeline & Distribution Use
- Time Span 2011- 2016
  - Consistent method of data collection
  - Consistent definition of state boundaries
  - 2017 data was not yet fully available

METHODOLOGY

Natural Gas Production

- Production data was obtained from the EIA website
- After reading "Definitions, Sources & Notes" Dry Production was chosen for the analysis as it is consumer grade natural gas that would be transported in transmission lines
- Transmission lines were the focus of the later capacity analysis

Natural Gas Gross Withdrawals and Production
(Volumes in Million Cubic Feet)

Area: U.S. **Period-Unit:** Monthly-Million Cubic Feet

Download Series History | Definitions, Sources & Notes

Show Data By: Data Series / Area	Graph	Clear	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	View History
Gross Withdrawals			2,757,416	2,888,227	2,875,410	3,001,122	2,958,366	2,721,454	1973-2018
From Gas Wells			NA	NA	NA	NA	NA	NA	1991-2018
From Oil Wells			NA	NA	NA	NA	NA	NA	1991-2018
From Shale Gas Wells			NA	NA	NA	NA	NA	NA	2007-2018
From Coalbed Wells			NA	NA	NA	NA	NA	NA	2002-2018
Repressuring			NA	NA	NA	NA	NA	NA	1973-2018
Vented and Flared			NA	NA	NA	NA	NA	NA	1973-2018
Nonhydrocarbon Gases Removed			NA	NA	NA	NA	NA	NA	1973-2018
Marketed Production			2,408,242	2,506,570	2,496,887	2,606,842	2,565,970	2,364,556	1973-2018
NGPL Production, Gaseous Equivalent			157,957	177,252	175,754	175,088	169,874	161,370	1973-2018
Dry Production			2,250,285	2,329,318	2,321,134	2,431,754	2,396,096	2,203,186	1997-2018

METHODOLOGY

Natural Gas Consumption

- Consumption data was obtained from the EIA website
- To be consistent with the production analysis and look only at gas transported via transmission lines, I included "Volumes Delivered to Consumers" and Pipeline & Distribution Use

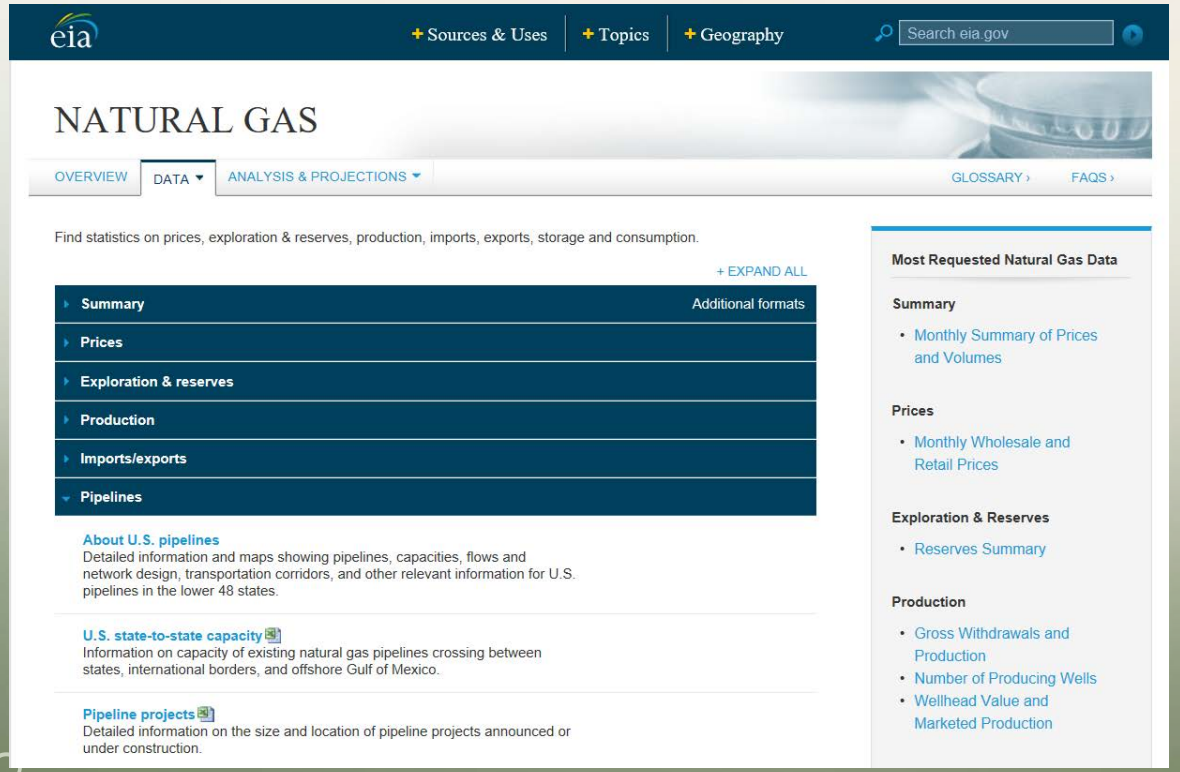
Natural Gas Consumption by End Use
(Million Cubic Feet)

Area: U.S. **Period:** Monthly

Download Series History | Definitions, Sources & Notes

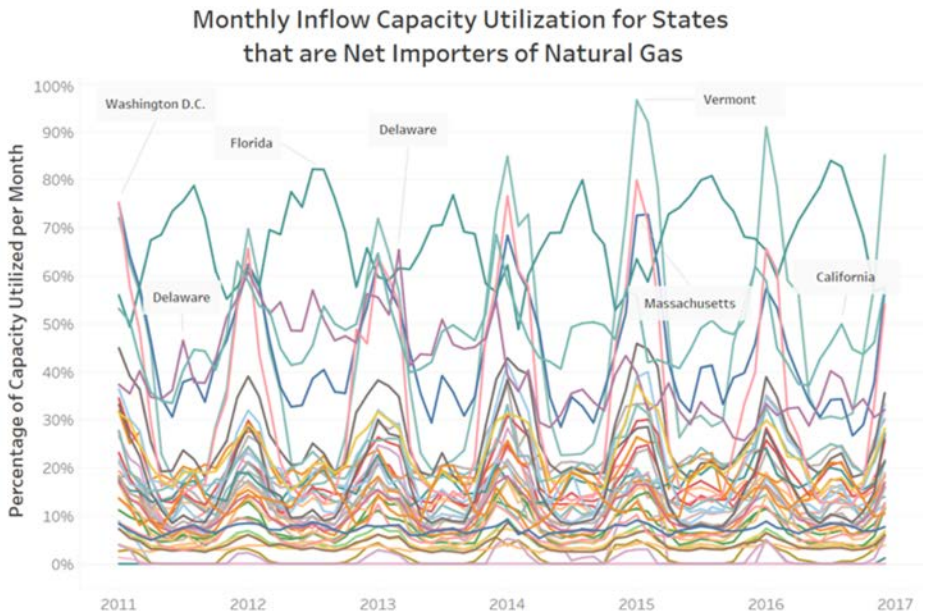
Show Data By: Data Series / Area	Graph	Clear	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	View History
Total Consumption			1,922,954	2,032,483	2,346,592	3,067,644	3,317,058	2,670,343	2001-2018
Lease and Plant Fuel			134,441	139,930	139,390	145,528	143,246	132,002	1980-2018
Pipeline & Distribution Use			48,794	51,573	59,544	77,840	84,169	67,759	2001-2018
Volumes Delivered to Consumers			1,739,719	1,840,980	2,147,659	2,844,276	3,089,643	2,470,582	2001-2018
Residential			115,095	204,245	466,811	824,610	973,319	686,819	1973-2018
Commercial			145,714	200,987	323,729	488,326	547,367	420,187	1973-2018
Industrial			613,266	652,255	690,730	759,417	770,377	690,216	2001-2018
Vehicle Fuel			3,575	3,694	3,575	3,694	3,684	3,327	1997-2018
Electric Power			862,068	779,799	662,814	768,229	794,896	670,032	2001-2018

U.S. STATE-TO-STATE CAPACITY DATA



	State Outflow Capacity		
1			
2			
3			
4	State From	year	Sum of Capacity (mmcfd)
5	Alabama	2017	20,687
6		2016	18,508
7		2015	18,508
8		2014	17,958
9		2013	17,458
10		2012	17,458
11		2011	17,238
12		2010	16,068
13		2009	15,943
14		2008	14,993
15		2007	14,838
16		2006	14,838
17		2005	14,838
18		2004	14,838
19		2003	14,590
20		2002	13,689
21		2001	11,791
22		2000	11,574
23		1999	11,374
24		1998	11,374
25		1997	11,197
26		1996	11,052
27		1995	10,997
28		1994	10,347
29		1990	9,756
30	Alabama Total		361,912
31	Alberta	2017	144
32		2016	144
33		2015	144
34		2014	144
35		2013	144

PIPELINE CAPACITY UTILIZATION RESULTS - IMPORTS



States at Risk for Natural Gas Shortages

- Vermont
- New England in General
- Florida
- California

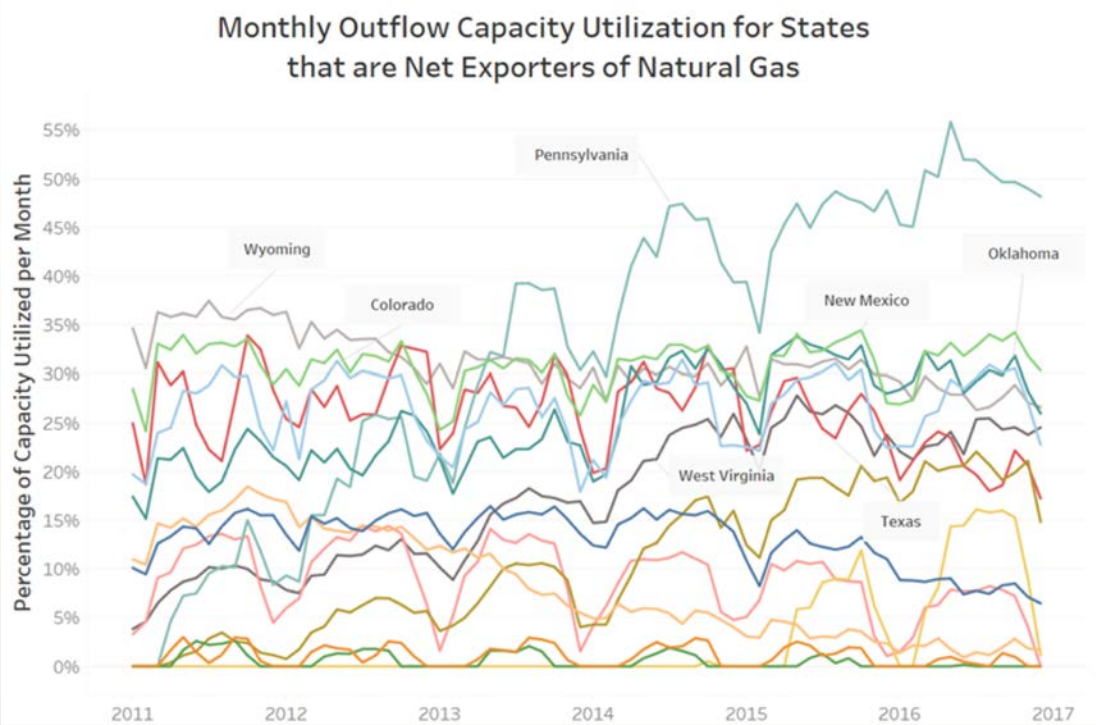
Reasons for Natural Gas Shortages

- Overreliance on Gas for Electricity (Florida, California) High Imports, Low or No Production
- Lack of Pipelines (Vermont, New England)

Consequences

- Resorting to Oil for Heat
- Power Outages
- NGL Storage Leaks

PIPELINE CAPACITY UTILIZATION RESULTS - EXPORTS



States Lacking Outflow Pipelines

- Pennsylvania

Reasons for Lack of Outflow Pipelines

- Old infrastructure, new production
- Environmental opposition to new projects

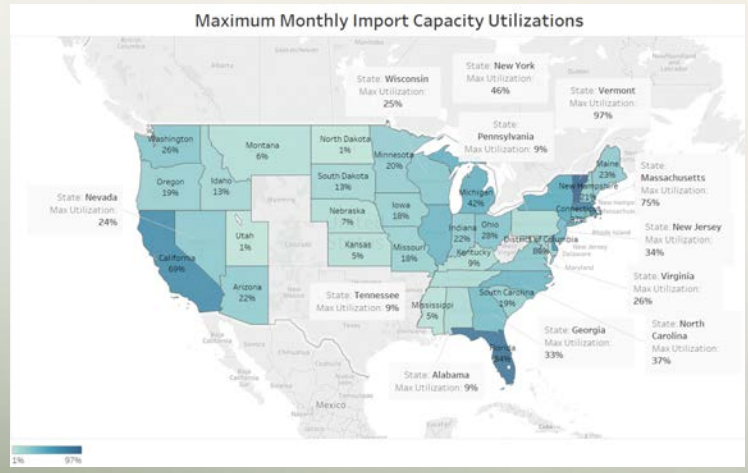
Consequences

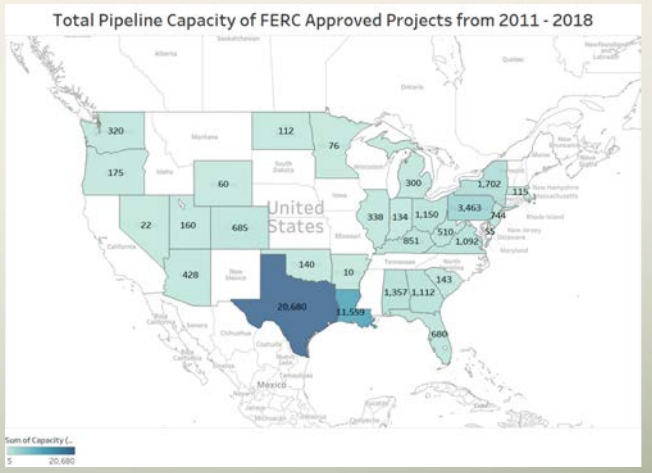
- Limited production – wells drilled but not active

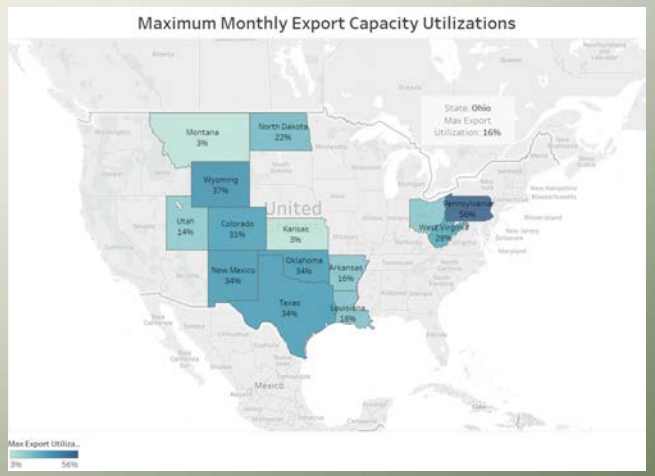
AGENDA

- Introduction
- Literature Review
  - Natural Gas Market Outlook in the U.S.
  - The Natural Gas Supply Chain
  - The Current Transmission System
  - The Approval Process for New Pipelines
  - Why Pipelines are Needed
- Analysis Goals & Results
  - Pipeline Inflow & Outflow Capacity Utilization
  - Adequacy of the FERC Approval Process
  - Age as a Risk Factor
- Recommendations
- Appendix: Methodology Details

ADEQUACY OF THE FERC APPROVAL PROCESS





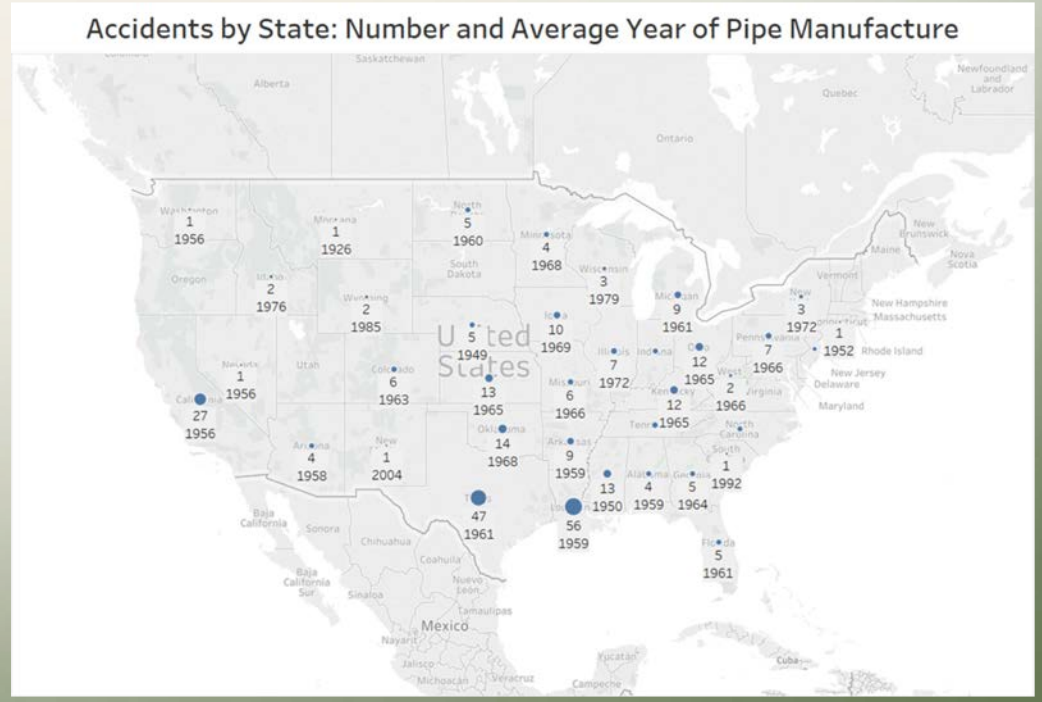


AGENDA

- Introduction
- Literature Review
  - Natural Gas Market Outlook in the U.S.
  - The Natural Gas Supply Chain
  - The Current Transmission System
  - The Approval Process for New Pipelines
  - Why Pipelines are Needed
- Analysis Goals & Results
  - Pipeline Inflow & Outflow Capacity Utilization
  - Adequacy of the FERC Approval Process
  - Age as a Risk Factor
- Recommendations
- Appendix: Methodology Details

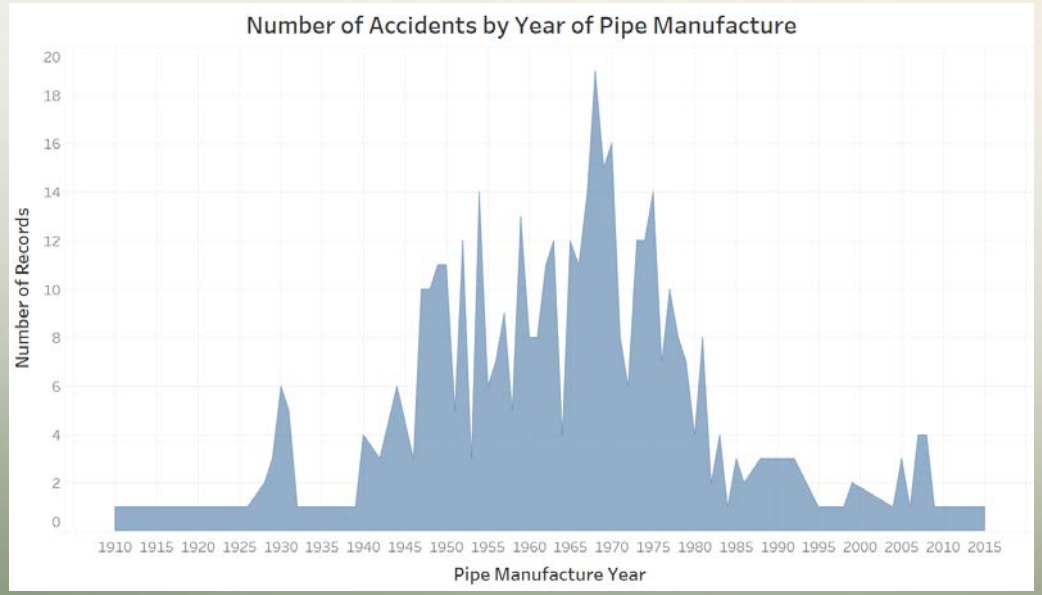
PHMSA ACCIDENTS DATA

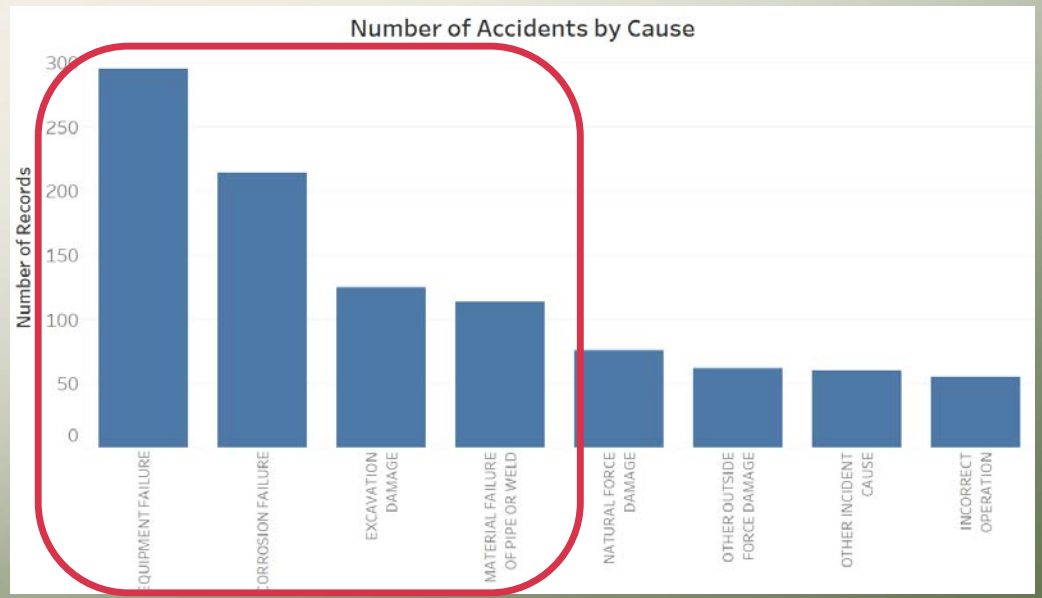
- PHMSA Pipeline Accident Data: 2010 - Present
- 1001 Accidents Total
- Date of Manufacture: 1910 – 2015
- Causes of Accidents
  - Equipment Failure
  - Corrosion Failure
  - Excavation Damage
  - Material Failure
  - Natural Force Damage
  - Other Outside Force Damage
  - Incorrect Operation
  - Other



PIPELINE AGE AND RISK FOR ACCIDENTS

PHMSA Pipeline Accident Data: 2010 - Present





Average year of manufacture: 1965

3 out of top 4 Causes of Failure Related to Age

AGENDA

- Introduction
- Literature Review
  - Natural Gas Market Outlook in the U.S.
  - The Natural Gas Supply Chain
  - The Current Transmission System
  - The Approval Process for New Pipelines
  - Why Pipelines are Needed
- Analysis Goals & Results
  - Pipeline Inflow & Outflow Capacity Utilization
  - Adequacy of the FERC Approval Process
  - Age as a Risk Factor
- Recommendations
- Appendix: Methodology Details

CONCLUSIONS & RECOMMENDATIONS

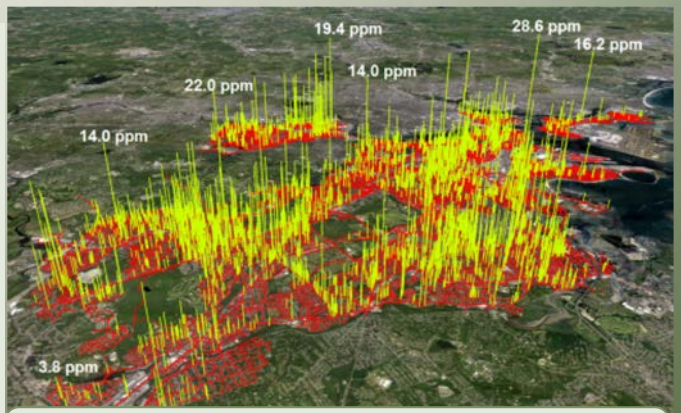
- Natural gas production & consumption is likely to continue to grow
- Some states are currently experiencing capacity shortages
- Pipelines are safer in terms of accidents
- Pipelines appear to be better alternatives than storage
- Age & corrosion are major risks for accidents
- Either additional pipeline capacity should be added or production / consumption should be reduced
- Update the FERC approval process for a more holistic approach to supply & demand
- States should diversity energy sources and not become overly reliant on natural gas seeking quick “wins” in emissions reductions

Natural Gas Well Pennsylvania

Propane Delivery in New Hampshire

Solar Production Unit tied to Gas Turbine in Florida

Methane exerts 86x the global warming potential of CO_2 in the atmosphere during the first 20 years.



Natural Gas Leaks in Boston

MAY 18, 2018

Northeast region slated for record natural gas pipeline capacity buildout in 2018

-U.S. EIA

Two-thirds of U.S. states may be putting their electricity consumers at financial risk because of an overreliance on natural gas.

-Union of Concerned Scientists

'Golden age of gas' threatens renewable energy, IEA warns

Agency says tripling output by 2035 from unconventional gas sources such as shale gas could end support for renewables

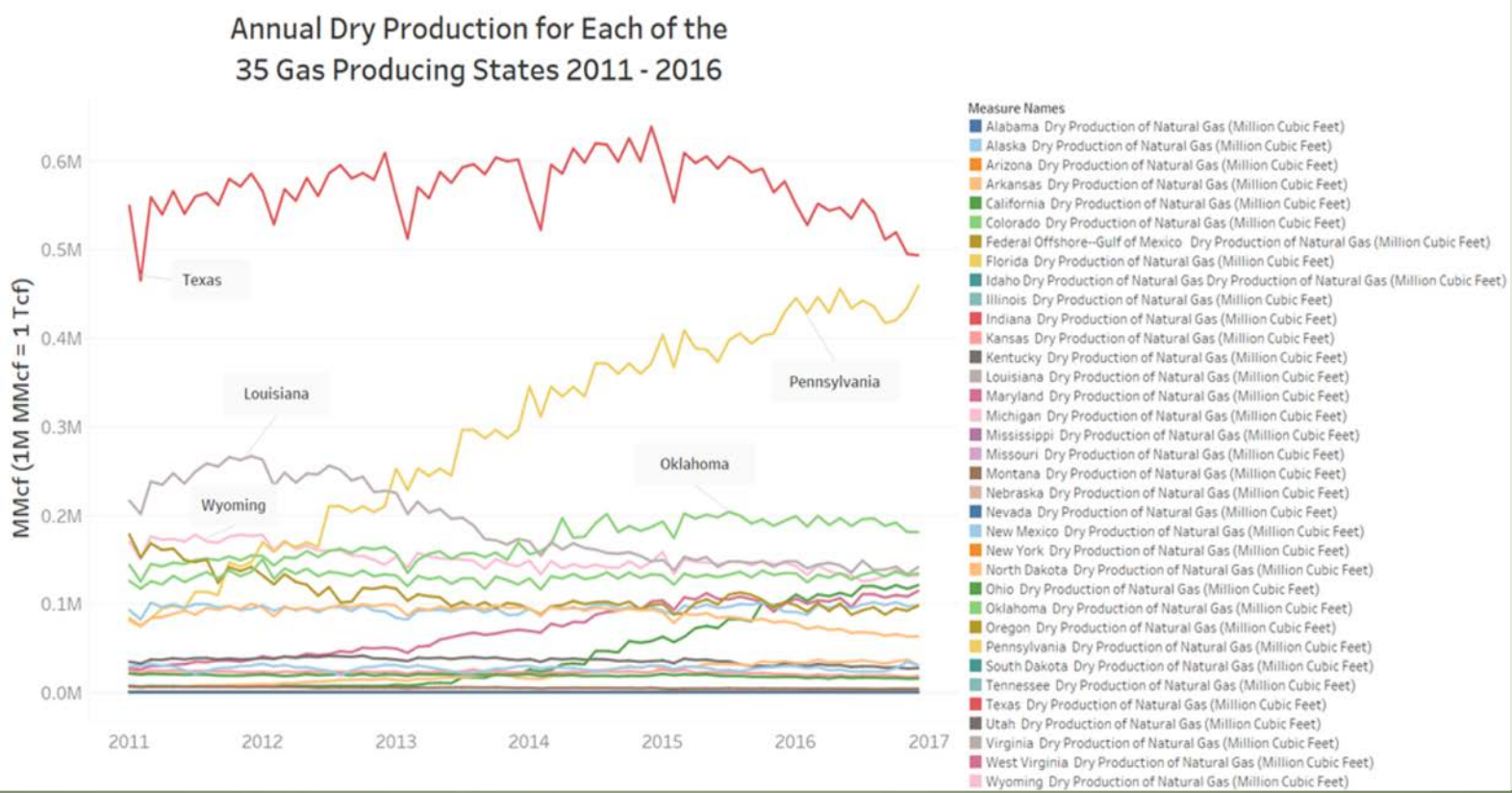
Sunshine State Is Set to Get More Solar After Florida Ruling

-Bloomberg

QUESTIONS?

APPENDIX

RESULTS – NATURAL GAS PRODUCTION TRENDS



Seasonality: Production trends upwards from March through December and dips drastically in February

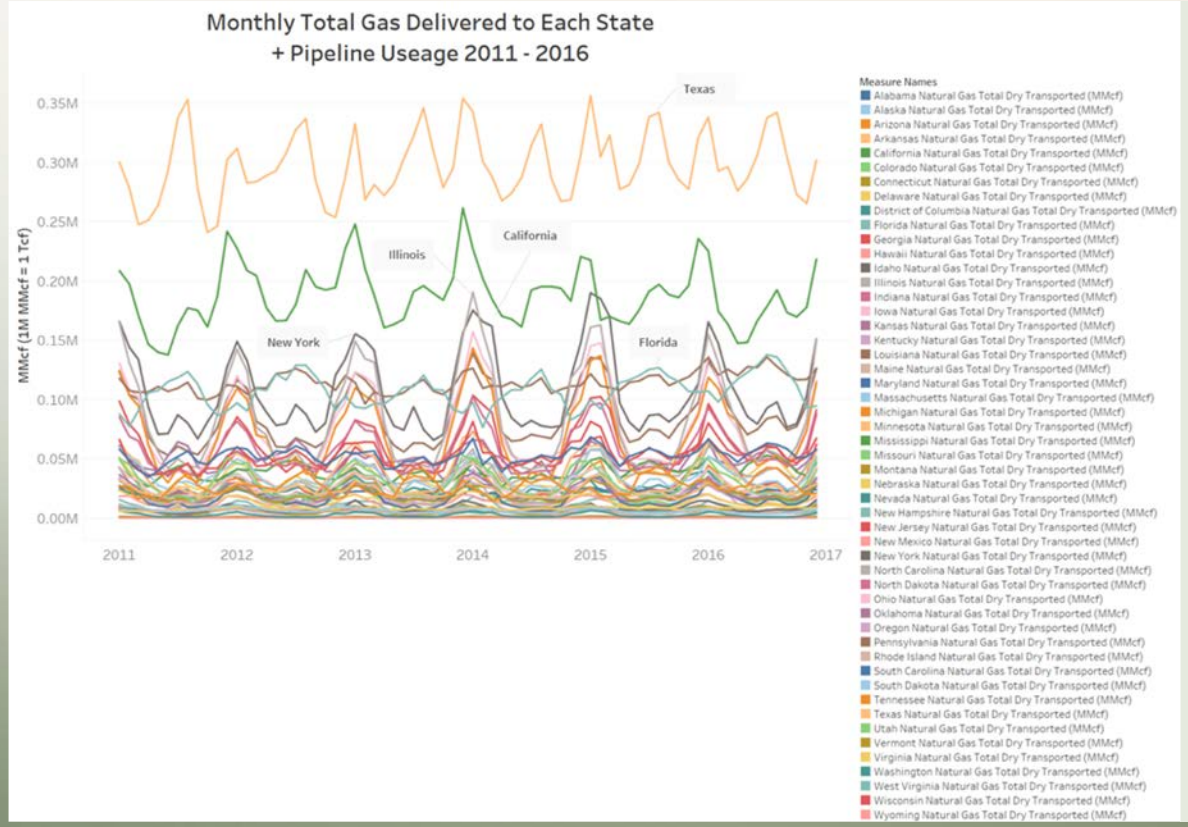
Largest growths occurred in:

- OH 1630%
- PA 449%
- ND 398%
- WV 329%

Largest declines occurred in:

- Fed. Offshore, GUFMEX 45%
- Montana 42%
- Louisiana 35%
- California 27%
- Kansas 26%
- Wyoming 22%
- Arkansas 22%
- Utah 21%
- Texas 10%

RESULTS – NATURAL GAS CONSUMPTION TRENDS



Seasonality: In most cases, delivery volumes increase after September, have the largest peak in January and decrease until May. Then there is a smaller increase with a local peak in July through August, and a decrease until September.

Largest growths occurred in:

- NC 70%
- VA 46%
- VT 40%
- DE 36%
- GA 35%

Largest declines occurred in:

- AK 34%
- ME 26%
- NH 17%
- RI 14%
- D.C. 12%
- KS 5%

METHODOLOGY – NATURAL GAS IMPORTS & EXPORTS

- Thought Process
  - For each state, how much natural gas would need to be imported or exported if each market was considered individually.
- Natural Gas Imports

$$IF\ Consumption > Production$$

$$THEN\ Natural\ Gas\ Import\ Volume = Natural\ Gas\ Consumption\ Volume - Natural\ Gas\ Production\ Volume$$

$$ELSE\ Natural\ Gas\ Import\ Volume = 0$$

- Natural Gas Exports

$$IF\ Production > Consumption$$

$$THEN\ Natural\ Gas\ Export\ Volume = Natural\ Gas\ Production\ Volume - Natural\ Gas\ Consumption\ Volume$$

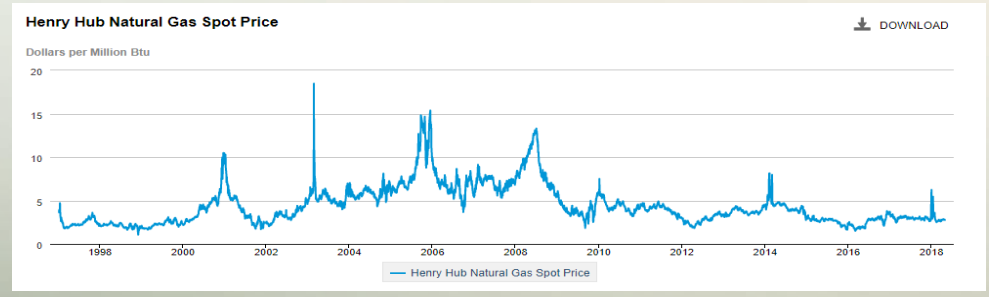
$$ELSE\ Natural\ Gas\ Export\ Volume = 0$$

METHODOLOGY – IMPORTS & EXPORTS ASSUMPTIONS

All gas produced in a state is also processed in a state	• Not always true. Typically < 5% is processed outside of a state
Natural gas crosses state lines only once	• Actual pipeline networks can be quite complex • A conservative and idealistic analysis
All natural gas is can be transported in any available transmission line	• All processed natural gas is of an average quality that meets pipeline specifications • In reality – pipelines can have inconsistent specifications
Only processed gas is transported in transmission lines	• No comment from EIA

DAILY VARIATION IN MONTHLY AVERAGES

- From the capacity utilization charts, it is observed that Vermont had an average import capacity utilization of 70.38% for February of 2014.



Estimated Daily Import Capacity Utilization for Vermont in February 2014					
2014 Feb- 3 to Feb- 7	56.27%	67.09%	88.32%	79.05%	68.83%
2014 Feb-10 to Feb-14	88.51%	85.81%	69.31%	61.02%	63.90%
2014 Feb-17 to Feb-21	70.38%	67.34%	69.79%	69.31%	72.52%
2014 Feb-24 to Feb-28	70.72%	59.03%	52.23%	48.39%	52.05%
2014 Mar- 3 to Mar- 7	80.70%	87.40%	74.84%	53.68%	51.67%

STATES AT RISK FOR NATURAL GAS SHORTAGES

- Florida
  - 4th highest consumer of natural gas
  - 2nd highest importer
  - 62% of electricity generated from natural gas in 2015
- California
  - 2nd highest consumer of natural gas
  - 1st highest importer
  - 50% of electricity generated from natural gas in 2016