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Shale Investment Dashboard in Ohio

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Executive Summary

This report presents findings from an investigation into shale-related investment in Ohio from researchers at Cleveland State and Youngstown State Universities. The investment estimates are cumulative from 2011 through the summer of 2016. Subsequent reports will estimate additional investment since the date of this report.

The investigation was made into upstream, midstream and downstream investments. The downturn in oil and gas prices in late 2014 that continued through 2016 has constrained upstream investment in Ohio, as drilling slowed. However low hydrocarbon prices have increased a nationwide appetite for natural gas and natural gas liquids. This has led to a continuation of midstream and downstream investment.

Since operating companies do not generally make investments publicly available, upstream investments were estimated by using approximations for typical expenditures on wells that are drilled in the Utica. Information for typical investments were obtained through a combination of industry interviews and publicly available data. Upstream investment in Ohio into the Utica through the summer of 2016 can be summarized as follows:

Total Estimated Upstream Utica Investment: 2011-Summer 2016

Undeveloped Land	**$16,153,370,000**
Developed Land	**$2,664,000,000**
Drilling	**$14,811,000,000**
Roads	**$888,000,000**
Near Lease Gathering Lines	**$2,664,000,000**
Lease Operating Expenses	**$372,100,000**
Royalties	**$1,682,000,000**
Total Estimated Upstream Investment	**$38,862,370,000**

Midstream investments were likewise estimated using estimated costs determined through industry interviews and estimated expenditures, together with publicly reported investments for various activities. Midstream investments include pipelines, including gathering and interstate systems. Ohio, of course, had an oil and gas business that predated shale development. However, it was dry gas only; there was no midstream natural gas processing. Accordingly, we assumed for this analysis that all wet gas infrastructure is shale development related. Dry gas midstream development, which consists of gathering lines and interstate pipeline development, is not readily separated from conventional oil and gas activities. However nearly all new midstream activity in Ohio has been a result of the large volumes of natural gas produced from

the Utica. Accordingly, all gathering lines and interstate pipelines are considered as relating to the Utica for purposes of estimating shale investment in Ohio.

Total Estimated Midstream Investment: 2012-Summer 2016

Gathering Lines	**$3,160,000,000**
Processing Plants	**$1,170,000,000**
Fractionation Plants	**$1,078,000,000**
Storage Tanks	**$234,000,000**
Railroad Terminals	**$117,000,000**
Interstate Transmission Lines	**$2,365,441,748**
Total Estimated Midstream Investment	**$8,124,441,748**

Downstream investments have been identified by the Study Team as those which consume large amounts of natural gas or natural gas liquids. Such investments also cannot be readily separated into shale or conventional oil and gas related development. However, we have assumed for this analysis that new downstream development (since 2012) relates directly to the low price hydrocarbon environment that began as a result of shale exploitation. This includes such things as new natural gas generation and new compressed natural gas refueling stations. New petrochemical plants, which require large investments, are still being considered for Ohio and were not part of the analysis unless construction has begun. Projects that have already begun, however, include a Marathon refinery expansion in Canton, Ohio and a fertilizer plant expansion in Lima, Ohio.

Total Estimated Downstream Investment: 2012-Summer 2016

Petrochemical Plants	**$315,000,000**
Natural Gas Plants	**$3,040,000,000**
CHP Plants	**$4,563,000**
Natural Gas Refueling Stations	**$37,600,000**
Total Estimated Downstream Investment	**$3,397,163,000**

Total investment through June 2016 is approximately $50.4 billion, including upstream, midstream and downstream. This does not include indirect development, such as development into new manufacturing as a result of lower energy costs.

1. INTRODUCTION

A. BACKGROUND.

This is the first of four studies, presented in the form of a dashboard, reporting investment resulting from oil and gas development in Ohio related to the Utica and Point Pleasant formations (hereinafter, the "Utica"). This analysis looks at investment separately for the upstream, midstream and downstream portions of the industry. For the upstream part, the research team examined the status of the drilling and producing of wells, and included estimates of spending therewith. For the midstream part, the research team looked at infrastructure downstream of production, from gathering to the point of hydrocarbon distribution. Midstream infrastructure being built in Ohio is directly the result of shale development, although not necessarily all Utica. Some Marcellus Shale gas may be processed and transported in Ohio. However, no conventionally extracted natural gas has been processed in Ohio.

For the downstream analysis, the research team considered those industries that directly consume large amounts of oil, natural gas or natural gas liquids. Since hydrocarbon consumption may or may not be related to shale development, the examination of downstream investment has been limited to those projects that have been deemed by the Study Team to be directly the result of the large amount of oil and gas being developed in the region as a result of the Marcellus and Utica shale formations.

This first Study is cumulative for investments made from 2011 through June of 2016. Subsequent reports will include incremental spending on a quarterly basis.

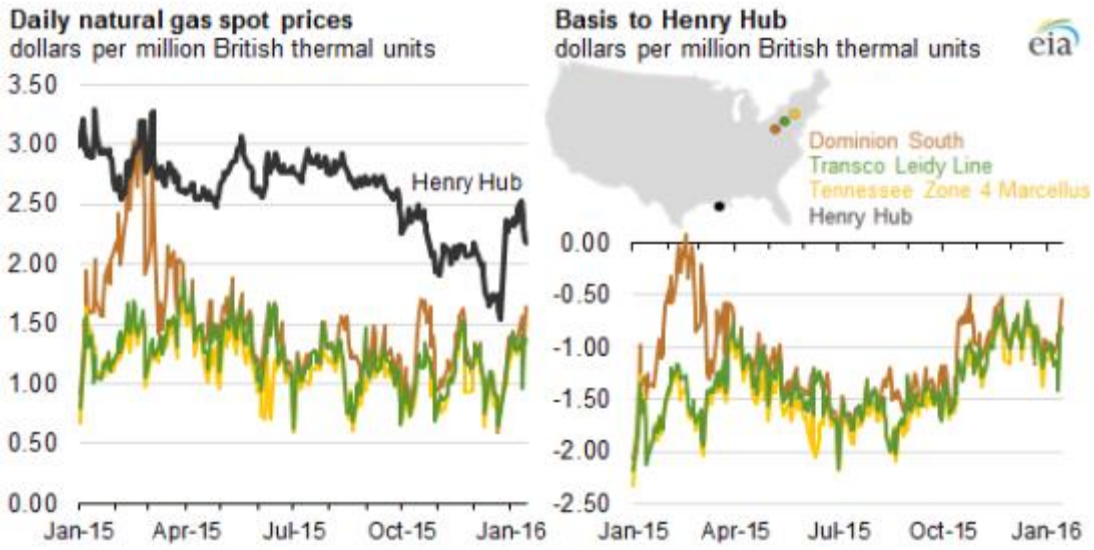
B. INDUSTRY TRENDS.

1. Hydrocarbon Pricing and Spark Trends

Investment rates, especially in the upstream sector, are closely related to hydrocarbon prices. Depressed hydrocarbon prices since the fall of 2014 have significantly slowed upstream activities into the Utica. Drilling rigs operating in Ohio in the Utica dropped from 47 in the summer of 2014 to 15 by October of 2016.

However low hydrocarbon prices can also stimulate demand, and as a result have a positive effect on investment rates in mid and downstream investment. For instance, the price differential between the Appalachian and Henry Hub natural gas indices is driving the development of new interstate natural gas pipelines in the Appalachian region. Likewise, industries that use natural gas as a feedstock or for energy generation have expanded operations in response to the low prices. Figure 1 below shows the natural gas differential between the Gulf Coast (Henry Hub) and Appalachian hubs through early 2016.

Figure 1: Spread Between Henry Hub, Appalachian Hubs[1]



Low natural gas prices have in particular created interest in development of petrochemical industries and power generation. The petrochemical industry requires significant new investments, planning and lead-time. As a result, much of the downstream investment in the region is still projected rather than incurred, as of the fall of 2016.

The power generation industry, on the other hand, has already begun to see significant investment in Ohio. Investment decisions into natural gas power generation is controlled principally by the "spark spread," which is how industry measures the difference between wholesale natural gas and electricity prices. The larger the spark spread, the more profitable natural gas generation will be.

Spark spread is calculated based upon the conversion efficiency for natural gas-fired generation systems using the following equation:

Spark spread ($/MWh) =
power price ($/MWh) – [natural gas price ($/MMBTU) * heat rate (MMBTU/MWh)]

For purposes of calculating spark spreads, the EIA deploys an average efficiency of around 50%, which is on the high end for natural gas turbines, and usually found only in large, multi-megawatt systems. However, these sorts of systems are and will be the subject of major new generation projects in Ohio.

[1] Source: U.S. Energy Information Administration, based on Natural Gas intelligence. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=24712 Accessed October 21, 2016.

In 2015, natural gas prices were very low and wholesale power generation prices were relatively high for the Mid-Atlantic region, which is the footprint for the PJM regional transmission organization[2] that includes Ohio. This attracted investment into natural gas-fired generation in Ohio. By 2016, the spark spread in the PJM regional transmission had dropped considerably, as wholesale electricity prices dropped to $34.76/MWh. Nevertheless, the Mid-Atlantic spark spread continued to be the highest in the United States:

Regional spark spreads, October 2016:

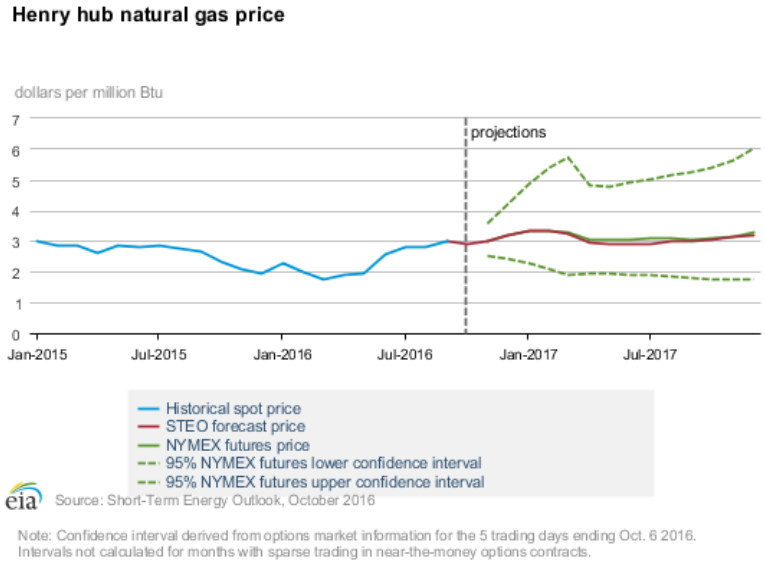
- Mid-Atlantic - $23.93/MWh
- Louisiana $18.13
- Southern California: $16.23
- Midwest: $13.57
- New England: $4.31[3]

Continued near term investment into natural gas power generation is likely. Natural gas prices are projected to continue to be relatively low, according to the Energy Information Agency. *See* Figure 2. However, we can expect that as natural gas pipeline expansion continues in the region, the differential between Henry Hub and the Appalachian hubs will diminish, and, as a result, so will the spark spread. Even with lower spark spreads, it appears that more natural gas generation will result from the closing of several coal generation plants in Ohio and elsewhere in the Midwest.

[2] States like Ohio that have deregulated electricity generation must belong to a Regional Transmission Organization (also known as Independent System Operators), which organizations manage interstate transmission and wholesale electricity markets, with Federal Energy Regulatory Commission oversight. Ohio belongs to the PJM Transmission RTO, which manages transmission and electricity markets for a group of deregulated Mid-Atlantic and Midwestern states, including New Jersey, Pennsylvania and Ohio. PJM is the largest RTO in North America in terms of electricity consumption.

[3] U.S. Energy Information Administration, based on Natural Gas intelligence. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=24712. Accessed October 21, 2016.

Figure 2: EIA Natural Gas Price Projections



Source: EIA (2016).

C. INVESTMENT STRATEGIES.

1. Upstream Strategies

Drilling and Production. Upstream investment strategies have been the most effected by the crash of oil and gas prices in the fall of 2014. Since late 2014, operating companies in Ohio have dramatically reduced their drilling activities, as they have in other basins. In the fall of 2014, there were some 47 rigs operating in Ohio.[4] In October 2016, there were only 15 rigs.[5] The result is that the upstream investment in Ohio has slowed dramatically.

Nevertheless, even though drilling has slowed, production has not. In the summer of 2014 natural gas throughput[6] was around 1.23 billion cubic feet BCF/day.[7] By June 2016, this had increased to 3.67 BCF/day.[8] There are several reasons for this. First, many of the wells drilled in 2013-14 were just coming on line in 2015-16. Second, operating and drilling companies have

[4] J. Funk. "Ohio Gas and Oil Production Soaring, Fewer Drilling Rigs at Work," *Cleveland Plain Dealer* (March 10, 2016), found at http://www.cleveland.com/business/index.ssf/2016/03/ohio_gas_and_oil_production_so.html.

[5] ODNR Division of Oil and Gas Resources, found at http://oilandgas.ohiodnr.gov/shale.

[6] Throughput refers to the volume of natural gas that passes a given location, usually a meter in a pipeline or plant, during a period of time, usually a day. Midstream infrastructure capacity is usually measured by daily throughput volume.

[7] Lendel, Iryna; Thomas, Andrew R.; Townley, Bryan; and Dick, Jeffrey C., "Mapping the Opportunities for Shale Development in Ohio" (2015). *Urban Publications*. 0 1 2 3 1328. http://engagedscholarship.csuohio.edu/urban_facpub/1328

[8] *See* section 3A below.

improved drilling efficiencies considerably: drilling companies have been able to reduce "spud to spud" time (meaning time from the beginning of drilling one well to the beginning of another well) from around 30 days in 2013 to 23 days in 2015.[9] Third, operating companies have also learned how to better manage their reservoirs, improving total recovery of hydrocarbons.[10] Finally, and perhaps most importantly, operators have been increasing the length of the horizontal laterals and increasing the number of completion zones. In 2014, lateral lengths were typically around 5000 feet for most producers. By 2016, Antero Resources' average lateral length was over 9000 feet.[11]

This last improvement has increased the cost of wells, but has also significantly increased the production per well. The strategy has been particularly effective in producing from the deeper, over-pressured Utica regions. To account for the differences in drilling costs associated with normal and over-pressured wells, the Study Team split the drilling into two different regions: northern counties (normal pressured) and southern counties (over pressured).
For purposes of this study, we have assumed a uniform cost for wells, depending upon whether they are normal or over-pressured. Industry interviews suggest that increases in lateral length and completion zones have been offset by reductions in costs for drilling and completion on a per foot basis. Obviously individual well costs since 2011 have varied considerably, but insofar as individual drilling and completion estimates -- called "authorities for expenditures" (AFEs) -- are not made publicly available, this provides a necessary and generally accurate estimation for upstream investment.

Water and Waste Water Facilities. The treatment of wastewater produced from oil and gas activity continues to be an industry issue in Ohio, and companies are still exploring methods for dealing with wastewater byproducts from drilling projects.[12] At one time it was thought that public water treatment facilities could handle oil and gas wastewater, however in 2015, the Ohio EPA banned the processing of oil and gas waste water in publicly owned facilities. Though controversial, deep well injection storage of produced water remains a popular technique of

[9] Lendel, et al, "Mapping Shale Opportunities in Ohio," *supra* note 7.
[10] However while better reservoir management improves the ultimate recovery of hydrocarbons from a well, it will likely reduce the initial production volumes, which may in turn tend to reduce near term throughput.
[11] *See*, "Antero Resources Announces 2017 Capital Budget," January 4, 2017, found at: Antero-Resources-Announces-2017-Capital-Budget-and-Guidance-and-Long-Term-Outlook-1.pdf. Antero projects a total of around $525 million in upstream investment in 2017 for the Utica and Marcellus, of which 30% was allocated to the Utica.
[12] Most wastewater consists of formation brine that is produced along with hydrocarbons, frequently containing naturally occurring radioactive materials (NORM). However, hydraulic fracturing also creates wastewater through the completion process. A typical well uses 5-10 million gallons of freshwater to fracture the well, and most of that water is returned to the surface with produced water. While it is not saltwater, it has toxic chemicals in it that require that it be disposed of safely. For an analysis of wastewater technology and the problems specific for the oil and gas industry, *see*: Alexander, Serena; Kellogg, Wendy A.; Lendel, Iryna; Thomas, Andrew R.; and Zingale, Nicholas C., "Water Resources Shaping Ohio's Future: Water Efficiency Manual for Industrial, Commercial, and Institutional Facilities (Report)" (2014). *Urban Publications*. 0 1 2 3 1239. http://engagedscholarship.csuohio.edu/urban_facpub/1239, at pages 80-86.

wastewater disposal for the oil and gas industry. According to the Columbus Dispatch, in 2015 Ohio disposed of approximately 29 million barrels of waste water in its nearly 200 existing injection wells.[13] However, the most widely used strategy for dealing with wastewater generated from shale development is to recycle the wastewater. In 2013, Chesapeake Energy reported that it saved close to $12 million through recycling and reuse of produced water in its Utica operations.[14] In the meantime, a number of companies in the Appalachian region continue to investigate new strategies for cost-effectively treating oil and gas wastewater.

2. Midstream Strategies

Processing and Fractionation. Midstream investment into processing and fractionation has also slowed somewhat in Ohio, but not necessarily because of the drilling slowdown. Rather, the investment process has been slowing down because much of the infrastructure necessary for the projected throughput has been built.

Pipelines. Pipeline building is continuing in anticipation of large volumes of natural gas and natural gas liquids being produced in the region. Low prices encourage more consumption, which in turn requires more pipeline throughput capacity. Further, an ongoing natural gas price differential between Appalachia and Henry Hub is encouraging new natural gas pipelines in the region, including high-pressure interstate pipelines. Likewise, local markets and price differentials are also driving investment in natural gas liquids pipelines.

Storage. No new natural gas or natural gas liquid storage facilities have been built in Ohio since the advent of shale development. However, that may change. Mountaineer NGL, LLC of Denver is currently in the planning phase for a natural gas liquid storage facility in Clarington, OH. The project is slated to break ground in early 2017 and proposes to add approximately 2 million barrels of initial storage capacity and 40,000 BBLS/day of load-in and load-out capacity. The facility would store ethane, propane, butane, and Y-grade products, and is scheduled to come online in early 2018.[15]

[13] L. Arenschield. "Injections of Wastewater Rise in Ohio Despite Lull in Fracking," *Columbus Dispatch* (March 7, 2016), found at: http://www.dispatch.com/content/stories/local/2016/03/07/injections-of-wastewater-rise-in-ohio-despite-lull-in-fracking.html.

[14] S. Hunt. "Who's Recycling Wastewater from 'Fracking'?," *Columbus Dispatch* (February 16, 2013), found at: http://www.dispatch.com/content/stories/local/2013/02/16/fracking-recyclers-a-mystery.html.

[15] B. Downing, "Mountaineer NGL Storage to proceed with Ohio facility," *Akron Beacon Journal (May 25, 2016),* found at: http://www.ohio.com/blogs/drilling/ohio-utica-shale-1.291290/mountaineer-ngl-storage-to-proceed-with-ohio-facility-1.685463. Chestnut Ridge Storage, LLC has proposed to develop an underground natural gas storage facility in portions of Fayette County, PA and Monongalia and Preston Counties in West Virginia. It is projected to be capable of eventually storing 25 BCF of gas. *See*: "new Underground Marcellus/Utica NatGas Storage Facility Proposed," *Marcellus Drilling News*, August 3, 2016, http://marcellusdrilling.com/2015/08/new-underground-marcellusutica-natgas-storage-facility-proposed/,

3. Downstream Strategies

Ethane Crackers. As of the fall of 2016, no companies had made a firm commitment to build an ethane cracker in Ohio. In the spring of 2016, however, Shell Chemical committed to build a multi-billion dollar ethane shale cracker in Monaca, PA, near Pittsburgh. Shell expects that the project will provide work for 6,000 temporary construction workers while it is being built, and 600 permanent, full-time employees to operate the facility once it is built.[16] In 2015, PTT Global Chemical proposed a $5.7 billion cracker to be built in Belmont County, Ohio. Despite rumors that a final investment decision had been delayed, PTT global maintains that a decision is on track for some time in 2017.[17] PTT Global also indicated that it had committed to spend around $100 million in engineering designs for the proposed facility.[18] World-class cracker facilities typically take 4-5 years to complete, so it remains to be seen what additional investment in the region will result from such potential facilities being built.[19]

Natural Gas Power Generation. In Ohio, statewide, in the fall of 2016, there were eight major natural gas power plant projects in various stages of development.[20] Four of these plants, located in Lucas Co., Trumbull Co., Carroll Co., and Butler Co., were under construction. Two others, located in Guernsey Co. and Pickaway Co., are in pre-development. The other two projects are in the application process. Though the plant projects vary in size in capacity, they will eventually mean over $7 billion dollars in investment in natural gas power across the state, and will provide an anticipated 8,000 MW increase in energy generation capacity.[21] Other potential investments include second plants in Oregon, Lordstown II, and a new plant at the former Ormet property in Monroe County.[22] In addition to these large scale gas generation facilities, a number of smaller combined heat and power plants have been built in the last several years. This trend will likely

[16] B. Downing, "Shell's $6 Billion Dollar Ethane Cracker in Western Pennsylvania Will Also Impact Ohio, West Virginia," *Akron Beacon Journal* (June 8, 2016), found at: http://www.ohio.com/news/local/shell-s-6-billion-ethane-cracker-in-western-pennsylvania-will-also-impact-ohio-west-virginia-1.688842

[17] B. Downing, "Belmont County cracker plant not delayed and is on track," *Akron Beacon Journal* (May 12, 2016), found at: http://www.ohio.com/blogs/drilling/ohio-utica-shale-1.291290/belmont-county-cracker-plant-not-delayed-and-is-on-track-1.682243.

[18] *Id*.

[19] For a discussion of likely economic development downstream of the cracker facilities, *see, generally*, Lendel, Iryna; Thomas, Andrew R.; and Townley, Bryan, "Midstream Challenges and Downstream Opportunities in the Tri-State Region" (2016). *Urban Publications*. 0 1 2 3 1413.
http://engagedscholarship.csuohio.edu/urban_facpub/1413

[20] "Statewide Impact of New Power Plants to Shale Play," "Bricker & Eckler Development Overview (Fall 2015)." *Bricker & Eckler LLP* (2015) found at:
www.bricker.com/documents/resource/Shale_Economic_Development_Chart.pdf

[21] *Id*.

[22] *See e.g.*, D. O'Brien, "Lordstown Power Plant Could Spawn Second Plant," *The Business Journal*, February 24, 2016, found at: http://businessjournaldaily.com/skilled-trades-get-ready-to-build-power-plants/, and B. Downing, "Company Offering Old Ormet Site for a Gas-Fired Power Plant," *Akron Beacon Journal*, March 7, 2016, found at: http://www.ohio.com/blogs/drilling/ohio-utica-shale-1.291290/company-offering-old-ormet-site-for-a-gas-fired-power-plant-1.666864

continue not only due to low gas prices, but also due to energy efficiency programs in Ohio that became unfrozen in December of 2016.

Oil and Condensate Refining. The Marathon plant located in Canton, OH is the only refinery operation in the state that is processing oil from the Utica.[23] Built in 1931, it has been owned and operated by Marathon Petroleum since 2005, when it was purchased from Ashland Oil, Inc. The Marathon plant has a current capacity of 90,000 BBLS/d, but is nearing the completion of a condensate splitter that will be used to process some of the large volume of wet gas being produced in the nearby Utica shale. Marathon Petroleum has stated that it allocated about $250 million for two condensate splitter projects – one at a plant in Catlettsburg, KY and the other at the Canton refinery.[24]

Fertilizer and Potash. The PotashCorp announced in 2014 a $190 million expansion to their existing facility in Lima, OH that was completed in the fall of 2015 and ended up totaling over $350 million in overall capital and maintenance investment.[25] This expansion amounted to a capacity growth in both ammonia and urea production. The ammonia segment of the plant expanded from a capacity of 88,000 tons annually to 750,000 tons annually while the urea segment expanded from 80,000 tons to 555,000 tons annually.[26] Recently, The PotashCorp announced a merger with Canadian competitor, Agrium - which will create the largest crop nutrient company in the world and the third largest natural resource company in Canada.[27]

Natural Gas Transportation. According to PoweredByCNG.com, there are 14 compressed natural gas (CNG) stations open to the public in Ohio. There are another 11 private stations, while 16 more stations are planned.[28] Another source, AltFuelPrices.com, identifies 43 total CNG stations in Ohio, plus one LNG (liquefied natural gas) station.[29] In addition to these, there is one hydrogen fuel station located in Canton, Ohio, which uses natural gas as a feedstock for hydrogen. Although some of these facilities predate shale development in Ohio, most of the facilities have been built in response to low natural gas prices resulting from shale development.

Other Downstream Investment. Two other more speculative areas of potential development relate to (1) methanol plants and (2) gas-to-liquids projects. The Study Team did not identify any

[23] Other refineries in Toledo and Lima, Ohio, refine crude imported from Canada and elsewhere.
[24] E. Pritchard, "Marathon to Invest at Canton Refinery," *Canton Republic* (December 5, 2013), found at: http://www.cantonrep.com/article/20131205/News/131209656.
[25] D. King, "Potash Shutting Down Temporarily to Finish Improvements in Lima," *Lima News* (August 17, 2015), found at: http://limaohio.com/news/149113/potash-shutting-down-temporarily-to-finish-improvements-in-lima
[26] "PotashCorp Announces $190 Million Expansion Project," *Lima News*, (August 8, 2014), found at: http://limaohio.com/archive/23599/news-news-50140642-potashcorp-announces-190-million-expansion-project.
[27] "Creation of a World-Class Integrated Global Supplier of Crop Inputs," (September 12, 2016), found at: http://www.worldclasscropinputsupplier.com/wp-content/uploads/AGU-POT-Presentation.pdf
[28] "Comprehensive List of Ohio CNG Stations," *Powered by CNG*, http://poweredbycng.com/ohio-cng-stations/
[29] http://www.altfuelprices.com/stations/CNG/Ohio/. For a map of locations, *see*: http://www.altfuelprices.com/station_map.php.

companies planning to develop methanol plants in Ohio. However there are apparently companies looking at building methanol plants in West Virginia,[30] so there may well be companies contemplating Ohio as well. Gas-to-liquid plants may also be built in the region, but not until oil prices recover. A large price differential between oil and gas drove some initial efforts in Ohio to build a gas-to-liquids plant in Ashtabula. However, those plans have been put on hold, apparently pending a better market for liquids.[31]

2. METHODOLOGY

A. UPSTREAM METHODOLOGY.

Investment into the upstream has been broken down into four categories. The first category is investment into wells, and includes one-time investments into land, drilling, roads and gathering lines. The second cost is incurred post-production, and is identified by operators as the "lease operating expense." This includes the storage, processing and disposal of produced water, among other expenses. The third investment is into royalties paid to mineral rights owners. The final investment is into lease bonuses. For this last category, only investment into undeveloped acreage is included, since the drilling cost formula we used includes land acquisition.

Operating companies do not make available their "authorities for expenditure," the common accounting device used to estimate well costs. Further, while many operators provide average well costs in their public investment documents, they do not usually break it down into specific areas of investment. As a result, the Study Team used industry interviews to estimate investment into various portions of the well, and then compared this to the overall well costs set forth in the investment presentations. The estimates did not differentiate between those portions of the investments that go directly into the Ohio economy, and those that go elsewhere.

The following estimated costs have been assumed for all wells and related upstream investments:

- Land: average investment - $1.5 mm/well. Based upon:
  - $7500/acre bonus.
  - 192 acres/well average.
- Drilling: Northern Counties - $7 mm/well; Southern Counties - $10 mm/well.[32]

[30] "Rumor: US Methanol Building 5 methanol Plants in WV," Marcellus Drilling News, http://marcellusdrilling.com/2016/08/rumor-us-methanol-building-5-methanol-plants-in-wv/, retrieved on November 21, 2106.

[31] "Ashtabula, OH GTL Plant on Hold 'Indefinitely,'" Marcellus Drilling News, http://marcellusdrilling.com/2016/08/ashtabula-oh-gtl-plant-on-hold-indefinitely/, retrieved on November 21, 2016.

[32] The difference in costs between counties are a result of the Utica being deeper in the southern counties than in the north, requiring more expensive drilling in over-pressured formations. The northern counties are: Carroll,

- Roads: average investments -- $500,000 per well. Based upon:
  - $1 mm/mile road improvement, with one mile per pad.
  - $250,000/bridge, $200,000/culvert, with one each per pad.
  - 3 wells per pad.[33]
- Near lease gathering: $1.5 mm/well. Based upon:
  - 4 miles of 8-inch gathering lines per pad.
  - $140,000/inch-mile.
  - 3 wells per pad.

Lease operating expenses were assumed to be around $12,000/month, ongoing through the life of the well. This cost is likely to go down over time, but for purposes of this study, it is assumed that they will last at least five years. The average lease operating expense was determined from industry interviews.

Royalty calculation is more complicated. It is based upon the total production and the price received for sales of the hydrocarbon. However, because much of the natural gas has been subject to processing, production records cannot be readily converted to royalty payments. Many assumptions are required to estimate the approximate price. Further, additional adjustments were required to account for transportation costs and local market conditions. These also vary over time, but were assumed to be constant in order to make a ballpark estimate of the total investment into royalties. Royalties were estimated on a per quarter basis for Utica production based upon the hydrocarbon content for a typical Utica well.

To estimate the royalties, the following assumptions were made, all based upon industry interviews, together with industry investor presentations:

- The typical well was drilled in the wet gas region, and not the dry gas or condensate regions.
- The average shrinkage was 12%, thereby making the residue gas volume 88% of the total natural gas production.
- The residue energy content was around 1100 MMBTU/MCF. Energy Information Agency prices were used to estimate royalties, which prices are based upon MMBTU at the Henry Hub market, and were adjusted accordingly.
- Residue in the Utica area was selling at prices around $0.65/MCF below the Henry Hub market (local price differential).
- Transportation costs of around $0.65/MCF were deducted from the royalty price.
- Around 44 barrels of liquids were recovered per million cubic feet of gas produced.

Harrison, Jefferson, Columbiana, Trumbull, Mahoning and Tuscarawas. The southern counties are: Noble, Guernsey, Belmont, Monroe and Washington.

[33] Pads are actually built for 6-8 wells, however early drilling is averaging around 3 wells per pad. This will change in the next several years as units are drilled out. Many operators are still putting resources into drilling and holding new units, thereby reducing the average number of wells per pad.

- Natural gas liquids were selling for around 30% of the EIA listed price for West Texas Intermediate crude oil.
- Condensate and oil in the Utica region were selling for around $10 below the EIA listed price for West Texas Intermediate crude (local price differential).
- The average royalty rate is 20%.

Finally, we estimated the investment into undeveloped acreage. This required several assumptions. First, we assumed that the average bonus paid was $5000/acre (less that the bonus paid on developed acreage, which we assumed to be, on average, the most attractive land). Second, we only researched publicly traded companies for undeveloped acreage holdings, and then only selected the top 6 companies, based upon the assumption that since those companies comprised over 80% of the drilling to date, they likely also own over 80% of the leases. This means that we are likely underestimating royalties paid. Finally, we used net acres held, not total acres, to avoid possible double counting of leases when working interests are sold in leaseholds. Operators pay bonuses upon the total acres, so this may also introduce some error in the estimate.

B. Midstream Methodology.

Midstream expenditures were estimated based upon industry "rules of thumb" the Study Team was able to ascertain through a combination of industry interviews, government reports, and industry Trade Journals. Estimated investments were then compared against investor presentations and other information gleaned from public sources to confirm their accuracy. Interviews were also used to confirm ranges of expenditures.

For purposes of estimating the investments for midstream processing plants, rules of thumb were developed based upon throughput capacities for facilities. These rules of thumb were applied to the processing plants that have been built in Ohio, using the throughput capacity estimates made available from public literature, such as investor presentations, company shareholder reports and media reports. Likewise, rules of thumb based upon throughput capacity were used to estimate fractionation plant investments and infrastructure downstream of the fractionation plants, such as storage facilities and loading terminals.

Pipeline investments can be estimated by using "inch-mile" cost estimates, and knowing the pipeline diameter and length. Interstate pipeline diameters and mileage can be readily determined from Federal Energy Regulatory Commission data. These estimates can be confirmed from investor presentations. However intrastate lines are more difficult to estimate, since information about these lines are available only if voluntarily disclosed by the midstream companies that build them. Table 1 provides an estimated cost for natural gas transmission pipelines published by the Oil and Gas Journal.

Table 1: Per Mile Cost Estimates for Natural Gas Pipelines.

Size (in.)	Right of Way	Material	Labor	Misc.	Total
8	$ -	$ -	$ -	$ -	$ -
12	$ 68,779.00	$ 188,942.00	$ 737,056.00	$ 438,626.00	$ 1,433,403.00
16	$ 267,288.00	$ 415,979.00	$ 1,937,269.00	$ 1,473,663.00	$ 4,094,199.00
20	$ 199,333.00	$ 329,680.00	$ 2,728,127.00	$ 1,740,590.00	$ 4,997,730.00
24	$ 134,000.00	$ 337,650.00	$ 2,021,810.00	$ 836,247.00	$ 3,329,707.00
30	$ 736,129.00	$ 920,316.00	$ 4,919,086.00	$ 3,406,645.00	$ 9,982,176.00
36	$ 504,104.00	$ 895,253.00	$ 3,301,095.00	$ 2,763,844.00	$ 7,464,296.00

Source: Oil and Gas Journal (2016).

For purposes of this Study, we have differentiated between gathering lines on or near the lease (around 4 miles per pad) and gathering lines that pick up the production at some central location and deliver it to a processing plant (trunk lines) or to an interstate pipeline. The former tend to be smaller diameter pipelines (typically 8 inches), with lower pressures; the latter tend to be larger diameter pipelines (12 inches and greater), with higher pressures. The investment costs for the lower pressure lease lines are included in the upstream "post production" costs, while the high-pressure trunk lines are included in the midstream "gathering" costs.

We have used rules of thumb to allocate investments to trunk line costs based upon plant throughput: using the plant size, we estimated the number and size of trunk lines required to service that plant. In some cases, we have used investor presentation, company website or interview information if available to corroborate investments. No investments into distribution lines were included in the Study, since it is assumed that these have not grown as a direct result of shale development. This assumption may be revisited for later iterations of this study if it appears that shale development is significantly affecting distribution line development.

Finally, for pipelines carrying liquids, the investment assumption is that expenditures will be comparable to those seen for gas pipelines. Liquids pipeline information is also generally available from public literature sources, so can be reasonably estimated by comparing the rules of thumb to investor information published by the operators of the lines.

The following estimated costs were assumed for midstream infrastructure:

- Gathering (Trunk) Lines.
  - 12 inch pipelines
    - $1.4 mm/mile
    - 170 miles per 1 BCFD throughput
  - 20 inch pipelines
    - $2.4 mm/mile
    - 30 miles per 1 BCFD throughput

    - Compressors
        - 3 compressor stations per 1 BCFD throughput
        - $10 mm/station
- Processing Plants.
    - $400,000/MMCFD throughput
    - $80 mm/200 MMCFD plant (typical skid size)
- Fractionation Plants.
    - $2800/BBLD
    - $100 mm per 36000 BBLD unit (typical size of plant)
- Storage Tankage: $80 mm for 1 BCFD throughput
- Rail Loading Terminals: $40 mm for 1 BCFD throughput

C. Downstream Methodology.

For downstream expenditures the Study Team made no assumptions regarding estimated costs of facilities or infrastructure. Instead, to estimate Utica-related Ohio investments, the Study Team relied upon publicly available reports. These reports were gathered from news media, trade association publications, company websites and investor presentations. The Study Team also used interviews from time to time to support investment estimates.

3. SHALE INVESTMENT UPDATES

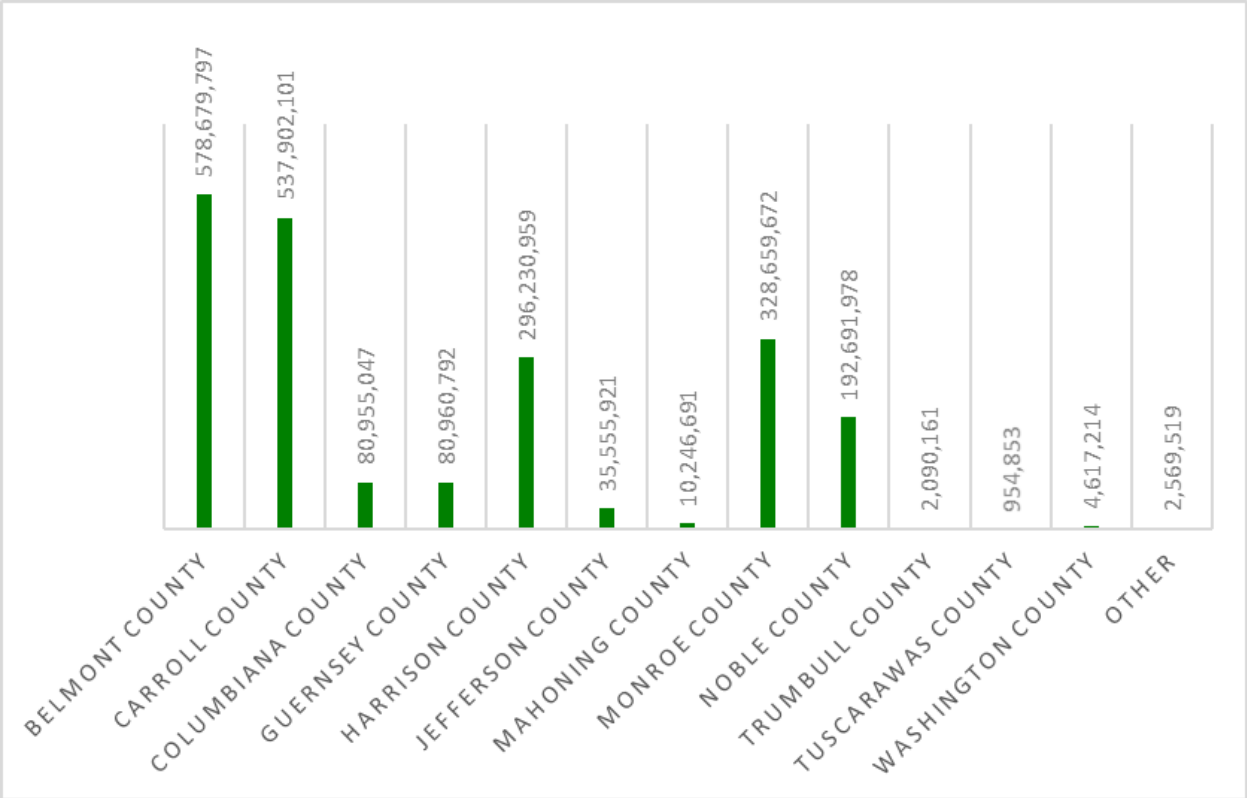
A. Upstream Development

1. Background

The Utica formation first established production in 2011 with nine wells placed into production. Since that time, a total of 1807 wells have been drilled with 1394 of those wells placed into production. The Ohio Department of Natural Resources Division of Oil and Gas Resources Management (ODNR DOGRM) issues weekly reports on well status and quarterly reports on production. The well status report of October 1, 2016 and the production report for the second quarter of 2016 provide the foundation for the analyses presented in this report.

The Utica is currently producing in nineteen eastern Ohio counties with the vast majority (ninety-nine percent) of producing wells located in twelve counties stretching from Trumbull County in the north to Washington County at the southern end of the play. Table 2 provides a summary of cumulative production and production for the second quarter of 2016 by county. Figure 3 compares the cumulative natural gas production by county.

Figure 3: Total Utica Production in MCF (Gas Equivalence) by County, through June 2016.



Data Source: Jeff Dick (using Ohio Department of Natural Resources Data) (2016).

Production is reported at the wellhead as gas measured in thousands of cubic feet (MCF) and as oil measured in barrels (BBLS). The Utica also produces significant volumes of natural gas liquids (NGLs) such as ethane, propane, butane and natural gasoline. These NGLs are produced with the natural gas stream and separated at midstream cryogenic and fractionation plants and not included in the ODNR production reports. For the purpose of this study, oil and gas production is combined as gas equivalents (MCF) based on the energy content of oil and gas, measured as British thermal units (Btu). Gas equivalents were calculated using the following formula:

Gas Equivalents (MCF) = Oil (BBLS) x 5.659 MCF/BBL + Gas (MCF)

The total production for the second quarter 2016 (Table 2) was 334,257,982 MCF gas (334 BCF), 4,839,792 BBLS oil and 361,646,365 MCF gas equivalents (362 BCF). The cumulative production from the Utica since 2011 stands at 2.2 TCF gas, 46 MMBBLS oil and 2.4 TCF gas equivalents. Table 2 breaks down production for the entire play by reporting period. Gas production for each period, as expected in a newly established play, has steadily increased over the preceding period with the exception of 2013 first quarter and 2015 third quarter. First quarter 2013 marks the beginning production reporting on a quarterly basis. The slight production volume reduction for third quarter of 2015 is a reflection of reduced oil and gas prices and its impact on Utica drilling

and production. Gas production per reporting period has increased by an average of 20.6 percent for 2014 second quarter through 2016 second quarter.

2. Production Analysis

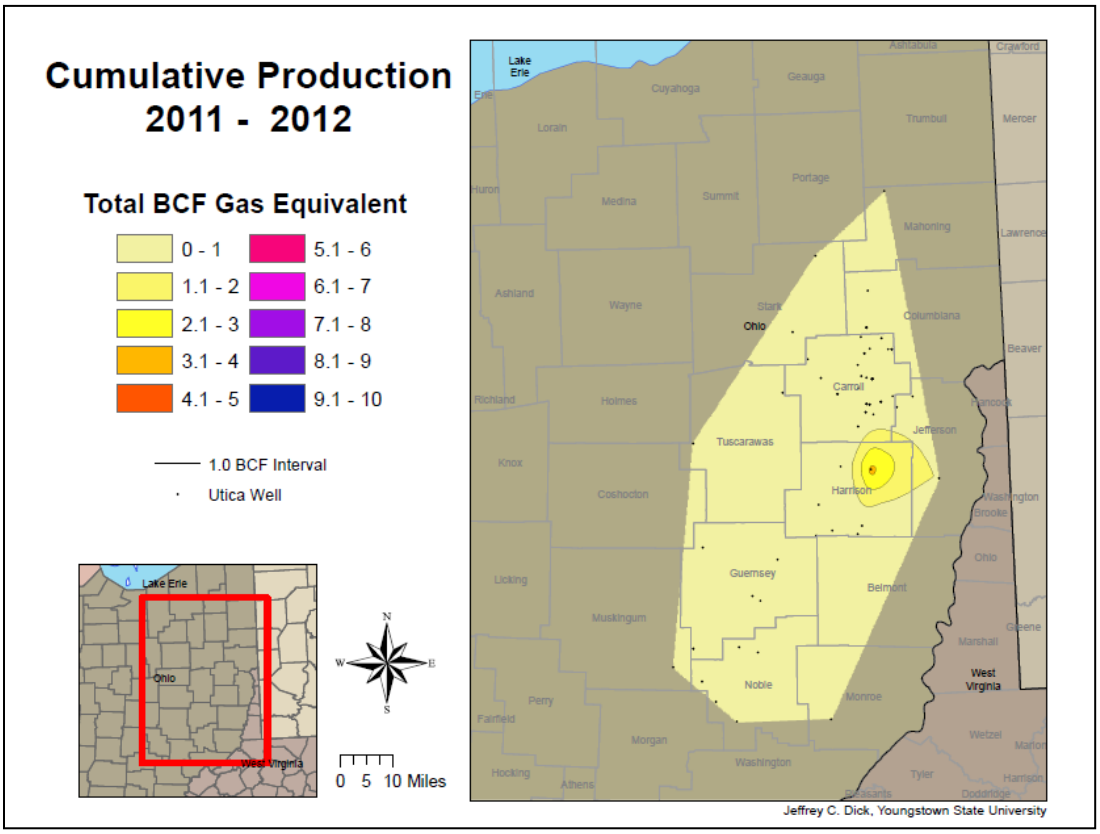
A meaningful way to summarize production is through the use of maps that show gas equivalent production measured in billions of cubic feet (BCF) as a function of time. A series of five maps for the periods 2011 through 2012, 2011 through 2013, 2011 through 2014, 2011 through 2015 and 2011 through 2016 (second quarter) summarize production in Figures 4, 5, 6, 7, and 8, respectively.

Table 2: Production by Reporting Period

Year	Quarter	Production Wells	Gas Equivalents (MCF)	Oil (BBL)	Gas (MCF)	Gas Prod. (% Change)
2016	2	1382	361,646,365	4,839,792	334,257,982	1.4%
2016	1	1328	360,582,286	5,485,854	329,537,838	9.3%
2015	4	1248	336,846,492	6,248,451	301,486,508	39.0%
2015	3	989	242,096,253	4,439,258	216,974,492	-2.2%
2015	2	992	253,429,927	5,578,255	221,862,582	20.8%
2015	1	907	208,667,049	4,432,195	183,585,256	11.4%
2014	4	810	184,954,459	3,558,836	164,815,008	26.5%
2014	3	688	147,171,872	2,984,534	130,282,395	48.4%
2014	2	535	101,480,943	2,422,179	87,773,834	30.8%
2014	1	415	78,006,674	1,928,076	67,095,693	57.2%
2013	4	371	50,807,259	1,433,731	42,693,774	28.4%
2013	3	269	40,747,160	1,323,812	33,255,706	123.7%
2013	2	189	18,012,520	556,437	14,863,645	80.4%
2013	1	117	10,056,202	321,439	8,237,177	-35.8%
2012	Annual	82	16,429,703	635,874	12,831,292	400.9%
2011	Annual	9	2,823,683	46,326	2,561,524	
		Totals	**2,413,758,847**	**46,235,049**	**2,152,114,706**	

Source: J. Dick (2016).

Figure 4: Distribution of Gas Equivalent Production for 2011 through 2012.



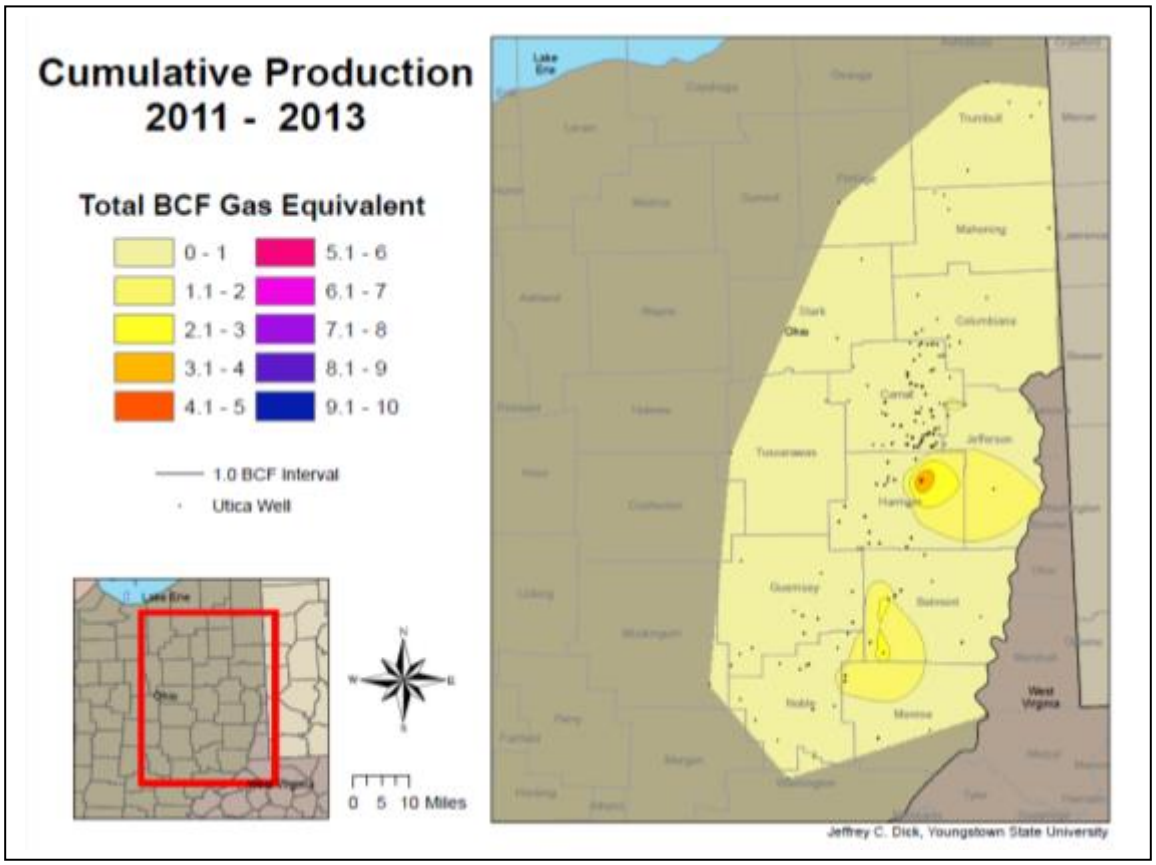
Source: J. Dick (2016).

The distribution of production for 2011 through 2012 is shown in Figure 4. This period represents the exploratory phase of the Utica with a total of eighty wells (80) in fourteen different counties placed in production. The focus of activity was Carroll and Harrison Counties, where Chesapeake was concentrating its efforts. Cumulative production for individual wells is generally less than one BCF, with the exception of Harrison County where the North American Coal Royalty Company Buell 8H well had produced 3.3 BCF. Chesapeake's exploration drilling had, at this point in time, established the Utica as a wet gas play with significant volumes of NGL production. Cumulative production for the period stands at 15.2 BCF gas, 682,200 BBLS oil and 19.3 BCF gas equivalents.

Drilling activity in 2013 had shifted from what could be considered exploratory drilling by Chesapeake in Carroll and Harrison to development drilling. At the same time, exploratory drilling in Belmont, Guernsey and Noble Counties extended the "core" of the play to the south where Antero Resources and Gulfport Energy established high volume dry and wet gas production wells. By the end of 2013, 283 additional wells had been placed in production, bringing the total number of producing wells to 363. The distribution of production for the period 2011 through 2013 is illustrated in Figure 5. Cumulative production for individual wells was still

generally less than one BCF, however; higher volume production of one to two BCF wells in Belmont and Monroe Counties demonstrated the beginning of a shift in drilling activities to the southern portion of the Utica play. Cumulative production for 2011-13 was 114 BCF gas, 4.3 million barrels (MMBBLS) oil and 139 BCF gas equivalents.

Figure 5: Distribution of Gas Equivalent Production for 2011 through 2013.



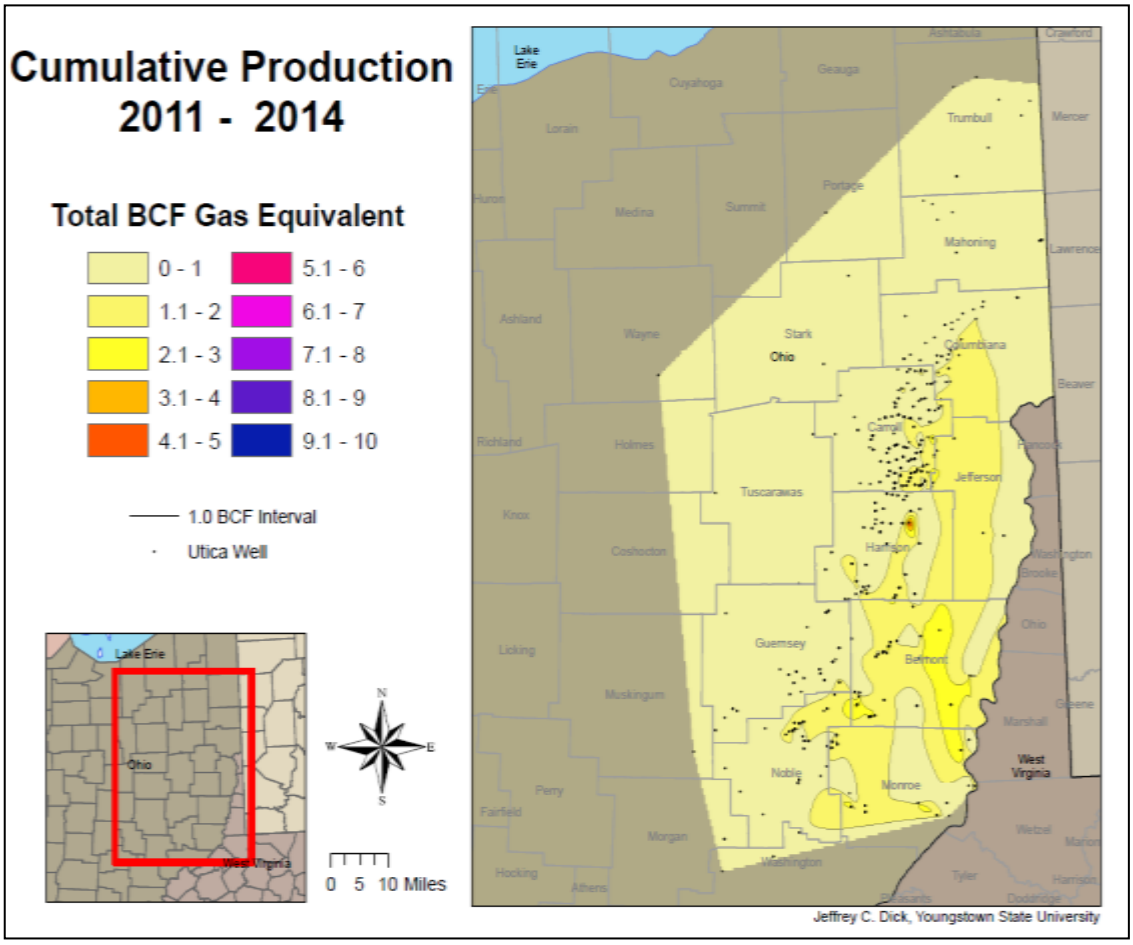
Source: J. Dick (2016).

Drilling activity in 2014 saw added exploratory drilling by Chesapeake in Columbiana County in the north and exploratory and development drilling by Antero, Gulfport, Eclipse, PDC, Consol and Hess in the southern counties of Belmont, Guernsey, Monroe and Noble. By the end of 2014 an additional 525 wells were placed in production, bringing the total number of producing wells to 808. The distribution of production for the period 2011 through 2014 is illustrated in Figure 6. Cumulative production for individual wells across the Utica play as a whole was still less than one BCF, however; production of one to two BCF wells in Columbiana, Jefferson, Harrison, Noble and Guernsey counties and two to three BCF wells in Belmont County established a new core area of Utica development in the southern and eastern portions of the play. Cumulative production for the 2011-14 was 564 BCF gas, 15.2 million barrels (MMBBLS) oil and 650 BCF gas equivalents.

The collapse of global oil prices in late 2014 had an impact on drilling activity in the Utica. Rig count dropped from a high of 48 rigs in December 2014 to 20 rigs in December 2015. Drilling

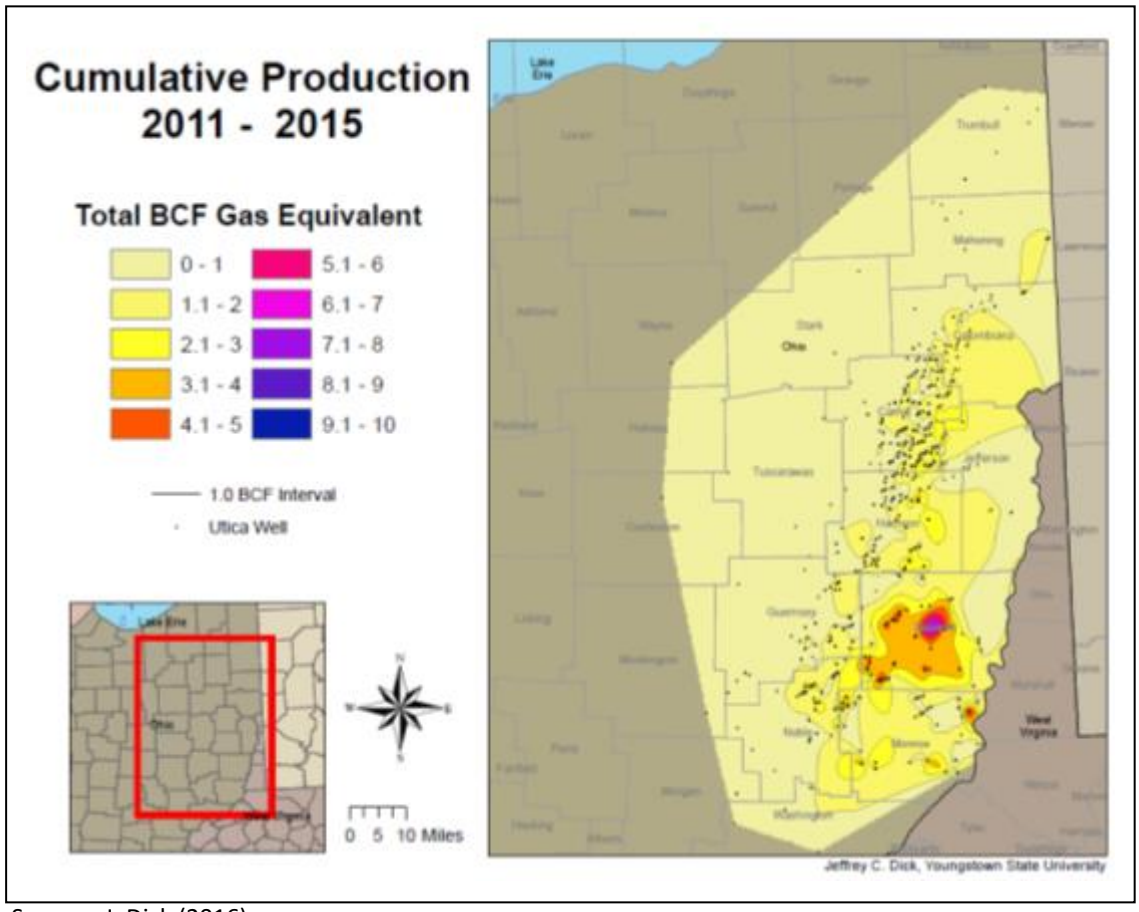
activity by year's end was concentrated in Belmont and Monroe counties, with Gulfport, Antero, Rice, Hess and Ascent as the major operating companies. A total of 447 new wells were placed into production, bringing the total number of producing wells to 1255. The lateral length of production wells was increasing and estimated ultimate recovery (EUR) of wells was increasing accordingly. The distribution of production for the period 2011 through 2015 is illustrated in Figure 7. The most notable change in production from 2014 to 2015 is the concentration of wells producing between three and five BCF in Belmont County. Three Rice Drilling wells in Smith Township of Belmont County had produced more than seven BCF during 2015 alone. Cumulative production for the period stands at 1488 BCF gas, 35.9 million barrels (MMBBLS) oil and 1691 BCF gas equivalents.

Figure 6: Distribution of Gas Equivalent Production for 2011 through 2014



Source: J. Dick (2016).

Figure 7. Distribution of Gas Equivalent Production for 2011 through 2015.

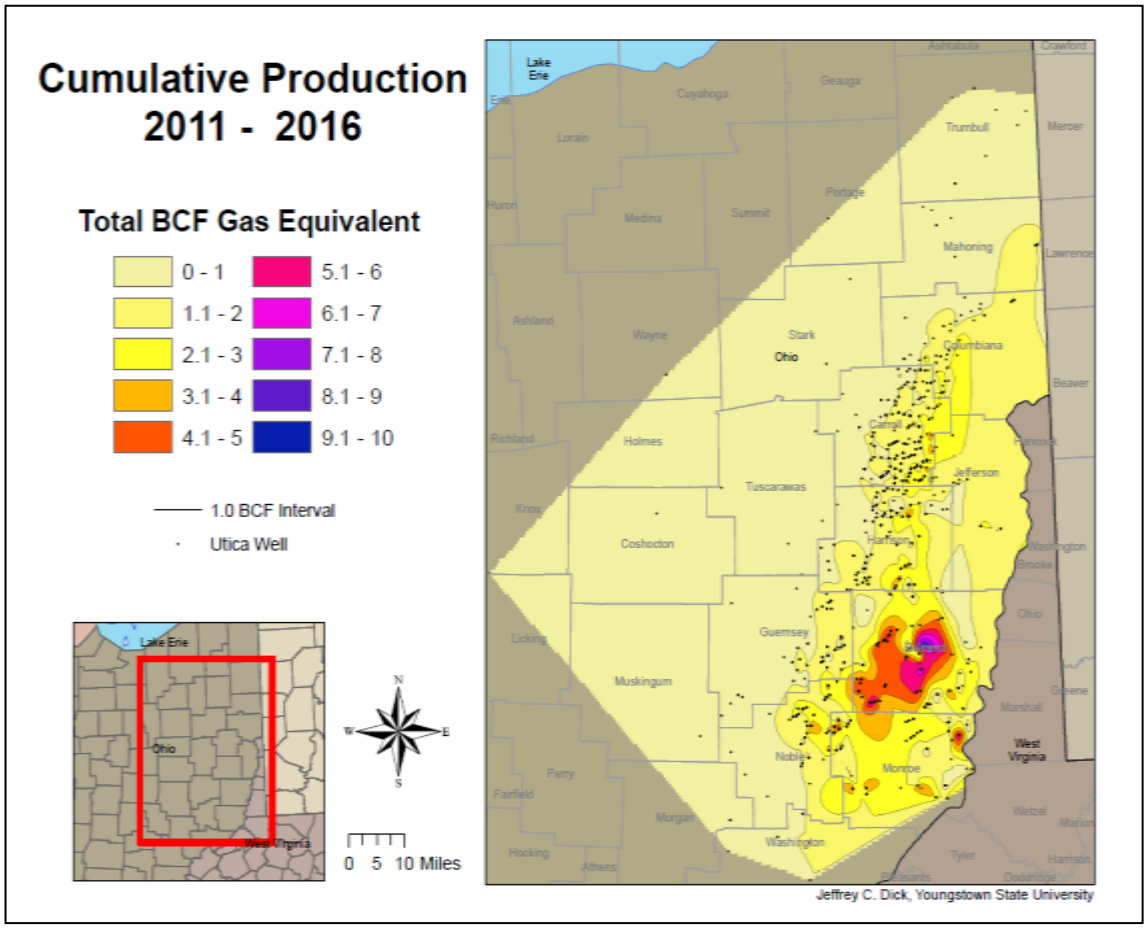


Source: J. Dick (2016).

The last ODNR production report used in this study was the second quarter of 2016. Figure 5 shows the distribution of production for the period 2011 through second quarter 2016. Utica rig count during this period bottomed out at eight rigs in early May 2016. During this period an additional 140 wells were placed into production, bringing the total number of producing wells to 1395.

The active operating companies during this period -- Ascent, Gulfport, Rice, Antero, XTO, Eclipse and Chesapeake -- were concentrating their efforts in Belmont, Jefferson, Monroe and Noble counties. Belmont County and northern Monroe County clearly has the greatest cumulative production with thirty six wells producing between 5.1 and 9.5 BCF. Rice Drilling's Bigfoot 9H well in Smith Township, Belmont County had produced 9.5 BCF gas and was expected to exceed 10 BCF gas by the end of 2016. Cumulative production for the period was 2152 BCF gas, 46.2 million barrels (MMBBLS) oil and 2413 BCF gas equivalents.

Figure 8: Distribution of Gas Equivalent Production for 2011 through Q2 2016.

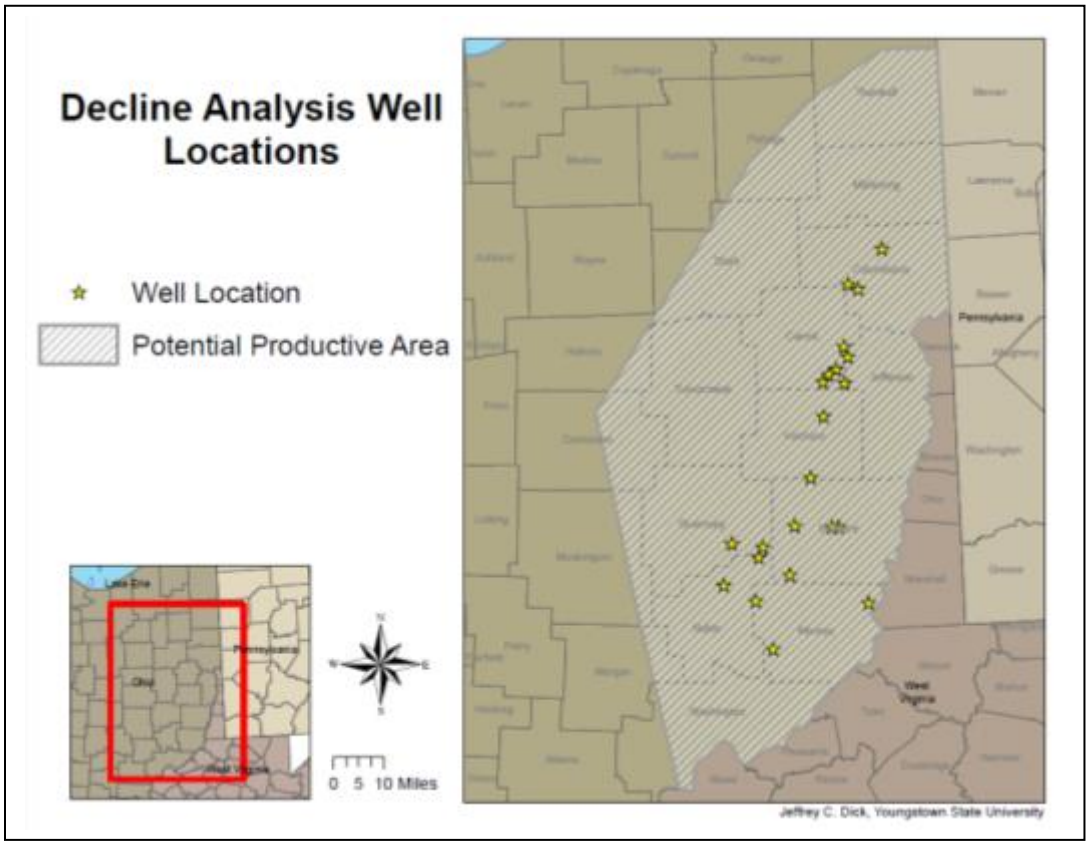


Source: J. Dick (2016).

3. Production Decline Analysis

Production naturally declines in shale wells with time. It is critically important to have an understanding of rates of decline for the purpose of estimating the EUR of individual wells and the Utica play overall. A total of twenty-two wells were selected for decline analysis using three criteria: 1) location, 2) duration of production record, and 3) quality of production record. Location is important because production characteristics vary spatially. A minimum of seven quarters of production results is necessary to define production decline during the first two years of production. Quality of production record was determined by the number of production days within any given quarter. The minimum number of production days for initial production is eighty percent of the days within that quarter. For example, a quarter having ninety-two days would require seventy-four days (92 days x 0.80 = 74 days) of production record. Production decline is expressed as percent production decline from initial reported production. Figure 9 shows the location of the twenty-two wells used in the production decline analysis.

Figure 9: Distribution Wells Used in Production Decline Analysis.



Source: J. Dick (2016).

Production decline results for the twenty-two wells organized by county are summarized in Table 3. Certain counties have similar decline characteristics. For example, Guernsey, Monroe and Noble counties show comparable production decline characteristics as do Columbiana and Jefferson counties. However, Belmont, Carroll and Harrison counties each have distinctive decline characteristics. It is important to note that production decline is a product of reservoir characteristics, which vary with location, and that decline is also a product of individual operator production strategies. This is well illustrated in Belmont County, where Rice Drilling Company manages its reservoir by constraining production so as to prevent decline during the first four or five quarters of production. Other operators in Belmont County do not appear to manage initial production in the same manner. This resulted in a 68 percent decline in the first year of production. Overall production decline for the Utica play, based on the twenty two wells stands at 56.1 percent in year one, followed by 72.5 percent and 80.3 percent in years two and three, respectively.

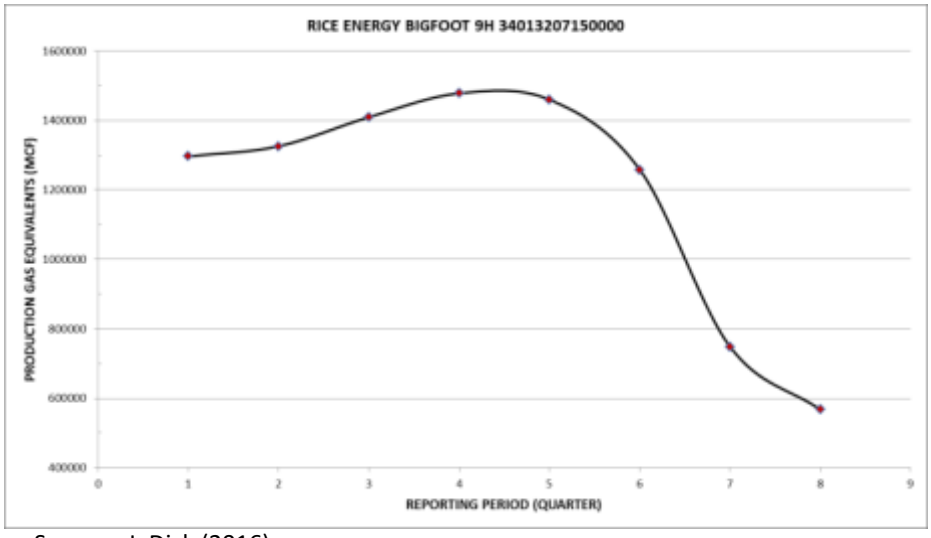
Table 3: Summary of Annual Percent Rate of Decline by County for 22 Production Wells.

Production Year	Overall Avg. Decline	Belmont	Belmont Controlled	Carroll	Columbiana	Guernsey	Harrison	Jefferson	Monroe	Noble
Year 1	56.1	68.4	0	33.3	41.8	55	93.3	45.6	56.9	54.1
Year 2	72.5	84	59.5	56.6	62	75.9	90.6	60.9	81.6	81.5
Year 3	80.3	81.4		62.4	69.9	78.6	98.2		85.7	85.6

Source: J. Dick (2016)

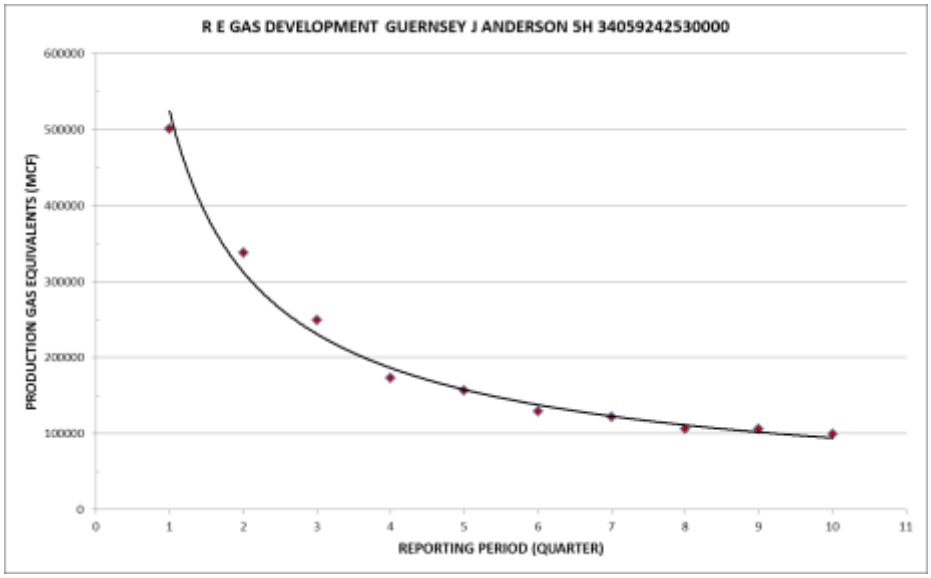
Production decline curves for four of the decline analysis wells further illustrate the variation in decline across the Utica play. Figures 10 through 13 provide a graphic representation of decline for wells located in Belmont, Guernsey, Monroe and Carroll counties. Figure 10 shows the production decline characteristics of Rice Drilling's Bigfoot 9H well in Belmont County. Rice Drilling restricts production in such a way that it actually increases over the four quarters from approximately 1.3 BCF to 1.5 BCF per quarter before starting to decline. By the end of eight quarters, production had declined fifty-nine percent while producing 9.55 BCF of dry gas.

Figure 10: Eight quarter decline for Rice Drilling Bigfoot 9H in Belmont County.



Source: J. Dick (2016).

Figure 11. Ten Quarters of Production for R E Gas Development J Anderson 5H in Guernsey County.

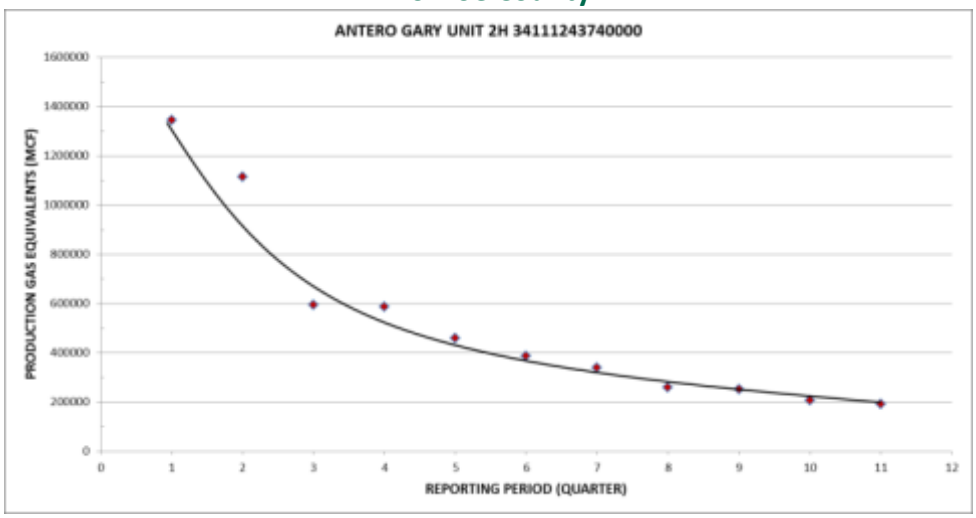


Source: J. Dick (2016).

The RE gas Development J Anderson 5H well in Guernsey County (Figure 11) and the Antero Resources Gary unit 2H well in Monroe County show similar decline characteristics, but sharply contrasting production volumes. Initial production of the Gary Unit well was approximately 1.3 BCF/qtr equivalent of combined wet gas and oil, while the R E Gas Development J Anderson well had an initial production of 501,000 MCF/qtr equivalent of combined wet gas and oil. The cumulative production of each well is 5.7 BCF and 2.2 BCF gas equivalents, respectively.

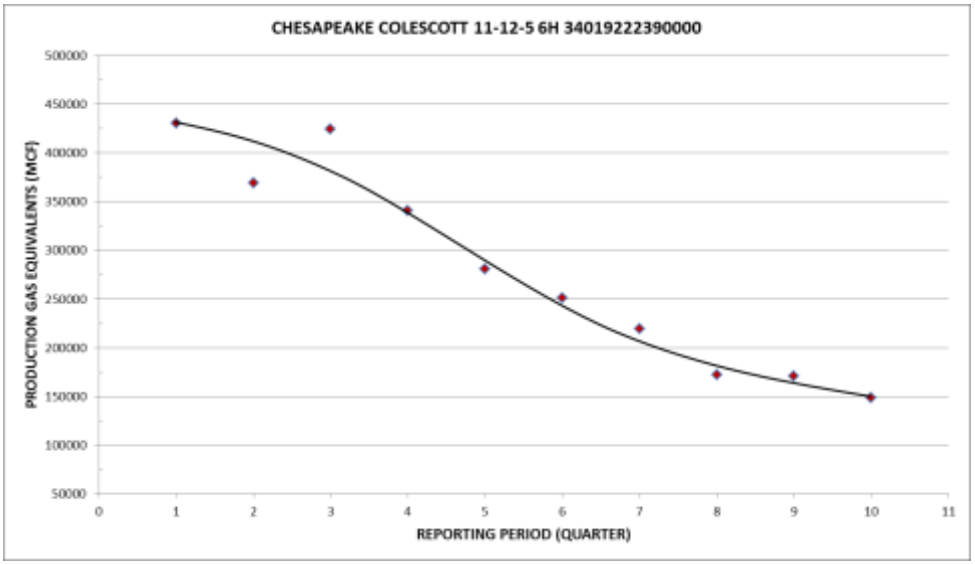
The Chesapeake Exploration Colescott 11-12-5 6H well in Carroll County is fairly representative of the production decline characteristics of Chesapeake's wells in Carroll County and western Columbiana County. This production of this well declined twenty-two percent in the first year followed by sixty percent and sixty five percent in years two and three, respectively. The cumulative production for this well is 3.1 BCF equivalents of wet gas and oil.

Figure 12: Eleven Quarters of Production for Antero Resources Gary Unit 2H Well in Monroe County.



Source: J. Dick (2016).

Figure 13. Ten Quarters of Production for Chesapeake Energy Colescott 11-12-5 6H Well in Carroll County.



Source: J. Dick (2016).

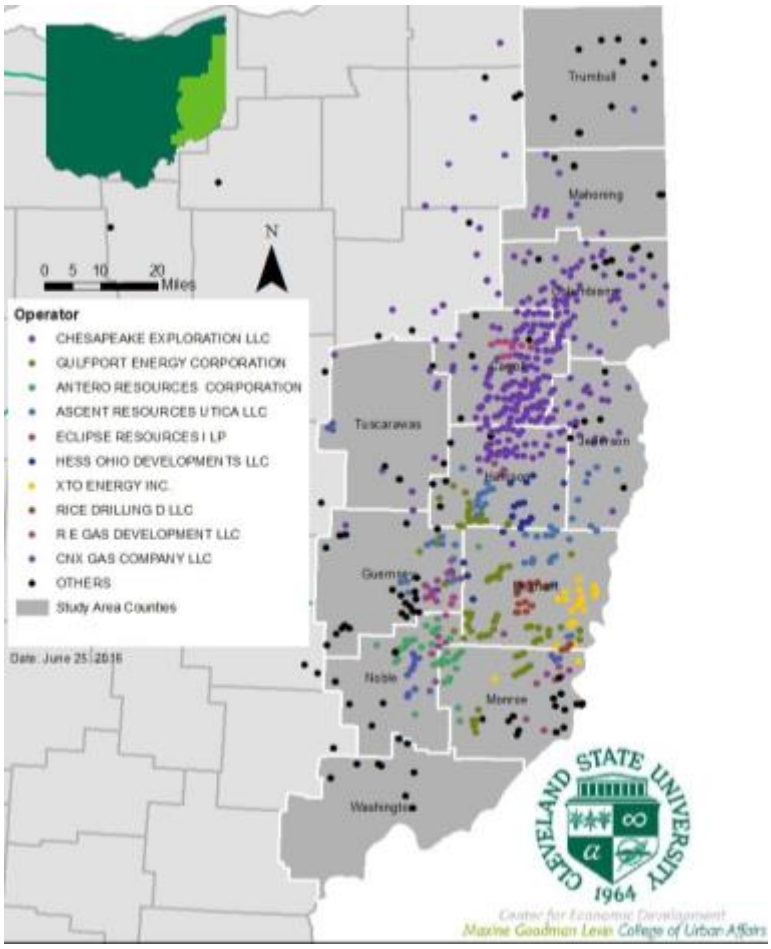
Chesapeake Exploration LLC continues to be the operator with the highest cumulative number of wells, with 684 wells. The other top nine well operators have total well numbers ranging between 37 and 246. Approximately 92% of wells in the 12 study counties are operated by the top 10 producers. Table 4 lists the Utica upstream companies drilling in Ohio. Figure 14 shows the main Utica upstream companies, with their well locations, colored coded by their respective well operator. The largest concentration of wells can be seen in Carroll, Columbiana and Jefferson County and their operator is Chesapeake Exploration LLC.

Table 4: Utica Upstream Companies Drilling in Ohio

Well Operators	Cumulative Number of Wells
CHESAPEAKE EXPLORATION LLC	684
GULFPORT ENERGY CORPORATION	246
ANTERO RESOURCES CORPORATION	170
ASCENT RESOURCES UTICA LLC	154
ECLIPSE RESOURCES I LP	88
HESS OHIO DEVELOPMENTS LLC	66
RICE DRILLING D LLC	50
CNX GAS COMPANY LLC	47
R E GAS DEVELOPMENT LLC	41
XTO ENERGY INC.	37
PDC ENERGY INC	28
TRIAD HUNTER LLC	13
ATLAS NOBLE LLC	12
CARRIZO (UTICA) LLC	11
HILCORP ENERGY COMPANY	11
HALCON OPERATING COMPANY INC	9
STATOIL USA ONSHORE PROP INC	9
CHEVRON APPALACHIA LLC	8
EQT PRODUCTION COMPANY	8
ARTEX OIL COMPANY	5
CHESAPEAKE APPALACHIA LLC	5
EM ENERGY OHIO LLC	5
HG ENERGY LLC	5
ENERVEST OPERATING LLC	4
AMERICAN ENERGY UTICA LLC	3
BRAMMER ENGINEERING INC	2
DEVON ENERGY PRODUCTION CO	2
BP AMERICA PRODUCTION COMPANY	1
PROTÉGÉ ENERGY III LLC	1
Total Number of Wells in 12 Counties	**1,725**

Note: Cumulative Number of Wells are calculated based upon the total numbers of Drilled, Drilling, and Producing
Source: Ohio Department of Natural Resources (June 25, 2016).

Figure 14: Main Utica Upstream Companies



Source: Ohio Department of Natural Resources (June 25, 2016)

Of the 1,725 wells within twelve counties, 109 were in the process of drilling in June of 2016, 297 wells had been drilled and were awaiting markets, and 1,319 wells were in the production phase. *See* Table 5, Ohio Utica Well Status.

Table 5: Ohio Utica Well Status – June 2016

Well Status	
Drilling	109
Drilled	297
Producing	1,319

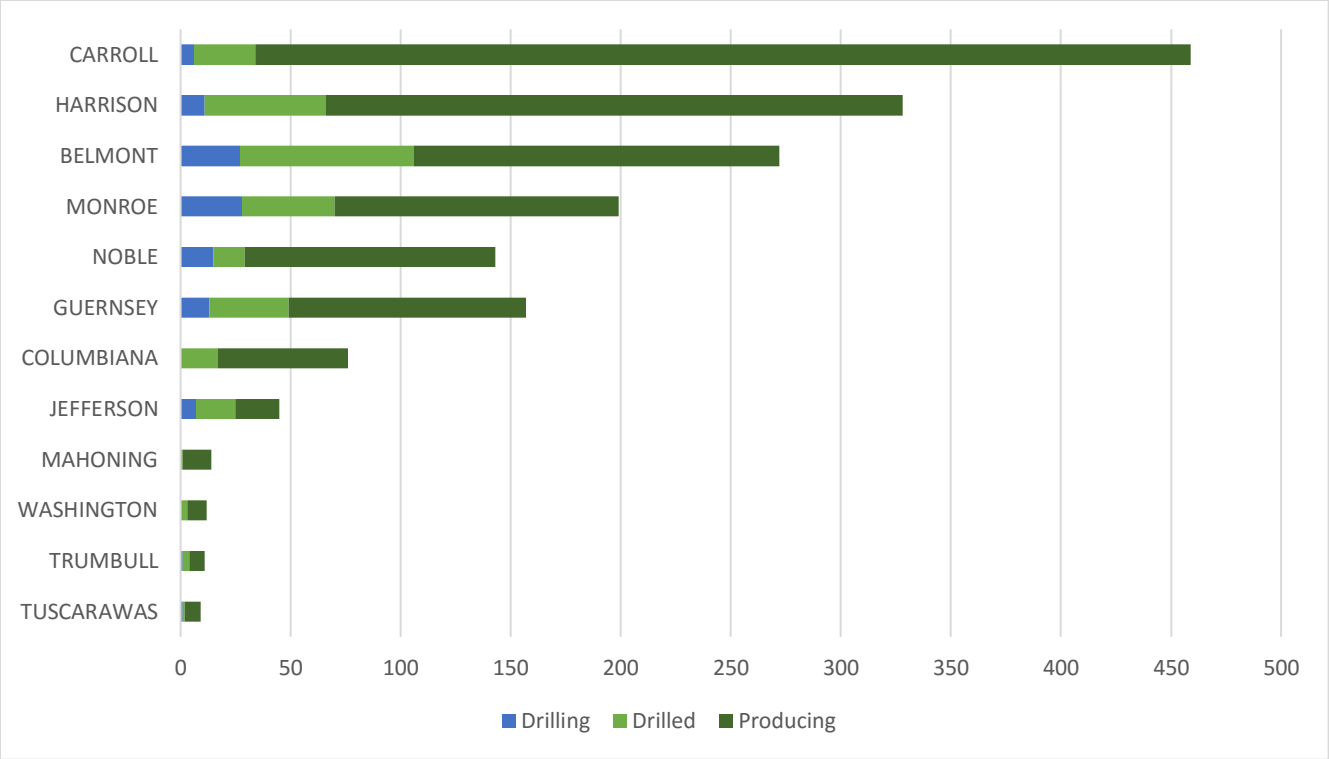
Source: Ohio Department of Natural Resources (June 25, 2016)

Of the twelve study counties, Carroll County had the highest number of total wells and the most producing wells with a total of 459 and 425, respectively. The most active drilling was in Monroe County, 28 wells. Belmont County had the largest number of drilled, but not yet producing, wells

with 79. Figure 15 shows the well status of all the wells in the study counties and Table 6 further illustrates the status of these wells by county.

It is important to note that when the ODNR reports 109 wells in the "drilling" status, this does not mean 109 wells were actively being drilled in June of 2016. The Ohio rig count in June 2016 showed 10 wells drilling, with 2 waiting to spud, according to RigData.[34] "Drilling" status is achieved, according to ODNR, once drilling activities have been reported by inspectors as having commenced. Many wells are begun and set aside, sometimes after the first casing string is set, pending additional activities from another rig. This is especially common before horizontal drilling begins. As a result, many wells are classified as drilling even though they have been dormant for a year or more, awaiting the next stage. However since it is impossible to know how far into the process these wells are, all of them have been presumed to have been drilled for purposes of estimating the investment.

Figure 15: Number of Wells by County



Source: Ohio Department of Natural Resource (June 25, 2016)

[34] "Weekly Report of Working Locations," Rigdata.com, May 27, 2016.

Table 6: Well Status by County (June 2016)

County	Drilled	Drilling	Producing	Total
CARROLL	48	6	28	425
HARRISON	54	11	55	262
BELMONT	63	27	79	166
MONROE	42	28	42	129
GUERNSEY	31	13	36	108
NOBLE	45	15	14	114
COLUMBIANA	57	0	17	59
JEFFERSON	31	7	18	20
MAHONING	16	0	1	13
WASHINGTON	9	0	3	9
TUSCARAWAS	11	1	1	7
TRUMBULL	3	1	3	7
Total	**297**	**108**	**1,319**	**1,725**

Source: ODNR (2016)

B. Upstream Investment Estimates

Upstream investments have been broken down into four areas: investments into drilling, near lease gathering costs, bonuses and royalties. The well costs include lease bonuses, so only bonuses paid for undeveloped acreage is estimated separately. The formula used for each calculation is set forth in section 2A above.

1. Investments into Drilling.

The following tables set forth the estimated investments to date made into drilling shale wells in Ohio. The estimated investments are based upon the formula set forth in section 2A above. As can be seen by the tables, Carroll County continues to be the leader in investment to date for wells, led by Chesapeake Exploration. Belmont County is second in drilling investment to date, even though Harrison County has more wells. This is due to the nature of the Utica in Belmont County, which generally requires deeper, more expensive high-pressure wells to be drilled. This also explains why Belmont County has more cumulative production than Carroll and Harrison, notwithstanding having fewer wells.

Table 7: Estimated Upstream Shale Investment by County (Millions of Dollars) (Excludes royalties, bonuses for undeveloped acreage and lease operating expenses)

County	No. of wells	Land	Drilling	Roads	Gathering	Total Amount ($mm)
CARROLL	460	$690.00	$3,220.00	$230.00	$690.00	$4,830.00
BELMONT	277	$415.50	$2,770.00	$138.50	$415.50	$3,739.50
HARRISON	328	$492.00	$2,296.00	$164.00	$492.00	$3,444.00
MONROE	203	$304.50	$2,030.00	$101.50	$304.50	$2,740.50
GUERNSEY	157	$235.50	$1,570.00	$78.50	$235.50	$2,119.50
NOBLE	144	$216.00	$1,440.00	$72.00	$216.00	$1,944.00
COLUMBIANA	76	$114.00	$532.00	$38.00	$114.00	$798.00
JEFFERSON	59	$88.50	$413.00	$29.50	$88.50	$619.50
WASHINGTON	12	$18.00	$120.00	$6.00	$18.00	$162.00
MAHONING	14	$21.00	$98.00	$7.00	$21.00	$147.00
TRUMBULL	11	$16.50	$77.00	$5.50	$16.50	$115.50
PORTAGE	9	$13.50	$63.00	$4.50	$13.50	$94.50
TUSCARAWAS	9	$13.50	$63.00	$4.50	$13.50	$94.50
STARK	7	$10.50	$49.00	$3.50	$10.50	$73.50
MORGAN	3	$4.50	$21.00	$1.50	$4.50	$31.50
COSHOCTON	2	$3.00	$14.00	$1.00	$3.00	$21.00
ASHLAND	1	$1.50	$7.00	$0.50	$1.50	$10.50
KNOX	1	$1.50	$7.00	$0.50	$1.50	$10.50
MEDINA	1	$1.50	$7.00	$0.50	$1.50	$10.50
MUSKINGUM	1	$1.50	$7.00	$0.50	$1.50	$10.50
WAYNE	1	$1.50	$7.00	$0.50	$1.50	$10.50
Grand Total	1776	$2,664.00	$14,811.00	$888.00	$2,664.00	$21,027.00

Source: The Authors (2016)

Table 8: Total Upstream Shale Investment in Ohio by Company (in millions of Dollars) (Excludes royalties, bonuses for undeveloped acreage and lease operating expenses)

Well Operators	No. of Wells	Land	Drilling	Roads	Gathering	Total ($mm)
		Millions of Dollars				
CHESAPEAKE EXPLORATION LLC	701	$1,051.50	$4,937.35	$350.50	$1,051.50	$7,390.85
GULFPORT ENERGY CORPORATION	247	$370.50	$2,337.46	$123.50	$370.50	$3,201.96
ANTERO RESOURCES CORPORATION	171	$256.50	$1,710.00	$85.50	$256.50	$2,308.50
ASCENT RESOURCES UTICA LLC	159	$238.50	$1,356.12	$79.50	$238.50	$1,912.62
ECLIPSE RESOURCES I LP	91	$136.50	$860.36	$45.50	$136.50	$1,178.86
HESS OHIO DEVELOPMENTS LLC	66	$99.00	$516.00	$33.00	$99.00	$747.00
RICE DRILLING D LLC	51	$76.50	$510.00	$25.50	$76.50	$688.50
CNX GAS COMPANY LLC	49	$73.50	$471.63	$24.50	$73.50	$643.13
R E GAS DEVELOPMENT LLC	42	$63.00	$337.02	$21.00	$63.00	$484.02
XTO ENERGY INC.	39	$58.50	$390.00	$19.50	$58.50	$526.50
PDC ENERGY INC	31	$46.50	$301.00	$15.50	$46.50	$409.50
TRIAD HUNTER LLC	13	$19.50	$130.00	$6.50	$19.50	$175.50
ATLAS NOBLE LLC	12	$18.00	$84.00	$6.00	$18.00	$126.00
CARRIZO (UTICA) LLC	11	$16.50	$110.00	$5.50	$16.50	$148.50
HILCORP ENERGY COMPANY	11	$16.50	$77.00	$5.50	$16.50	$115.50
HALCON OPERATING COMPANY INC	9	$13.50	$63.00	$4.50	$13.50	$94.50
STATOIL USA ONSHORE PROP INC	9	$13.50	$90.00	$4.50	$13.50	$121.50
CHEVRON APPALACHIA LLC	8	$12.00	$56.00	$4.00	$12.00	$84.00
EQT PRODUCTION COMPANY	8	$12.00	$80.00	$4.00	$12.00	$108.00
DEVON ENERGY PRODUCTION CO	7	$10.50	$55.00	$3.50	$10.50	$79.50
ARTEX OIL COMPANY	6	$9.00	$57.00	$3.00	$9.00	$78.00
ENERVEST OPERATING LLC	6	$9.00	$45.00	$3.00	$9.00	$66.00
MOUNTAINEER KEYSTONE LLC	6	$9.00	$42.00	$3.00	$9.00	$63.00
CHESAPEAKE APPALACHIA LLC	5	$7.50	$35.00	$2.50	$7.50	$52.50
EM ENERGY OHIO LLC	5	$7.50	$50.00	$2.50	$7.50	$67.50
HG ENERGY LLC	5	$7.50	$50.00	$2.50	$7.50	$67.50
AMERICAN ENERGY UTICA LLC	3	$4.50	$27.00	$1.50	$4.50	$37.50
BRAMMER ENGINEERING INC	2	$3.00	$14.00	$1.00	$3.00	$21.00
BP AMERICA PRODUCTION COMPANY	1	$1.50	$7.00	$0.50	$1.50	$10.50
NGO DEVELOPMENT CORP.	1	$1.50	$7.00	$0.50	$1.50	$10.50
PROTÉGÉ ENERGY III LLC	1	$1.50	$10.00	$0.50	$1.50	$13.50
Grand Total	1776	$2,664.00	$14,815.94[35]	$888.00	$2,664.00	$21,031.94[35]

Source: The Authors (2016).

[35] Since some operators drill in both the northern and southern counties, we used a weighted average cost of drilling for the various operators to estimate investment. The result of this estimate is a slight discrepancy in total investment compared to shale investment totals by county set forth in Table 7.

2. Lease Operating Expenses

Near lease gathering investments have been estimated on a per quarter basis, assuming an average cost of around $12,000/month. These investments are set forth below.

Table 9: Total Lease Operating Expenses

Year	Quarter	Production Wells	Quarterly Lease Operating Expenses ($mm)
2016	2	1382	49.8
2016	1	1328	47.8
2015	4	1248	44.9
2015	3	989	35.6
2015	2	992	35.7
2015	1	907	32.7
2014	4	810	29.2
2014	3	688	24.8
2014	2	535	19.3
2014	1	415	14.9
2013	4	371	13.4
2013	3	269	9.7
2013	2	189	6.8
2013	1	117	4.2
2012	Annual	82	3.0
2011	Annual	9	0.3
		Totals	**372.1**

3. Royalties.

Royalty investments have been estimated on a per quarter basis, assuming the formula set forth in Section 2A above. Total estimated royalties spent on Ohio properties to date are around $27.8 billion. The breakdown by quarter for oil, residue gas and natural gas liquids is set forth below.

Table 10: Total Royalties from Oil in Millions of Dollars Through June 2016

Year	Quarter	Oil (BBL) Royalty Price $/BBL	Royalty ($mm)
2016	2	19.99	19.4
2016	1	19.99	22
2015	4	43.4	54.2
2015	3	43.4	38.6
2015	2	37	41.2
2015	1	37	32.8
2014	4	91.22	65
2014	3	91.22	54.4
2014	2	83.58	40.4
2014	1	83.58	32.2
2013	4	93.85	27
2013	3	93.85	24.8
2013	2	90.78	10.2
2013	1	90.78	5.8
2012	Annual	90.93	11.6
2011	Annual	91.87	0.8
		Subtotal	**480.4**

Table 11: Total Royalties from Residue Gas in Millions of Dollars Through June 2016

Year	Quarter	Residue Gas (MCF) Royalty Price $/MCF	Royalty ($mm)
2016	2	1.21	71
2016	1	1.21	70
2015	4	1.82	96.8
2015	3	1.82	69.6
2015	2	1.99	77.6
2015	1	1.99	64.2
2014	4	3.16	91.6
2014	3	3.16	72.4
2014	2	3.88	60
2014	1	3.88	45.8
2013	4	2.68	20.2
2013	3	2.68	15.6
2013	2	2.36	6.2
2013	1	2.36	3.4
2012	Annual	1.73	3.8
2011	Annual	3.75	1.6
		Subtotal	**769.8**

Table 12: Total Royalties from Natural Gas Liquids in Millions of Dollars Through June 2016

Year	Quarter	NGL (BBL) Royalty Price $/MCF	Royalty ($mm)
2016	2	12.00	35.28
2016	1	12.00	34.78
2015	4	21.36	56.66
2015	3	21.36	40.78
2015	2	18.80	36.7
2015	1	18.80	30.38
2014	4	40.49	58.72
2014	3	40.49	46.42
2014	2	37.43	28.92
2014	1	37.43	22.1
2013	4	41.54	15.6
2013	3	41.54	12.16
2013	2	40.31	5.28
2013	1	40.31	2.92
2012	Annual	40.37	4.56
2011	Annual	40.75	0.92
		Subtotal	**432.18**

4. Undeveloped Acreage.

Undeveloped acreage has been estimated for the Utica region based upon the drilling activity of top five drilling companies in the region, plus Ascent, which company has acquired a significant leasehold in the Utica, even though it is not yet a top drilling company. The top five drillers have together comprised over 80% of the wells drilled to date, and it is assumed that they likewise have over 80% of the leases. The estimated investments into undeveloped acreage is set forth below.

All estimates assume $5000/acre lease bonus. Companies may have acquired acreage through land companies or from other operators at significantly more cost than this. However the estimated original bonus was considered by the Study Team to be most appropriate for this analysis. Further, only net lease acreage was used to avoid possible double counting, although bonuses would have been paid on the gross lease acreage originally. This may result in underestimating the total investment. Likewise, using only acreage from the top five drillers, plus Ascent, may also introduce some error.

Table 13: Total Estimated Investments into Undeveloped Acreage in Millions of Dollars Through June 2016

Operator	Undeveloped Acreage	Estimate Bonus Investment ($mm)
Gulfport[36]	171,919	860
Chesapeake[37]	2,514,000	12,570
Antero[38]	126,798	634
Rice[39]	52,049	260
Ascent[40]	300,000	1,500
Eclipse[41]	65,908	330
Total		**16,153**

[36] http://ir.gulfportenergy.com/all-sec-filings/content/0001628280-17-001359/0001628280-17-001359.pdf
[37] http://www.chk.com/Documents/investors/20150908_Latest_IR_Presentation.pdf, and http://www.chk.com/investors/sec-filings
[38] https://www.fool.com/investing/2016/08/17/the-5-companies-dominating-the-utica-shale-play.aspx
[39] http://investors.riceenergy.com/phoenix.zhtml?c=252759&p=IROL-sec&secCat01Enhanced.1_rs=21&secCat01Enhanced.1_rc=10
[40] http://ascentresources.com/operations.html
[41] http://ir.eclipseresources.com/sites/eclipseresources.investorhq.businesswire.com/files/report/additional/ECR_AR_260150.pdf

C. MIDSTREAM DEVELOPMENT

1. Midstream Buildout

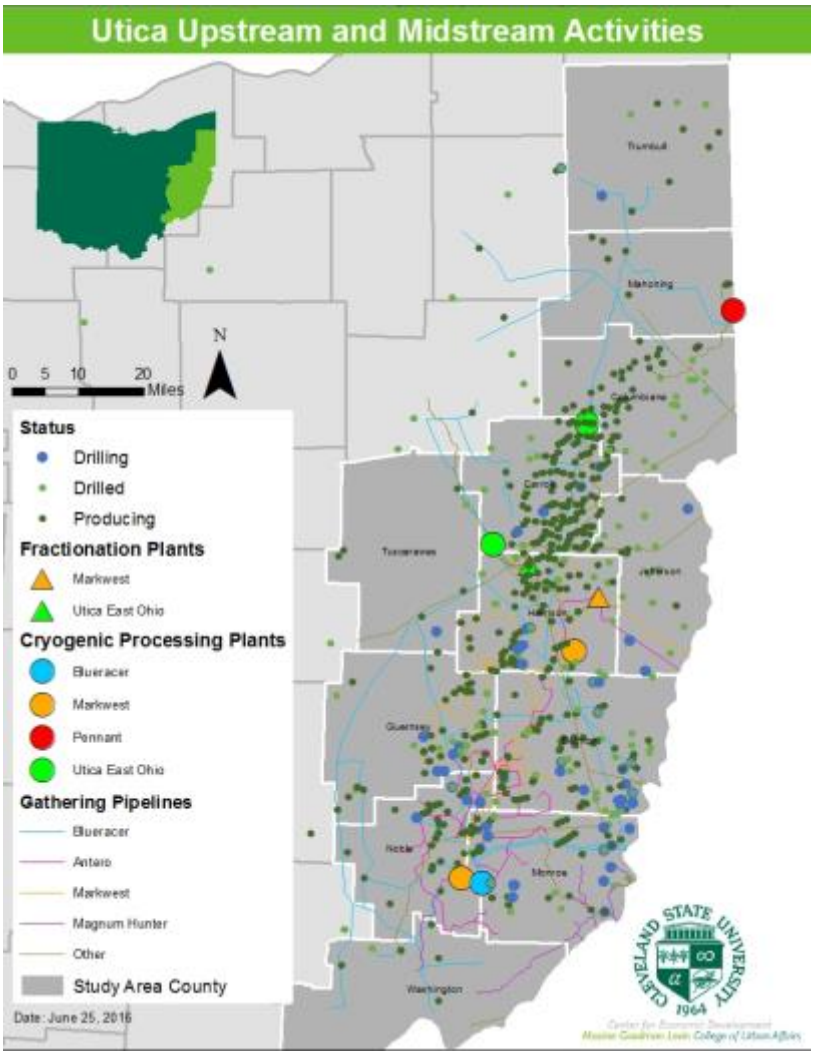
In Belmont and Monroe counties, midstream dry gas gathering facilities are being developed by Rice Midstream Holdings and Gulfport Energy are developing gathering lines and water service assets. This new development amounts to approximately $640 million in investment.[42] Likewise, MarkWest Energy and the Energy & Mineral Group are developing a dry gas gathering system of 250 miles of pipelines and 200,000 HP of compression which is around $1 billion in investment.[43] Summit Midstream Partners and XTO Energy are also building a dry gas gathering system in and around Belmont County, investing an estimated $400 million. Likewise, PVR Partners has invested around $150 million into a 45-mile gas gathering system for Hess Energy Corporation in Belmont, Harrison and Jefferson Counties.[44]

Wet gas requires substantially more midstream investment than does dry gas, however. There are nine natural gas processing plants spread throughout eastern Ohio, including cryogenic, fractionation and de-ethanization processes. These plants are shown at 8 locations on Figure 16, "Utica Upstream and Midstream Activities" (the ninth plant is a de-ethanization facility co-located with a cryogenic plant in Cadiz).

Six of the plants are cryogenic. These plants separate natural gas liquids from the natural gas stream using a combination of physical (temperature and pressure) and chemical processes. Once the liquids are separated, they are transported as an undifferentiated mixture (gas, solid, liquid, enzymes, suspension, or isotope) to a "fractionation plant," where the mixture is divided into a number of smaller quantities ("fractions") in which the composition varies according to a gradient. Fractions include ethane, propane, butane and other "pure products." There are two fractionation plants in Ohio, plus one de-ethanization plant, where ethane is removed from the natural gas liquids mixture by means of distillation.

[42] "Bricker & Eckler Development Overview (Fall 2015)." *Bricker & Eckler LLP* (2015) found at: www.bricker.com/documents/resource/Shale_Economic_Development_Chart.pdf
Water support service is an upstream investment, however no breakdown between investment into water support and gathering lines was available.
[43] *Id*.
[44] *Id*.

Figure 16: Utica Upstream and Midstream Activities



Source: Ohio Department of Natural Resources (June 25, 2016); Investor Presentations

A network of almost 2,000 miles of gathering and transmission pipelines connect these plants across eastern Ohio, with most of the lines centered in southeastern Ohio. These pipelines transport condensate, NGLs and natural gas. There are some 30 different pipelines that are either proposed or under construction, many of which are for dry gas gathering. Some of the gathering lines are shown on Figure 16, color coded by operator.

2. Estimated Midstream Investments.

Midstream investment associated with wet natural gas has been estimated based upon the processing capacity set forth by the various midstream companies operating in Ohio in their investor presentations and reports. The estimated investments set forth in Table 14 used the formula described in section 2B.

Table 14: Existing Processing Capacity in the Utica, June 2016

Location	Type of Processing			
	Cryogenic Processing (mmcf/d)	C3+ Fractionation (mbbl/d)	C2+ Fractionation (mbbl/d)	De-Ethanization (C2) (mbbl/d)
M3 Momentum				
Kensington	750	0	0	0
Leesville	250	0	0	0
Harrison	0	90	135	0
Total	**1,000**	**90**	**135**	**0**
Caiman				
Berne I+II	400	0	0	0
Total	**400**	**0**	**0**	**0**
MarkWest				
Seneca	800	0	0	0
Cadiz	525	0	0	40
Hopedale	0	120	0	0
Total	**1,325**	**120**	**0**	**40**
NiSource				
Hickory Bend	200	0	0	0
Total	**200**	**0**	**0**	**0**
Grand Total	**2,925**	**210**	**135**	**40**

Source: The Authors (2016).

Table 15 includes a wet gas gathering system in its estimate, based upon the typical number of miles and pipeline diameters associated with gathering systems for processing plants. Table 15 also includes the estimated investments for processing and fractionation plants along with storage and railroad loading terminals.

For dry gas gathering systems, the Study Team used industry reports to estimate the investments. The reported dry gas gathering line system investment is set forth together with the estimated wet gas gathering system in Table 16.

Table 15: Estimated Utica-Related, Wet Gas Midstream Investment in Ohio by Corporation (in millions of dollars) 2011-2016

Estimated Investments	Categories	Blueracer (Caiman)	Markwest (MarkWest)	Pennant (NiSource)	Utica East Ohio (M3 Momentum)	Total Amount ($mm)
Midstream Wet Gathering Lines	12 inch lines	$190	$220	$48	$238	$696
	20 inch lines	$58	$67	$14	$72	$211
	Compressors	$24	$28	$6	$30	$88
Processing Plants	$400,000/mmcfd	$160	$530	$80	$400	$1,170
Fractionation Plants	$2800/bbld	$0	$448	$0	$630	$1,078
Storage Tankage	$80 mm for 1 BCFD	$64	$74	$16	$80	$234
Rail Loading Terminals	$40 mm for 1 BCFD	$32	$37	$8	$40	$117
Total Amount		**$528**	**$1,404**	**$172**	**$1,490**	**$3,594**

Source: The Authors (2016). Does not include dry gas gathering pipelines, interstate gas pipelines or natural gas liquid pipelines.

Table 16: Total Estimated Midstream Gathering Line Investment in Ohio by Corporation (in millions of dollars) 2011-2016

Company	System	Total Investment ($mm)
Blue Racer	Wet	$272
MarkWest	Wet	$315
Pennant	Wet	$68
Utica East Ohio	Wet	$340
Rice Midstream	Dry	$640
MarkWest & Energy and Mineral Grp.	Dry	$1,000
Summit Midstream	Dry	$400
PVR Partners	Dry	$125
Total		**$3,160**

Source: The Authors (2016).

Finally, investment into interstate natural gas and natural gas liquids pipelines were determined from using Table 1, together with published reports for pipeline diameter and total miles. That investment is set forth below in Table 17. In addition, we also tracked investor reports for estimated Ohio investments. When the two estimates differed, we relied on the reported Ohio investment for the total midstream summary investment.

Table 17 shows the investment through June 2016 in completed or under construction interstate pipelines. In addition to these pipelines, three pipeline projects have been proposed that were awaiting approval in June of 2016. These include Rover Pipeline, LLC (reported Ohio investment of $4.5 billion), KinderMorgan Utopia East ($500 million), and Nexus Gas Transmission ($2 billion) pipeline projects. Of these three projects, Rover will be the first built, with construction already begun in the spring of 2017.

Table 17: Estimated Investment into Interstate Natural Gas Pipelines and Natural Gas Liquid or Condensate Pipelines (in millions of dollars)

Project	Status	Total Miles	Ohio Miles	Pipe Diameter	Ohio Compressor HP	Estimated Ohio Investment[45]	Reported Ohio Investment
Leach Xpress (LX)	Under Construction	161	160.5	36	62400	$1,435	$1,518
Spectra Ohio Pipeline Energy Network (OPEN)	Completed	76	76	30	9400	$648	$432
Equitrans Ohio Valley Connector (OVC)	Completed	50	50	16-30	21000	$445	$416
					Totals	**$2,528**	**$2,366**

Source: The Authors (2016).

D. Downstream Development

1. Petrochemical Plants.

The biggest downstream investments relating to shale gas are petrochemical plants, including refineries. Ethane and Propane crackers can cost $4-5 billion each. While no company has yet announced that it will build a cracker in Ohio, as of the fall of 2016, Ohio has seen major investments into two petrochemical plants. The estimated investment is set forth in Table 18.

[45] Estimated Ohio investment is based on rules of thumb obtained from industry interviews, whereas reported Ohio investment appears to be what was actually spent according to company public investor reports.

Table 18: Downstream Petrochemical Investment in Millions of Dollars (2016)

Company/Facility	Location	Total Investment ($mm)
PotashCorp	Lima, OH	$190
Marathon	Canton, OH	$125
Total		**$315**

Source: The Authors (2016).

2. Natural Gas Power Plants.

Ten new natural gas power plants are under construction or in the planning stages across the state as of late 2016. These plants are expected to provide over 10,000 MW of new power. Four of these ten projected plants are already under construction, and have been included as investments in this study. The 10 new power facilities are being built in 8 locations, set forth in Figure 17 below.

The rise in natural gas power plants has been attributable primarily to the record "spark spreads" in the PJM Interconnect geographic footprint, the regional transmission organization that manages transmission and the wholesale electricity market for a number of states in the Mid-Atlantic region, including Ohio. Long-term natural gas price projections have enabled investors to justify building these facilities despite Ohio having a deregulated electricity generation market.

Figure 17: New & Projected Power Plant Investment in Ohio - 2016

Source: *Bricker and Eckler*

The four plants already under construction are located in Lucas, Trumbull, Carroll and Butler counties. Investments therefore are set forth in Table 19. The locations for the other six plants in various stages of development are: Pickaway, Columbiana, Harrison and Guernsey Counties, together with two proposed sister plants for the Oregon (Lucas County) and Lordstown (Trumbull County) locations where plants are already under construction.[46]

Table 19: Estimated Investment – Natural Gas Power Plants Under Construction in Ohio 2016

#	Name	Corp.	Location	County	Status	MW	Investment ($mm)
1	Oregon Clean Energy Center	Oregon Clean Energy, LLC	Oregon, OH	Lucas	Under Construction	860	$800
2	Lordstown Energy Center	Clean Energy Future-Lordstown, LLC	Lordstown, OH	Trumbull	Under Construction	800	$890
3	Carroll County Energy	Advanced Power	Washington TWP, OH	Carroll	Under Construction	742	$800
4	Middletown Energy Center	NTE Energy	Middletown, OH	Butler	Under Construction	525	$550
						Total	$3,040

Source: *Bricker & Eckler*

In addition to these plants, natural gas prices have also led to increased development of combined heat and power plants. CHP plants are usually designed for heat or steam generation, with electricity as a byproduct. Traditionally companies in Ohio have used coal-fired boilers to generate heat. However, the new BoilerMACT laws have encouraged many companies to switch to natural gas-fired boilers. Low natural gas prices certainly have also accelerated this transition. Nevertheless, because it is difficult to say that shale development has directly led to this change, boilers are not included in this investment study. Combined heat and power plants, on the other hand, are more clearly a direct result of shale development, since the spark spread is an important factor in their development.

Table 20 shows the estimated investment in Ohio for CHP plants since shale gas development in the region began to be significant. Continued investment into CHP in Ohio is likely not only due to the low cost of natural gas but also due to the energy efficiency portfolio which has re-emerged in Ohio following the sunset of Ohio Senate Bill 310, which had frozen Ohio's portfolio standards through December 31, 2016.

[46] Plants proposed for Pickaway Co., Columbiana Co., Guernsey Co., and Harrison Co. would total an estimated additional investment of $3.8 billion. In addition to these four plants, the development of a second 960 MW Lordstown plant was announced in early 2017 with an estimated cost of $900mm, and a second 960 MW plant is also in the pre-application phase of development in Oregon, OH. *See*: http://www.bizjournals.com/columbus/news/2017/01/09/slideshow-here-are-the-10-natural-gas-plants-in.html

Table 20: Natural Gas Fired Combined Heat and Power Plants in Ohio, 2012-2015.

City	Facility Name	Application	Year	Capacity (KW)	Fuel Class	Estimated Investment (thousands of dollars)
Dublin	Dublin Community Recreation Center	Community Services	2015	248	Natural Gas	$558
Cincinnati	Brighton Tru-Edge Heads	Fabricated Metals	2014	200	Natural Gas	$450
Medina	Medina High School	Schools	2014	125	Natural Gas	$281
Fresno	Pearl Valley Cheese	Agriculture	2013	65	Natural Gas	$146
Toledo	ProMedica Wildwood Orthopedic and Spine Hospital	Hospitals / Healthcare	2013	130	Natural Gas	$293
Cleveland	Dominion East Ohio Gas Company headquarters	Office Building	2012	1,000	Natural Gas	$2,250
Toledo	University of Toledo Data Center	Business Services	2012	260	Natural Gas	$585

Note: Estimated investment is estimated based on a formula: $2250/kW x kW capacity = Estimated Investment.
Source: U.S. DOE Combined Heat and Power Installation Database Retrieved from https://doe.icfwebservices.com/chpdb/state/OH Accessed October 21 2016. DOE information is through December 31, 2015.

3. Natural Gas Transportation.

Construction of new compressed natural gas stations cost around $1,000,000 per station, depending upon the size and application.[47] The Stark Area Regional Transit Authority built a publicly available CNG station in 2012 at its bus fleet facility for around $1.6 million dollars. In the fall of 2016, it was selling gas to vehicles for around $2.10 per gallon of gasoline equivalent (gge).[48] Assuming that the average investment per station in Ohio was around $1 mm, then the estimated total investment into CNG stations since 2012 is around $37.6 mm (including SARTA at $1.6 mm). A list of the CNG stations built through June 2016 is set forth in Table 21 below.

[47] "CNG Station Construction and Economics," NGV America (2014), found at: http://www.ngvamerica.org/stations/cng-station-construction-and-economics/. This cost excludes land cost.
[48] Communication with SARTA. See also "SARTA Unveils NEO's First Public CNG Station," SARTA (May 14, 2012), found at: http://www.sartaonline.com/sarta-unveils-northern-ohio-s-first-public-cng-sta.

Table 21: CNG Stations Investment in Ohio since 2012

#	Station Name	City	Open Date
1	Clean Energy - Stark Area Regional Transit Authority	Canton	4/15/2012
2	Quasar	Zanesville	4/16/2012
3	City of Columbus - Fleet Management	Columbus	4/17/2012
4	CNG Trans	Reynoldsburg	4/20/2012
5	IGS CNG Services - City of Dublin	Dublin	6/28/2012
6	IGS CNG Services - Orrville	Orrville	8/29/2012
7	Clean Energy - Cleveland Hopkins International Airport	Brook Park	9/27/2012
8	Kalmbach Clean Fuels	Upper Sandusky	10/21/2013
9	GAIN Clean Fuel - J Rayl Transport	Akron	1/1/2014
10	Stackhouse CNG	Orwell	1/15/2014
11	Lewisville CNG	Lewisville	2/15/2014
12	Caldwell CNG	Caldwell	2/15/2014
13	American Natural Gas	Dayton	4/15/2014
14	GAIN Clean Fuel	Columbus	4/15/2014
15	American Bulk Gas CNG	Youngstown	4/27/2014
16	City of Columbus - CNG North	Columbus	7/15/2014
17	IGS CNG Services - Girard - Mr Fuel	Girard	7/15/2014
18	Trillium CNG - Speedway LLC	Mount Vernon	8/28/2014
19	American Natural Gas	Findlay	9/10/2014
20	Trillium CNG - Kenton Agriculture Campus Expansion	Kenton	9/25/2014
21	New Concord CNG	New Concord	10/1/2014
22	ampCNG	Canton	10/18/2014
23	IGS CNG Services - Findlay - Speedway	Findlay	10/30/2014
24	Love's Travel Stop #332	Burbank	11/17/2014
25	GAIN Clean Fuel - City of Hamilton	Hamilton	12/19/2014
26	Quasar	Cleveland	1/1/2015
27	IGS CNG Services - City of Dayton	Dayton	2/16/2015
28	IGS CNG Services - Duchess BP	Obetz	3/15/2015
29	Trillium CNG - Honda Parkway	Marysville	7/11/2015
30	CNG-One LLC	Hudson	7/15/2015
31	IGS CNG Services - Marengo	Marengo	8/17/2015
32	American Natural Carrollton Station	Carrollton	11/17/2015
33	Trillium CNG	Troy	11/20/2015
34	Clean Energy - Vandalia Pilot Flying J #97	Vandalia	1/19/2016
35	IGS CNG Services - Montgomery County Solid Waste	Moraine	6/29/2016
36	Clean Energy - Ace Taxi Service	Cleveland	7/15/2016
37	CNG Pitstop	Dover	10/17/2016
Total Estimated Investment		**$37,600,000.00**	

Source: NGV America and other sources (2016).

In addition to CNG, cheap natural gas stemming from shale development also promotes liquefied natural gas (LNG) and hydrogen refueling stations. LNG is preferred over GNG for large trucks because it allows for longer times between refueling, and significant reductions in time lost refueling. In 2016, there were four LNG refueling station in Ohio – located in Seville, London, Vandalia, and Franklin. These were not included in the investment estimates.

Hydrogen is used with fuel cell electric vehicles. Hydrogen can be made from renewable sources through electrolysis. However, due to low natural gas prices, the most cost effective strategy for

making hydrogen is through steam reforming of methane. There is currently one hydrogen refueling station in Ohio, also located at the Stark Area Regional Transit Authority bus depot. The cost for building the hydrogen refueling station was around $2 million.[49]

4. CONCLUSION

Upstream investment resulting from shale development in Ohio has slowed as a result of low hydrocarbon prices since late 2014. However midstream and downstream investment has continued largely unabated. Even so, upstream investment continues to be the target of the most shale investment into the region. Total upstream expenditures in Ohio resulting from shale development since 2012 has been over $70 billion, total midstream has been around $8.1 billion and total direct downstream has been around $3.4 billion.

The center of upstream investment activity has moved from the Carroll County region south to the Belmont County region. Carroll County still leads by a large margin in total number of wells drilled, but Belmont County has surpassed Carroll County in total production. We can expect drilling investment to continue to be focused in Belmont and adjacent counties, and likewise expect new investment in mid and downstream to be moving toward Belmont County.

Downstream development in the petrochemical and refinery business has just begun, and is likely to grow in the coming years as natural gas and natural gas liquids provide an inexpensive feedstock. Investment into natural gas fueled electricity generation, expected to reach over 11,000 MW in the next several years, will likely continue until gas prices rise and spark spreads are reduced. Investment into natural gas related transportation, totaling around $37 million since 2012, is also likely to continue, including hydrogen refueling stations, as a result of low natural gas prices.

[49] *Id*.

About the Research Team

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About the Energy Policy Center
The Energy Policy Center is housed within the Maxine Goodman Levin College of Urban Affairs at Cleveland State University. The mission of the EPC is to help overcome social and institutional barriers to the implementation of solutions to energy challenges by providing an objective channel for the free exchange of ideas, the dissemination of knowledge, and the support of energy related research in the areas of public policy, economics, law, business and social science. For more information, go to http://urban.csuohio.edu/epc/.