

11-12-2019

Shale Investment Dashboard in Ohio Q3 and Q4 2018

Andrew R. Thomas

Cleveland State University, a.r.thomas99@csuohio.edu

Mark Henning

Cleveland State University, m.d.henning@csuohio.edu

Follow this and additional works at: https://engagedscholarship.csuohio.edu/urban_facpub



Part of the [Urban Studies and Planning Commons](#)

How does access to this work benefit you? Let us know!

Repository Citation

Thomas, Andrew R. and Henning, Mark, "Shale Investment Dashboard in Ohio Q3 and Q4 2018" (2019). *All Maxine Goodman Levin School of Urban Affairs Publications*. 0 1 2 3 1628.

https://engagedscholarship.csuohio.edu/urban_facpub/1628

This Report is brought to you for free and open access by the Maxine Goodman Levin School of Urban Affairs at EngagedScholarship@CSU. It has been accepted for inclusion in All Maxine Goodman Levin School of Urban Affairs Publications by an authorized administrator of EngagedScholarship@CSU. For more information, please contact library.es@csuohio.edu.



Prepared for:
JOBSONIO

Prepared by:
Andrew R. Thomas
Mark Henning

November 12, 2019

**SHALE INVESTMENT
DASHBOARD IN OHIO
Q3 AND Q4 2018**

**Energy Policy
Center**

2121 Euclid Avenue Cleveland, Ohio 44115
<http://urban.csuohio.edu>

1. INTRODUCTION	5
2. SHALE INVESTMENT UPDATES.....	6
A. UPSTREAM DEVELOPMENT.....	6
1. Overview.....	6
2. Production Analysis.....	8
B. UPSTREAM INVESTMENT ESTIMATES	12
1. Investments into Drilling	12
2. Lease Operating Expenses.	14
3. Royalties.....	16
4. Lease Renewals and New Leases.	16
C. ESTIMATED MIDSTREAM INVESTMENTS	18
D. DOWNSTREAM DEVELOPMENT	22
1. Natural Gas Power Plants	22
2. Combined Heat and Power Plants	24
3. Refineries, Petrochemical Plants and Other Downstream Investment	24
3. CONCLUSION	26
4. APPENDICES	28
APPENDIX A. CUMULATIVE OHIO SHALE INVESTMENT	28
APPENDIX B. METHODOLOGY	35
1. Upstream Methodology.....	35
2. Midstream Methodology.....	37
3. Downstream Methodology.....	39

LIST OF TABLES

Table 1: Shale Production by Reporting Period	8
Table 2: Production by County for July-December 2018.....	9
Table 3: Ohio Utica Well Status as of December 2018	11
Table 4: Well Status by County (December 2018).....	11
Table 5: Estimated Upstream Shale Investment by County, July-December 2018	13
Table 6: Estimated Upstream Shale Investment in Ohio by Company, July-December 2018.....	13
Table 7: Estimated Lease Operating Expenses for July-December 2018 by County	14
Table 8: Estimated Lease Operating Expenses for July-December 2018 by Operator	15
Table 9: Total Royalties from Oil.....	16
Table 10: Total Royalties from Residue Gas	16
Table 11: Total Royalties from Natural Gas Liquids	16
Table 12: Total Est. Investments into Undeveloped Acreage (New & Renewed Leases).....	17
Table 13: Midstream Transmission and Gathering Line Investment.....	19
Table 14: Additional Midstream Investment, July through December 2018	20
Table 15: Natural Gas Fired Combined Heat and Power Plants in Ohio.....	24

Table 16: Utica Upstream Companies Drilling in Ohio	32
Table 17: Total Lease Operating Expenses through December 2018.....	33
Table 18: Cumulative Utica-Related Upstream Investments in Ohio through Dec. 2018.....	33
Table 19: Cumulative Utica-Related Midstream Investments in Ohio through Dec. 2018.....	34
Table 20: Cumulative Utica-Related Downstream Investments in Ohio through Dec. 2018.....	34
Table 21. Downstream Production Processes for Petrochemical Building Blocks	40

LIST OF FIGURES

Figure 1: Production by County for Q3 and Q4 of 2018	7
Figure 2: Production by Operator for Q3 and Q4 of 2018.....	7
Figure 3: Distribution of Gas Equivalent Production for July-December 2018.....	10
Figure 4: Existing & Projected Natural Gas Power Plants.....	23
Figure 5: Total Utica Production in Bcfe (Gas Equivalence) by County through Dec. 2018	28
Figure 6: Total Utica Production in Bcfe by Operator through December 2018.....	28
Figure 7: Cumulative Number of Wells by County	29
Figure 8: Distribution of Gas Equivalent Production for 2011 through December 2018	30
Figure 9: Distribution of Utica Wells by Status as of December 2018.....	31
Figure 10. Shale/Natural Gas Value Chain	40

Executive Summary

This report presents findings from an investigation into shale-related investment in Ohio. The investment estimates are cumulative from July through December of 2018. Prior investments have been included in previous reports that are available from Cleveland State University.¹ Subsequent reports will estimate additional investment since the date of this report. Investment in Ohio into the Utica during the second half of 2018 can be summarized as follows:

Total Estimated Upstream Utica Investment: July - December 2018

Lease Renewals and New Leases	\$741,380,000
Drilling	\$1,456,700,000
Roads	\$7,020,000
Lease Operating Expenses	\$231,000,000
Royalties	\$1,104,980,000
Total Estimated Upstream Investment	\$3,541,080,000

Total Estimated Midstream Investment: July - December 2018

Gathering Lines	\$111,180,000
Gathering System Compression and Dehydration	\$89,640,000
NGL Storage	\$6,000,000
Rail Transloading Facilities	\$25,000,000
Total Estimated Midstream Investment	\$231,820,000

Total Estimated Downstream Investment: July - December 2018

CHP Plants	\$44,100,000
Natural Gas Refueling Stations	\$3,825,000
Petrochemical Plants	\$125,000
Total Estimated Downstream Investment	\$48,050,000

¹ The five previous reports on shale investment in Ohio up to July 2018 can be found at:

http://engagedscholarship.csuohio.edu/urban_facpub/1464/

http://engagedscholarship.csuohio.edu/urban_facpub/1500/

https://engagedscholarship.csuohio.edu/urban_facpub/1517/

https://engagedscholarship.csuohio.edu/urban_facpub/1576/

https://engagedscholarship.csuohio.edu/urban_facpub/1597/

Total investment from July through December 2018 was approximately \$3.8 billion, including upstream, midstream and downstream. Indirect downstream investment, such as development of new manufacturing as a result of lower energy costs, was not investigated as part of this Study. Together with previous investment to date, cumulative oil and gas investment in Ohio through December of 2018 is estimated to be around \$77.8 billion. Of this, \$53.8 billion was in upstream, \$19.5 billion in midstream, and \$4.4 billion in downstream industries.²

While drilling investments were slightly down in the second half of 2018 compared to the first half, total upstream investments were up. The story of upstream development in the Utica continues to follow the theme of greater production from fewer wells, with laterals for new wells averaging more than 12,000 feet throughout the play. As determined from Ohio Department of Natural Resources Division of Oil and Gas (ODNR) data for shale well drilling, 117 new wells were drilled during the third and fourth quarters of 2018, 40 fewer than that drilled in the first half of the year. Yet ODNR production data indicate that the volume of gas-equivalent shale production in the second half of 2018 was 17.7% higher than in the first half. New well development continued to be concentrated in the southern counties, with Jefferson and Monroe counties having the highest number of new wells, with 27 and 23, respectively.

Ascent Resources and Gulfport Energy were once again the top producers for Q3 and Q4 of 2018, having produced 372.8 and 181.8 billion cubic feet equivalent (Bcfe), respectively. Rice Drilling was third in production at 176.2 Bcfe, followed by Chesapeake Exploration (now Encino)³ at 159.5 Bcfe, Eclipse Resources at 107.0 Bcfe, and Antero Resources at 106.0 Bcfe. These six companies made up around 82.7% of the total production for the second half of 2018.

The second half of 2018 in Ohio saw limited investment in midstream infrastructure, with no new gas processing or fractionation added during this period.⁴ Midstream investments in the second half of 2018 consisted primarily of gathering system buildout, with \$111.2 million spent on gathering lines and \$89.6 million spent on gathering system compression and dehydration. No new interstate pipeline projects were started during the third or fourth quarters of 2018. Development of new processing facilities and NGL pipelines have since commenced in 2019 and will be included in future reports.

In downstream developments, two combined heat and power (CHP) plants with a total capacity of 22.5 MW were installed, representing an estimated investment of \$34.1 million. No natural gas power plants broke ground in the second half of 2018. However, more than \$1.5 billion worth of natural gas power plant construction starts occurred in May 2019 and will be included in the next report. No major investments related to the proposed ethane cracker in Belmont County

² Numbers may not add up precisely due to rounding.

³ Chesapeake's sale of its Ohio assets to Encino Acquisition Partners was completed in November 2018. See <https://marcellusdrilling.com/2018/11/encino-takes-over-from-chesapeake-in-ohio-utica-big-plans/>

⁴ While part of the construction for MarkWest's Hopedale IV fractionation facility took place in the second half of 2018, the project was initiated in February 2018 and therefore included as midstream investment in the previous Shale Dashboard.

were identified for the study period, although PTT Global did make a small purchase of residential real estate in September 2018. At the end of 2018, PTT had obtained all major regulatory approvals needed from the Ohio EPA to move forward with the project.⁵ Finally, additional Q3 and Q4 2018 downstream investment identified by the Study Team included \$3.8 million in compressed or liquefied natural gas refueling stations.

1. INTRODUCTION

This is the sixth CSU study 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 made in Ohio between July 1 and December 31, 2018, separately considering the upstream, midstream and downstream portions of the industry. For the upstream part, the Study Team estimated spending primarily based upon the likely costs of drilling new and operating existing wells, together with royalties and lease bonuses.

For midstream estimates, the Study Team looked at new infrastructure built during the relevant time period downstream of production, from gathering to the point of hydrocarbon distribution. This included pipelines, processing, natural gas liquid storage, and intermodal transloading facilities.

For the downstream analysis, the Study 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 dependent on, or 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 sixth Study includes as Appendix A the cumulative investment made in Ohio resulting from shale development, based upon all previous reports that tracked total investment from early 2011 through December 2018.⁶ The methodology for determining the investments is set forth in Appendix B, and has been updated since the last report. Subsequent reports will include incremental spending on a six-month basis.

⁵ <https://www.naturalgasintel.com/articles/116939-ohio-ethane-cracker-clears-final-regulatory-hurdles>

⁶ See fn 1, *supra*.

2. SHALE INVESTMENT UPDATES

A. UPSTREAM DEVELOPMENT

1. Overview.

A total of 117 new wells were listed by the Ohio Department of Natural Resources as “drilled,” “drilling,” or “producing” during the period of July 1 to December 31, 2018.⁷ This represents a 25% reduction in new well development compared to the first half of 2018. The total number of producing wells in the Utica was 2,120 on December 31, 2018, an 8% increase from the end of June 2018. Total production in billion cubic feet equivalent (Bcfe) for this period was 1,334 Bcfe, led by Belmont County with 498 Bcfe. Monroe County was second with 292 Bcfe, followed by Jefferson County with 201 Bcfe.⁸

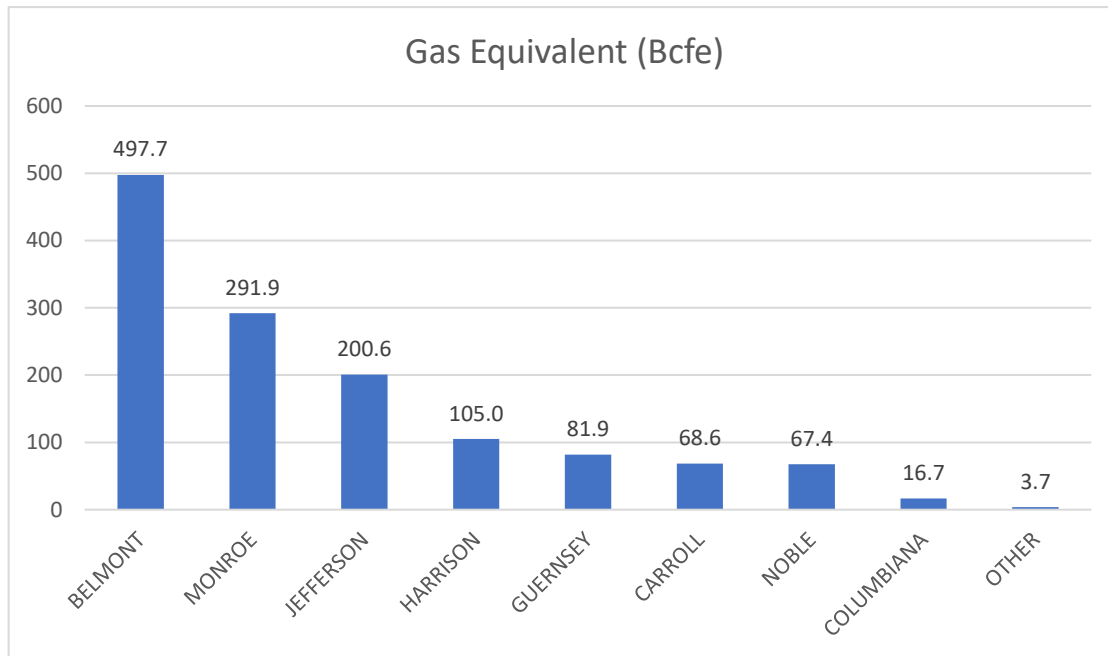
The Ohio Department of Natural Resources (Division of Oil and Gas Resources Management) (ODNR) issues weekly reports on well status and quarterly reports on production. The ODNR production reports for the third and fourth quarters of 2018 provide the foundation for the upstream analyses presented in this Study.

The Utica is currently identified by the ODNR as producing in seventeen eastern Ohio counties with the vast majority (ninety-eight percent) of producing wells located in eight counties stretching from Columbiana in the north, to Monroe and Noble at the southern end of the play. Table 1 provides a summary of cumulative production and production for the third and fourth quarters of 2018. Total cumulative production in Billions of cubic feet equivalent (Bcfe) by county and by operator through December 2018 can be found in Appendix A as Figures 6 and 7. New drilling and production have been moving steadily from the north (primarily Carroll County) to the south (primarily Belmont County) since 2014.

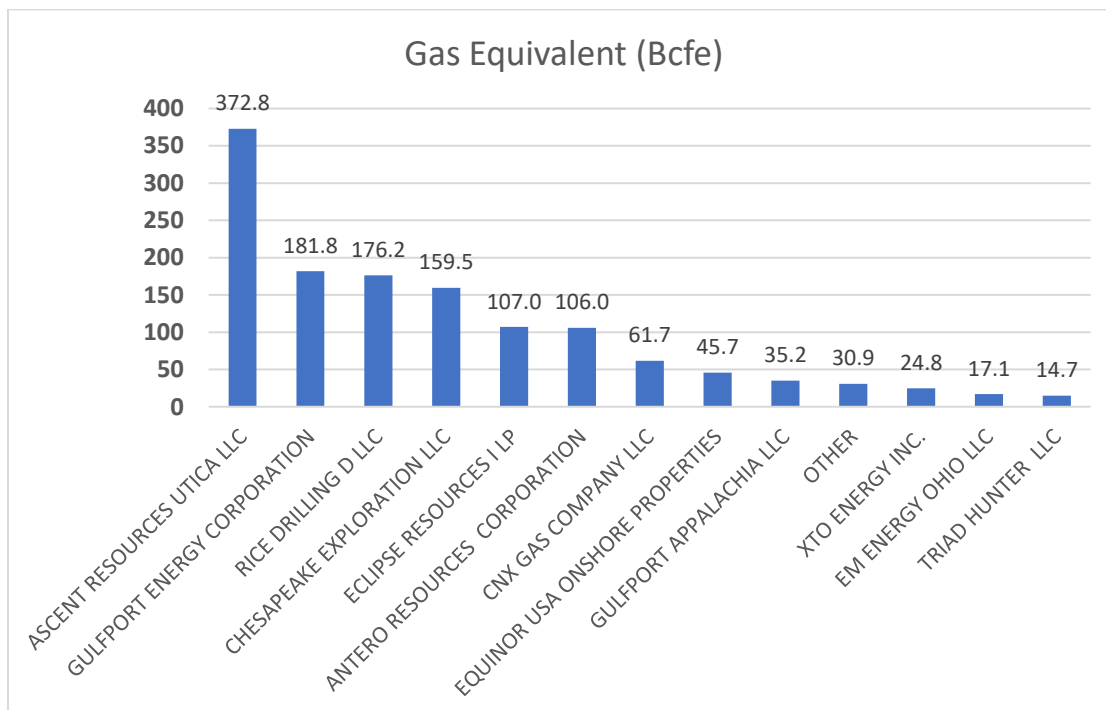
Total quarters 3 and 4 production for 2018 are set forth by county and operator in Figures 1 and 2 below.

⁷ The number of new wells was determined using ODNR Cumulative Permitting Activity reports for the beginning and end of the 6-month period (see <http://oilandgas.ohiodnr.gov/shale>). Wells are assigned an American Petroleum Institute API number, which is included in the ODNR reports. Wells were considered new if they had a status of drilled, drilling, or producing at the end of the 6-month period but did not have any one of these status designations at the beginning of it.

⁸ Production is reported to the ODNR at the wellhead as gas measured in thousands of cubic feet (Mcf) and as oil measured in barrels (bbl). The Utica also produces significant volumes of natural gas liquids (NGLs) such as ethane, propane, butane and natural gasoline. These NGLs are separated from the natural gas stream 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 (Mcfe) 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 (Mcfe) = Oil (bbl) x 5.659 Mcf/bbl + Gas (Mcf).

Figure 1: Production by County for Q3 and Q4 of 2018

Source: ODNR (2019).

Figure 2: Production by Operator for Q3 and Q4 of 2018

Source: ODNR (2019).

2. Production Analysis.

Production can be summarized through the use of tables that show gas equivalent production measured in billions of cubic feet equivalent as a function of time. This summary is set forth in Table 1. Despite a slowed drilling rate, production has increased in all but two quarters since 2013. Table 2 sets forth production by county for the second half of 2018. Figure 3 sets forth the geographic distribution of production for the same period.

Table 1: Shale Production by Reporting Period

Year	Quarter	Production Wells	Gas (Mcfe)	Oil (bbl)	Gas Equivalents (Mcfe)	Gas Equivalent Production (% Change from Previous Quarter)
2018	4	2201	663,534,323	5,810,484	696,415,852	9.3
2018	3	2198	605,716,125	5,545,536	637,098,313	9.9
2018	2	2002	554,306,916	4,488,104	579,705,097	4.7
2018	1	1906	531,291,017	3,942,251	553,600,215	5.1
2017	4	1866	503,066,907	4,193,562	526,784,387	8.7
2017	3	1769	460,844,826	4,207,674	484,656,053	18.1
2017	2	1646	387,725,175	4,019,281	410,512,053	4.7
2017	1	1530	369,913,713	3,877,717	391,904,993	2.5
2016	4	1492	362,107,422	3,568,077	382,364,866	-0.2
2016	3	1442	360,681,356	3,954,095	383,057,580	5.9
2016	2	1382	334,257,982	4,839,792	361,646,365	0.3
2016	1	1328	329,537,838	5,485,854	360,582,286	7.0
2015	4	1248	301,486,508	6,248,451	336,846,492	39.1
2015	3	989	216,974,492	4,439,258	242,096,253	-4.5
2015	2	992	221,862,582	5,578,255	253,429,927	21.5
2015	1	907	183,585,256	4,432,195	208,667,049	12.8
2014	4	810	164,815,008	3,558,836	184,954,459	25.7
2014	3	688	130,282,395	2,984,534	147,171,872	45.0
2014	2	535	87,773,834	2,422,179	101,480,943	30.1
2014	1	415	67,095,693	1,928,076	78,006,674	53.5
2013	4	371	42,693,774	1,433,731	50,807,259	24.7
2013	3	269	33,255,706	1,323,812	40,747,160	126.2
2013	2	186	14,863,645	556,437	18,012,520	79.1
2013	1	117	8,237,177	321,439	10,056,202	-38.8
2012	ANNUAL	82	12,831,292	635,874	16,429,703	481.9
2011	ANNUAL	9	2,561,524	46,326	2,823,683	
		Total	6,951,302,486	89,841,830	7,459,858,256	

Source: ODNR (2019).

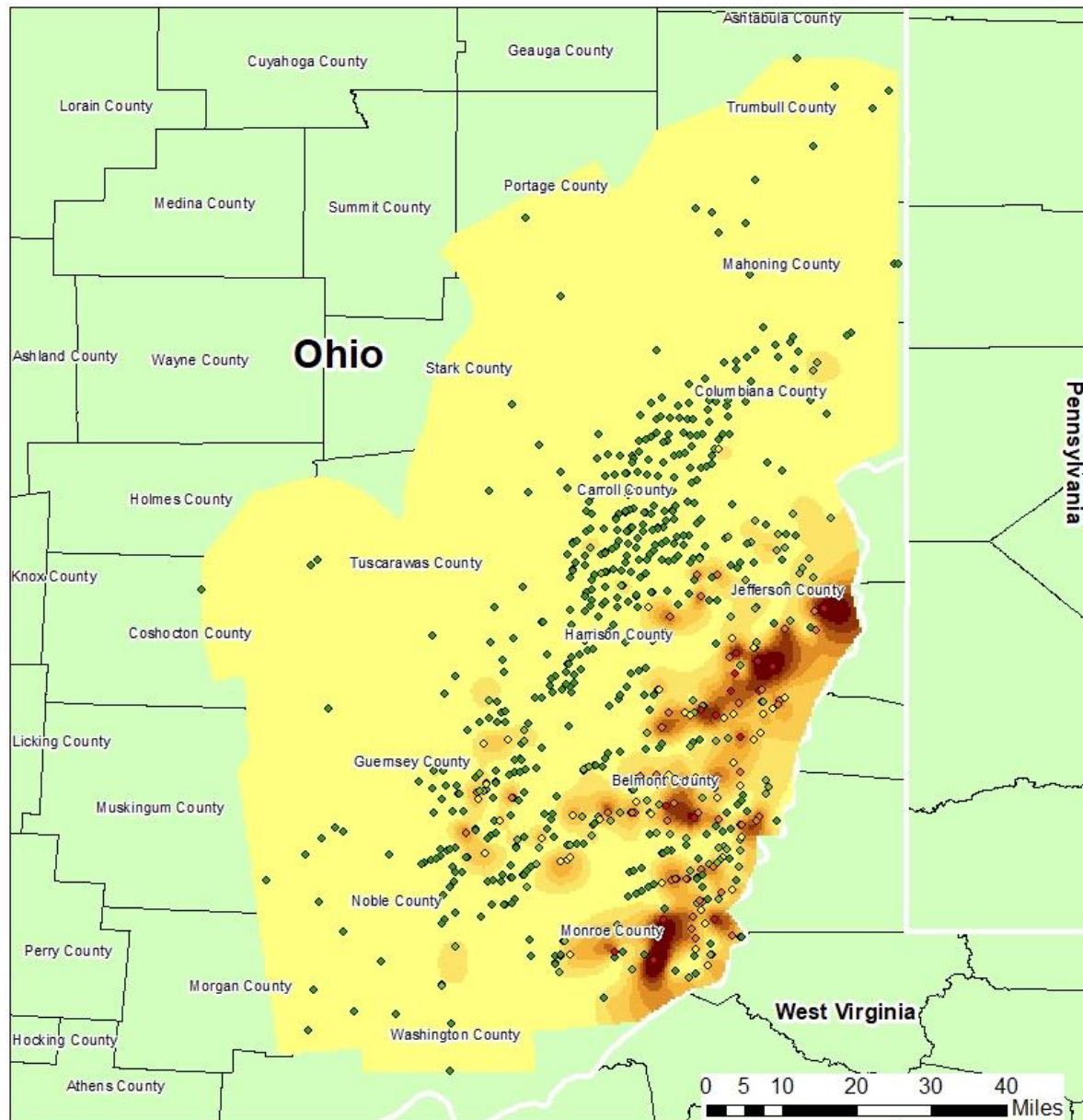
Table 2: Production by County for July-December 2018

County	Gas (Mcfe)	Oil (bbl)	Gas Equivalents (Mcfe)	Production Wells ⁹
BELMONT	497,581,376	15,094	497,666,793	432
CARROLL	58,399,896	1,808,368	68,633,451	469
COLUMBIANA	16,584,340	20,246	16,698,912	70
COSHOCTON	15,725	73	16,138	1
GUERNSEY	44,516,869	6,605,036	81,894,768	191
HARRISON	94,976,289	1,764,786	104,963,213	368
JEFFERSON	200,574,142	17	200,574,238	154
MAHONING	773,708	5,675	805,823	12
MONROE	291,240,827	120,674	291,923,721	296
MORGAN	96,018	4,823	123,311	2
MUSKINGUM	22,727	561	25,902	1
NOBLE	61,950,778	967,944	67,428,373	179
PORTAGE	16,956	167	17,901	1
STARK	70,239	1,973	81,404	3
TRUMBULL	216,423	1,932	227,356	7
TUSCARAWAS	155,045	10,617	215,127	5
WASHINGTON	2,059,090	28,034	2,217,734	11
Total	1,269,250,448	11,356,020	1,333,514,165	2,200

Source: ODNR (2019)

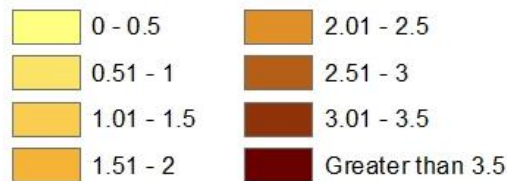
⁹ Represents the average number of production wells for the third and fourth quarters of 2018.

Figure 3: Distribution of Gas Equivalent Production for July-December 2018



**2018 Q3 & Q4
Production**

BCF of Gas Equivalent per Well



Producing Wells



Of the 2,491 total wells identified from the ODNR records for cumulative drilling activity as of December 2018, 138 were in the process of drilling, 233 wells had been drilled and were awaiting markets, and 2,120¹⁰ were in the production phase. See Table 3, Ohio Utica Well Status. Belmont County continued to lead in total wells after surpassing Carroll County in the first half of 2018. (see Table 4).

Table 3: Ohio Utica Well Status as of December 2018

Well Status	No. of Wells
Drilled	233
Drilling	138
Producing	2,120
Total	2,491

Source: Ohio Department of Natural Resources (2019)

Table 4: Well Status by County (December 2018)

County	Drilled	Drilling	Producing	Total
ASHLAND	1	0	0	1
BELMONT	59	23	436	518
CARROLL	7	1	468	476
COLUMBIANA	15	0	71	86
COSHOCTON	1	0	1	2
GUERNSEY	16	18	186	220
HARRISON	13	20	347	380
JEFFERSON	30	25	127	182
KNOX	1	0	0	1
MAHONING	1	0	13	14
MEDINA	1	0	0	1
MONROE	63	37	278	378
MORGAN	1	0	2	3
MUSKINGUM	0	0	1	1
NOBLE	5	12	162	179
PORTAGE	7	1	1	9
STARK	5	0	2	7
TRUMBULL	3	1	7	11
TUSCARAWAS	3	0	6	9
WASHINGTON	1	0	11	12
WAYNE	0	0	1	1
Total	233	138	2,120	2,491

Source: ODNR (2019)

¹⁰ The discrepancy between the number of “Producing” wells in Table 3 and “Production” wells in Table 2 is due to how wells are reported in the ODNR’s *Shale Well Drilling & Permitting* and *Well Production* spreadsheets. For a particular point in time, a given well may be classified as non-producing in the spreadsheet for cumulative activity yet have a record of production in the well production spreadsheet.

B. UPSTREAM INVESTMENT ESTIMATES

Upstream investments have been broken down into four areas: investments into drilling, including road construction associated with well development; lease operation (post-production) expenses; new lease and lease renewal bonuses; and royalties on well production. The methodology used for each calculation is set forth in Appendix B. Average drilling costs were updated for this study, based upon reports from publicly traded operating companies. We continued to differentiate between northern counties, where the Utica shale is shallower and less pressured (\$11.7 million per well) and southern counties, where the shale is deeper and more more pressured (12.9 million per well).

This section covers upstream investments between July and December of 2018. Cumulative upstream investments to date in Ohio, including 2012-2018, are set forth in Table 18 of Appendix A.

1. Investments into Drilling.

The following tables set forth estimated investments for the study period made into drilling shale wells in Ohio. Jefferson County was the leader in new upstream investment, with 27 new wells and an investment of around \$309.4 million between July and December of 2018. Monroe and Harrison Counties were second and third, with 23 and 22 new wells, respectively, to go along with \$298.1 and \$258.1 million invested. See Table 5. Road-related investments for this version of the Shale Investment Dashboard reflect the average road costs per well determined from a 2017 report by Energy-In-Depth¹¹ describing Road Use Maintenance Agreements (RUMAs) that companies have entered into with local governments for infrastructure improvements since Utica production began in 2011. The data for that report were obtained directly from the engineer's office for the top eight oil and natural gas producing counties in Ohio.¹²

Ascent Utica Resources LLC, nearly two-thirds of whose new wells were in the lower cost, more northerly counties, was the leading operator investor during the six-month period, with 58 new wells and an estimated \$696.2 million invested, followed by Eclipse Resources with 21 new wells and an estimated \$272.2 million invested. Chesapeake Exploration,¹³ which was active entirely in northern counties, drilled 14 wells with an estimated investment of \$160.4 million. See Table 6.

Cabot Oil & Gas drilled multiple exploratory wells in Ashland County during the latter half of 2018, probing the potential of the Knox formation at the western edge of Ohio's Utica shale.¹⁴ The Study Team appraised Cabot's exploration investment in Ohio during the study period at \$23.9

¹¹ See "Ohio's Oil & Gas Industry Road Improvement Payments." Prepared by The Ohio Oil & Gas Association and Energy in Depth. <https://www.energyindepth.org/wp-content/uploads/2017/11/2017-Utica-Shale-Local-Support-Series-Ohios-Oil-and-Gas-Industry-Road-Payments.pdf>

¹² The previously used method for determining road investments was a rule-of-thumb estimate based on an analysis by this study team of lease operating expenses for Gulfport Energy, as obtained from company financial reports.

¹³ As noted earlier in this report, Chesapeake sold its Utica holdings to Encino as of 12/31/2018.

¹⁴ <http://www.kallanishenergy.com/2018/09/10/cabot-to-drill-two-more-exploratory-wells-in-ohio-by-dec-31/>

million, based on industry analysts.¹⁵ Cabot has not, to date, reported production from these wells, and subsequently discontinued its Ashland County exploration efforts in early 2019.¹⁶

Table 5: Estimated Upstream Shale Investment by County, July-December 2018

County	No. of New Wells	Drilling (\$)	Roads (\$)	Total Amount (\$)
BELMONT	20	\$258,000,000	\$1,200,000	\$259,200,000
COLUMBIANA	2	\$22,800,000	\$120,000	\$22,920,000
GUERNSEY	20	\$258,000,000	\$1,200,000	\$259,200,000
HARRISON	22	\$250,800,000	\$1,320,000	\$252,120,000
JEFFERSON	27	\$307,800,000	\$1,620,000	\$309,420,000
MONROE	23	\$296,700,000	\$1,380,000	\$298,080,000
NOBLE	3	\$38,700,000	\$180,000	\$38,880,000
Total	117	\$1,432,800,000	\$7,020,000	\$1,439,820,000¹⁷

Source: The Authors (2019)

Table 6: Estimated Upstream Shale Investment in Ohio by Company, July-December 2018

Operators	No. of Wells	Drilling	Roads	Total Amount (\$)
ANTERO RESOURCES CORP.	3	\$38,700,000	\$180,000	\$38,880,000
ASCENT RESOURCES UTICA LLC	58	\$692,700,000	\$3,480,000	\$696,180,000
CHESAPEAKE EXPLORATION LLC	14	\$159,600,000	\$840,000	\$160,440,000
ECLIPSE RESOURCES I LP	21	\$270,900,000	\$1,260,000	\$272,160,000
EM ENERGY OHIO LLC	2	\$25,800,000	\$120,000	\$25,920,000
EQUINOR USA ONSHORE PROPERTIES INC.	3	\$38,700,000	\$180,000	\$38,880,000
GULFPORT ENERGY CORPORATION	1	\$12,900,000	\$60,000	\$12,960,000
RICE DRILLING D LLC	3	\$38,700,000	\$180,000	\$38,880,000
TRIAD HUNTER LLC	5	\$64,500,000	\$300,000	\$64,800,000
UTICA RESOURCE OPERATING LLC	1	\$12,900,000	\$60,000	\$12,960,000
XTO ENERGY INC.	6	\$77,400,000	\$360,000	\$77,760,000
Total	117	\$1,432,800,000	\$7,020,000	\$1,439,820,000¹⁸

Source: The Authors (2019)

¹⁵ Based on budgeted spending for exploration of \$75 million in 2018 between plays in Texas and Ohio and dry hole costs of \$51.1 million for the Permian exploratory effort. See <https://www.spglobal.com/marketintelligence/en/news-insights/trending/gsoquajvr2mjkwpdmoxxg2>. See also <https://www.naturalgasintel.com/articles/115217-cabot-pulls-plug-on-permian-exploratory-effort-pushes-ahead-in-ohio>

¹⁶ <https://www.mansfieldnewsjournal.com/story/news/2019/03/07/report-cabot-halts-drilling-richland-ashland-counties/3068857002/>

¹⁷ Excludes royalties, bonuses for undeveloped acreage and lease operating expenses.

¹⁸ *Id.*

2. Lease Operating Expenses.

Post-production investments have been estimated on a half-year basis, assuming an average cost of around \$17,500/month/well. This estimate is based upon recent operator reports.¹⁹ These investments are set forth below. Consistent with total number of production wells, Carroll County and Belmont County lead the lease operating expense investment, with an estimated \$49.2 and \$45.4 million invested, respectively.

Table 7: Estimated Lease Operating Expenses for July-December 2018 by County

County	No. of Production Wells ²⁰	Lease Operating Expenses for Period
BELMONT	432	\$45,360,000
CARROLL	469	\$49,245,000
COLUMBIANA	70	\$7,350,000
COSHOCTON	1	\$105,000
GUERNSEY	191	\$20,055,000
HARRISON	368	\$38,640,000
JEFFERSON	153	\$16,065,000
MAHONING	12	\$1,260,000
MONROE	295	\$30,975,000
MORGAN	2	\$210,000
MUSKINGUM	1	\$105,000
NOBLE	179	\$18,795,000
PORTAGE	1	\$105,000
STARK	3	\$315,000
TRUMBULL	7	\$735,000
TUSCARAWAS	5	\$525,000
WASHINGTON	11	\$1,155,000
	Total	\$231,000,000

¹⁹ The per-month rule-of-thumb for lease operating expenses per producing well for this report is based on Ascent's and Gulfport's unit lease operating expenses for 2018 as reported in company financial statements.

²⁰ The number of wells producing was determined by taking the average of the number of such wells as identified by ODNR on July 1, 2018 and December 31, 2018. It is assumed that this number of average production wells incurred lease operating expenses for all six months.

Table 8: Estimated Lease Operating Expenses for July-December 2018 by Operator

Operator	No. of Production Wells	Lease Operating Expenses for Period
ANTERO RESOURCES CORPORATION	216	\$22,680,000
ARTEX OIL COMPANY	6	\$630,000
ASCENT RESOURCES UTICA LLC	370	\$38,850,000
ATLAS NOBLE LLC	12	\$1,260,000
CHESAPEAKE APPALACHIA LLC	4	\$420,000
CHESAPEAKE EXPLORATION LLC	720	\$75,600,000
CHEVRON APPALACHIA LLC	8	\$840,000
CNX GAS COMPANY LLC	53	\$5,565,000
EAP OHIO LLC	30	\$3,150,000
ECLIPSE RESOURCES I LP	131	\$13,755,000
EM ENERGY OHIO LLC	10	\$1,050,000
ENERVEST OPERATING LLC	5	\$525,000
EQUINOR USA ONSHORE PROPERTIES	28	\$2,940,000
GEOPETRO LLC	1	\$105,000
GULFPORT APPALACHIA LLC	14	\$1,470,000
GULFPORT ENERGY CORPORATION	304	\$31,920,000
HESS OHIO DEVELOPMENTS LLC ²¹	32	\$3,360,000
HILCORP ENERGY COMPANY	15	\$1,575,000
M & R INVESTMENTS OHIO LLC	1	\$105,000
NORTHWOOD ENERGY CORP	5	\$525,000
PENNENERGY RESOURCES LLC/R E GAS DEVELOPMENT LLC ²²	40	\$4,200,000
PIN OAK ENERGY PARTNERS LLC	14	\$1,470,000
PROTEGE ENERGY III LLC	1	\$105,000
RICE DRILLING D LLC	101	\$10,605,000
TRIAD HUNTER LLC	13	\$1,365,000
UTICA RESOURCE OPERATING LLC	28	\$2,940,000
XTO ENERGY INC.	38	\$3,990,000
Total		\$231,000,000

²¹ The sale of Hess Corp. and CNX's joint venture Utica interests to Ascent was completed in the second half of 2018. See <https://www.nsenergybusiness.com/news/cnx-hess-complete-sale-of-utica-shale-play-assets-to-ascent-resources/>

²² The sale of Rex Energy's assets in the Utica to PennEnergy was completed in the second half of 2018. <https://www.oilandgas360.com/pennenergy-ceo-talks-rex-energy-asset-acquisition/>

3. Royalties.

Royalty investments have been estimated on a per quarter basis, assuming the formula set forth in Appendix B. Total estimated royalties spent on Ohio properties between January and June 2018 were around \$1.1 billion. The breakdown by quarter for oil, residue gas and natural gas liquids is set forth in Tables 9, 10, and 11 below. The average price for natural gas was \$3.19/MMBtu during the second half of 2018, up from \$2.76 in the first half of 2018.²³ Regional oil prices decreased from \$63.60/bbl for the third quarter of 2018 to \$52.82/bbl for the fourth quarter, on average.

Table 9: Total Royalties from Oil
July - December 2018 (in millions of dollars)

Year	Quarter	Oil Price ²⁴ \$/bbl	Oil Royalty (20%) \$/bbl	Royalty (\$mm)
2018	4	\$52.82	\$10.56	\$61.38
2018	3	\$63.60	\$12.72	\$70.54
			Subtotal	\$131.92

Table 10: Total Royalties from Residue Gas
July - December 2018 (in millions of dollars)

Year	Quarter	Residue Gas Price ²⁵ \$/Mcf	Residue Gas Royalty (20%) \$/Mcf	Royalty (\$mm)
2018	4	\$3.01	\$0.60	\$351.98
2018	3	\$4.00	\$0.80	\$426.85
			Subtotal	\$778.83

Table 11: Total Royalties from Natural Gas Liquids
July - December 2018 (in millions of dollars)

Year	Quarter	NGL Price \$/bbl	NGL Royalty (20%) \$/bbl	Royalty (\$mm)
2018	4	\$15.85	\$3.17	\$92.53
2018	3	\$19.08	\$3.82	\$101.70
			Subtotal	\$194.23

4. Lease Renewals and New Leases.

New leases and lease renewal investments have been estimated for the Utica region based upon the drilling activity of the top eight drilling companies in the region. These eight companies have together drilled over 80% of the Utica wells to date, and it is assumed that they likewise control

²³ Reflects average Columbia-Appalachia natural gas prices over the respective periods. See https://www.naturalgasintel.com/data/data_products/bidweek?region_id=appalachia&location_id=NEATCO.

²⁴ <http://ergon.com/prices>

²⁵ Based on conversion factor of 1.1 MMBtu/Mcf.

over 80% of the leases. The estimated investments into undeveloped acreage is set forth below in Table 12.

There are several potential sources of error in this estimate. All estimates assume \$5000/acre lease bonus for new leases and for five-year renewals, which may not accurately reflect actual lease bonus rates. Additional factors that may make the estimate inaccurate include the following: (1) only net undeveloped lease acreage was used to avoid possible double counting (producing companies often collaborate on development), although bonuses would have been paid on the gross lease acreage; and (2) the assumption that new or renewed leases make up 20% of undeveloped acreage during the six month period may be too high or too low. The 20% assumption is based upon the notion that leases typically contain 5 year primary terms, and as a result around 20% of leases require bonus payments each year to maintain the acreage.

**Table 12: Total Est. Investments into Undeveloped Acreage (New & Renewed Leases)
July-December 2018 (in millions of dollars)**

Operator	Undeveloped Acreage	Estimated Bonus Investment (\$mm)
ANTERO RESOURCES CORPORATION	86,151	43.08
ASCENT RESOURCES UTICA HOLDINGS, LLC	228,786	114.39
CHESAPEAKE EXPLORATION LLC	680,000	340.00
CNX RESOURCES CORPORATION	259,519	129.76
ECLIPSE RESOURCES I LP	48,097	24.05
GULFPORT ENERGY CORPORATION	136,839	68.42
Rice Drilling D LLC (EQT)	34,368	17.18
XTO ENERGY INC	9,000	4.50
Total	1,482,760	741.38

C. ESTIMATED MIDSTREAM INVESTMENTS

Midstream investment includes transmission and gathering pipelines, additional investments in storage facilities, and investments in compressor stations, which included compressor engines, dehydration units, and generators installed as part of these stations. Rail and transloading facilities for storing and handling natural liquids are also included.

Pipeline investments were estimated using mileage and size information from the Public Utilities Commission of Ohio, and cost information from the INGAA Foundation. Similarly, compressor station investments were based on estimated cost per unit of power output for the region as obtained from the INGAA. A full description of the methodology can be found in Appendix B.

Additional investment information was collected from midstream company investor presentations, news reports, and other sources including Ohio EPA permits. The following two tables summarize midstream investments identified by the Study Team for the second half of 2018. Table 13 sets forth gathering and transmission line investments while Table 14 sets forth all other midstream investments, including that for compression.²⁶

Some costs related to these projects may have occurred outside the six-month window for this study. However, because the investments cannot easily be separated and tracked while construction is ongoing, the investments are treated as though made entirely during the study period if construction on the project was begun then.

²⁶ For project mileage and compressor station deployment within Ohio, see <https://www.ferc.gov/CalendarFiles>. For compressor station horsepower ratings, see <http://epawwwextp01.epa.ohio.gov:8080/ords/epaxp/f?p=999:10:0:>

**Table 13: Midstream Transmission and Gathering Line Investment
July through December 2018**

Company	Additions to Infrastructure	Total Amount (\$mm)
Antero Midstream	<ul style="list-style-type: none"> 2.23 miles of 16" pipeline 	6.55
Blue Racer Midstream	<ul style="list-style-type: none"> 1.42 miles of 8.6" pipeline 1.84 miles of 10.8" pipeline 	5.88
Cardinal Gas Services (Williams)	<ul style="list-style-type: none"> 1.06 miles of 8.6" pipeline 1.40 miles of 10.8" pipeline 	4.43
Eclipse Resources (Montage Rscs)	<ul style="list-style-type: none"> 2.23 miles of 8.6" pipeline 	3.53
Eureka Midstream	<ul style="list-style-type: none"> 0.37 miles of 8.6" pipeline 1.43 miles of 12.8" pipeline 12.30 miles of 20" pipeline 	49.05
MarkWest	<ul style="list-style-type: none"> 7.95 miles of 12" pipeline²⁷ 	17.50
Ohio Gathering	<ul style="list-style-type: none"> 3.60 miles of 12" pipeline²⁸ 	7.93
Utica Gas Services (Williams)	<ul style="list-style-type: none"> 6.31 miles of 8.6" pipeline 3.21 miles of 10.8" pipeline 	16.31
	Total	\$111.18

Source for Gathering Lines (unless otherwise footnoted): PUCO Gathering Construction Reports (2019)

²⁷ See <https://napiipelines.com/north-american-pipeline-project-roundup-september-2018/>

²⁸ See <http://wwwapp.epa.state.oh.us/dsw/401Applications/185981/185981%20DA%20Miller%20Farms%20WSG%20GR%20to%20Hoop%20C%20Pipeline.pdf>. See also https://ebiz.epa.ohio.gov/Notices/jsp/view_notice.jsp?noticeID=51336

Table 14: Additional Midstream Investment, July through December 2018

Company	Additions to Infrastructure	Total Amount (\$mm)
E2 Ohio	<ul style="list-style-type: none"> Hayes Facility, Guernsey County 1 compressor 	2.40
Cobra Pipeline	<ul style="list-style-type: none"> Churchtown Compressor Station, Washington County 1 compressor 	1.89
Eureka Midstream	<ul style="list-style-type: none"> German Ridge Compressor Station, Monroe County 3 compressors 	17.53
Fortress Transportation	<ul style="list-style-type: none"> Long Ridge Energy Terminal, Monroe County Rail and Pipeline Infrastructure Improvements (U.S. DOT BUILD Grant)²⁹ Rail loop track construction project³⁰ 	25.00
Strike Force East	<ul style="list-style-type: none"> Catapult Compressor Station, Belmont County 3 compressors 2 dehydration units 	64.73
Utica Gas Services	<ul style="list-style-type: none"> Brush Creek Central Delivery Point (CDP), Jefferson County 1 dehydration unit 2,000 bbl of storage for condensate, produced water, crude oil, and/or petroleum liquids 	3.09
Mountaineer NGL	<ul style="list-style-type: none"> Storage facility in Monroe County 	6.00 ³¹
Total		120.64

Adding the amounts in the above tables yields a total midstream investment for the second half of 2018 of \$231.8 million.

Other than the gathering lines identified above, no interstate or large intrastate pipeline projects were identified for the second half of 2018 that were not already captured in previous reports. However, several new pipeline projects commenced in 2019 and will be accounted for in future reports. These include: (1) RH Energy's Risberg Pipeline in Ashtabula County, where Ohio construction began in June 2019;³² (2) Shell Energy's Falcon ethane pipeline that entered the construction phase in March 2019 and will connect the Scio and Cadiz fractionation plants in Ohio to the planned Pennsylvania Chemicals Project Ethane Cracker in Monaca, PA;³³ and (3) the Harrison Hub propane pipeline that Williams installed in 2019 to connect its fractionator in

²⁹ <https://www.longridgeenergy.com/news/2018-07-12-long-ridge-energy-terminal-announces-completion-of-rail-construction-project-creating-the-appalachian-basins-first-unit-train-and-barge-transloading-facility>

³⁰ Email correspondence with Lone Ridge Energy. See also <https://www.longridgeenergy.com/news/2018-07-12-long-ridge-energy-terminal-announces-completion-of-rail-construction-project-creating-the-appalachian-basins-first-unit-train-and-barge-transloading-facility>

³¹ This amount represents the difference between spending to-date according to the company's president and investments identified in previous iterations of the Shale Dashboard. See

<https://www.timesleaderonline.com/news/local-news/2019/08/ethane-storage-coming-to-monroe/>

³² <https://marcellusdrilling.com/2019/06/ohio-portion-of-risberg-pipeline-construction-begins/>

³³ <https://www.timesonline.com/news/20190314/shells-falcon-ethane-pipeline-enters-construction-phase>

Moundsville, WV to the Utica East Ohio Midstream fractionation facility in Harrison County.³⁴ Additionally, construction on TransCanada's \$200 million Buckeye Xpress project for replacing 64-miles of large-diameter natural gas pipeline was slated to begin in 2019.³⁵

Investment in processing and storage slowed in the second half of 2018, but activity in these areas also picked up in 2019 and will be included in future reports. This includes the Hopedale V fractionator (80,000 bbl/d of C3+ processing) projected for a late 2019 construction start at the MPLX facility in Jewett, Ohio.³⁶ The Mountaineer NGL storage project has secured all necessary permits and could begin construction in early 2020.³⁷ Additionally, Marathon announced in early 2019 that it is considering development of an underground NGL storage facility near the company's Hopedale facility in Harrison County to store ethane, butane and propane.³⁸

Cumulative midstream investments through the end of 2018 are set forth in Table 19 in Appendix A.

³⁴ https://investor.williams.com/sites/williams.investorhq.businesswire.com/files/event/additional/2019_European_Investor_Meetings-_FINAL.pdf

³⁵ See <https://www.tcenergy.com/globalassets/pdfs/natural-gas/buckeye-xpress/transcanada-buckeye-xpress-project-fact-sheet.pdf>. See also, <https://marcellusdrilling.com/wp-content/uploads/2019/03/NatGas-Pipelines-Bring-Major-Investment-Jobs-Appalachian-Basin.pdf>

³⁶ stratasadvisors.com/-/media/Files/XLS/Midstream/2019/1Q19-Midstream-Infrastructure-download.xlsx

³⁷ <https://www.timesleaderonline.com/news/local-news/2019/08/ethane-storage-coming-to-monroe/>

³⁸ <https://www.shaledirectories.com/blog/marathon-considers-building-ngl-storage-hub-in-harrison-county-oh/>

D. DOWNSTREAM DEVELOPMENT

1. Natural Gas Power Plants

The nation has seen a number of new natural gas power plants coming online near shale plays, assisted by growing networks of pipelines which enable distribution of natural gas. Over the past four reports we have noted 10 new natural gas-powered power plants in Ohio that were in the planning, construction, or newly operational stages since 2015. Ohio's House Bill 6, which will subsidize regional nuclear and coal generation, may slow future natural gas power plant development in Ohio.³⁹

As with pipeline investments, expenditures are considered for purposes of this report as one-time investments by the builder during the six-month Study window, since it is difficult to separate the investments into half-year segments. However, major projects such as pipelines and gas plants usually take a year or more to develop. The 10 current and projected natural gas power facilities across 8 locations, including their current status, are set forth in Figure 5 below.

No investment in new natural gas generation plants was identified during the second half of 2018. The South Field Energy facility in Columbiana County and the Long Ridge Energy Center in Monroe County broke ground in May 2019; investments for these plants will be included in the next shale report.⁴⁰ Financing for the \$1.6 billion Guernsey Power Station was obtained in August 2019 and construction on the fully-permitted 1,875 MW electric generating facility could begin by the end of the year.⁴¹ Construction on the \$925 million Trumbull Energy Center is also slated for the second half of 2019.⁴²

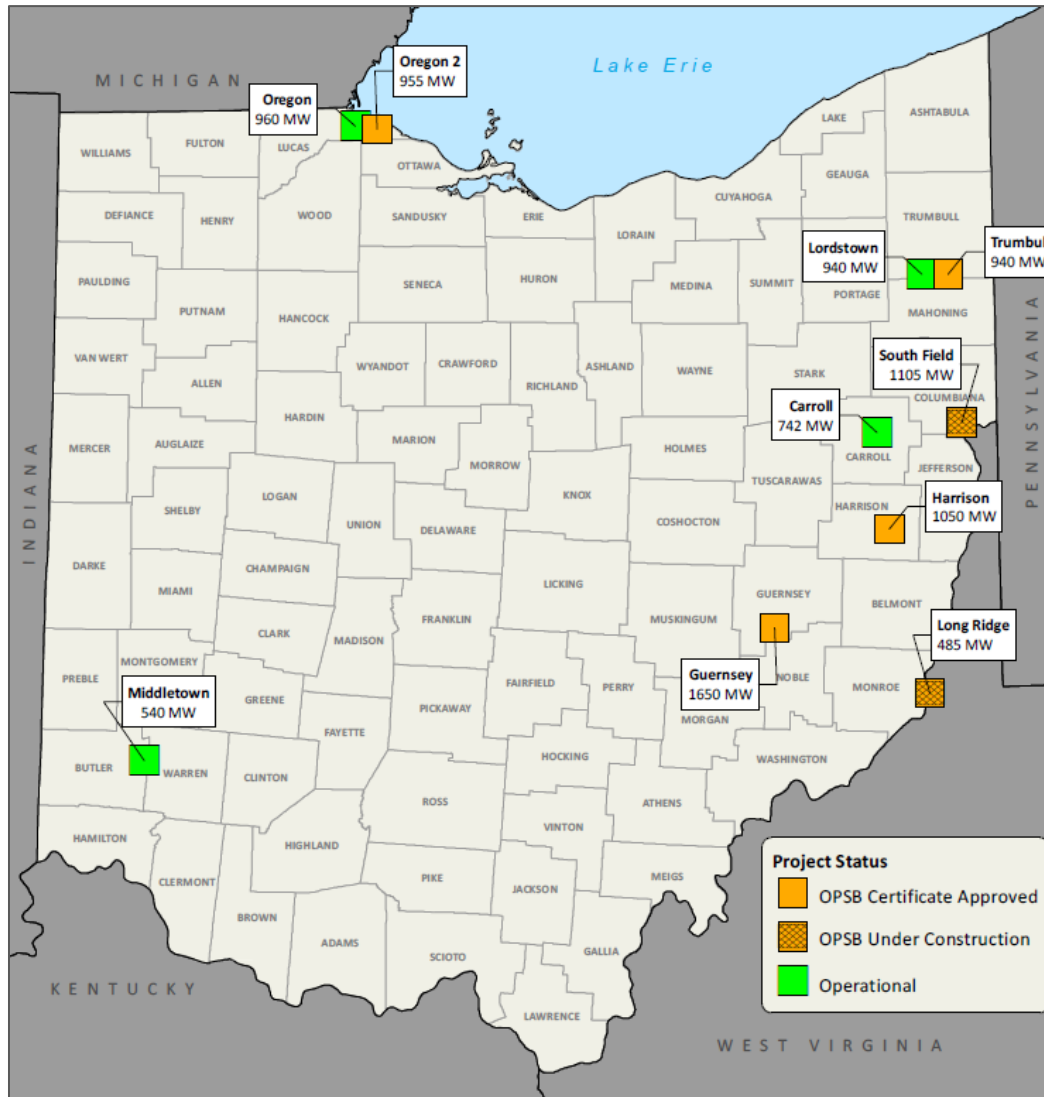
³⁹ See <https://www.dispatch.com/business/20190823/hb6-fallout-15-billion-in-natural-gas-power-plant-investments-pulled-from-ohio>

⁴⁰ See <https://www.southfieldenergy.com/news/south-field-energy-breaks-ground-for-1182-megawatt-energy-facility/>. See also <https://wtov9.com/news/local/construction-begins-for-hannibal-gas-fired-power-plant>

⁴¹ <https://www.daily-jeff.com/news/20190830/16b-financing-obtained-for-guernsey-power-station>

⁴² <https://www.constructionequipmentguide.com/energy-company-expects-to-break-ground-on-plant/44422>

Figure 4: Existing & Projected Natural Gas Power Plants



Source: Ohio Power Siting Board (August 2019)

2. Combined Heat and Power Plants

Continued low natural gas prices have also led to an increase in the regional development of combined heat and power (CHP) plants. CHP plants are usually designed for heat or steam generation, with electricity as a secondary product, thereby improving overall system efficiency. Table 15 shows the estimated investment for CHP plants in Ohio during the study period.

Table 15. Natural Gas Fired Combined Heat and Power Plants in Ohio

City	Facility Name	Application	Capacity (MW)	Prime Mover	Estimated Investment (\$mm)
Circleville	Sofidel Tissue Plant	Pulp & Paper	15	Combustion Turbine	20.9
Findlay	Cooper Tire & Rubbery Company	Rubber & Plastics	7.5	Combustion Turbine	13.2
Columbus	Ohio State University	District Energy	N/A	Combustion Turbine	10.0

Source (except for Ohio State): U.S. DOE Combined Heat and Power Installation Database⁴³

Note: Estimated investment is based on \$1,394 per kW for a 15 MW gas turbine CHP plant and \$1,760 per kW for a 7.5 MW gas turbine CHP plant.⁴⁴

Investment into CHP on the campus of Ohio State University during the study period was for professional and design services related to a \$288 million plant that is still going through the approval process.⁴⁵ As mentioned in the previous shale report, Cleveland Thermal's Hamilton plant has been issued a final permit-to-install by the Ohio EPA. However, construction on the Cleveland plant has not yet commenced.⁴⁶

3. Refineries, Petrochemical Plants and Other Downstream Investment

Average construction costs for new compressed natural gas (CNG) stations are around \$1.2 million per station, while refueling infrastructure costs for liquefied petroleum gas (LPG) are around \$225,000 per station.⁴⁷ Three new CNG refueling stations (in Columbus, Chardon, and Kent) and one new LPG station (in Columbia Station) opened during the second half of 2018.⁴⁸

⁴³ <https://doe.icfwebservices.com/chpdb/>

⁴⁴ Derived from Combined heat and Power Cost-benefit Analysis tool available through the Center for Energy, Economic & Environmental Policy at Rutgers. See <http://ceeep.rutgers.edu/wp-content/uploads/2015/07/CHP-Database-Technical-and-Financial-Parameters-v.4-06032015.xlsx>

⁴⁵ See <https://www.smartenergydecisions.com/news/2019/08/27/energy-efficient-chp-proposed-for-ohio-state>. See also <https://news.osu.edu/university-sees-sustainability-improvements-from-energy-partnership/>

⁴⁶ See <https://www.epa.ohio.gov/dapc/newpermits/issued>

⁴⁷ See https://afdc.energy.gov/files/u/publication/cng_infrastructure_costs.pdf. See also https://afdc.energy.gov/files/u/publication/propane_costs.pdf

⁴⁸ See <https://afdc.energy.gov/>

Altogether this represents an estimated investment into natural gas transportation of \$3.8 million.

While little additional downstream investment occurred during the study period, future reports will reflect increased activity along this portion of the shale gas supply chain. For example, PTT Global increased its purchases of residential property near the proposed ethane cracker site in Belmont County from \$125,000 in the second half of 2018 to \$800,000 for the first half of 2019.⁴⁹ As of December 2018, the petrochemical company also received its final Ohio EPA air permit-to-install for the cracker plant and resolved all issues related to appeal of this permit (water permitting was previously secured in 2017).⁵⁰

Other downstream projects being tracked include expansion of Husky Energy's Lima refinery, initiated in October 2019 to increase the facility's capacity by 40,000 bbl/day, and Petmin's \$500 million pig iron plant in Ashtabula, where site preparation is scheduled to commence in the second half 2019 with construction projected to commence in Q1 2020.⁵¹ Steelmaking based on Direct Reduction—as will be employed at the Ashtabula plant via Tenova's HYL Energiron ZR process—fundamentally depends on natural gas-derived hydrogen to reduce iron ore to iron as part of the steel production process.⁵²

Cumulative downstream investments reported to date in Ohio, including 2012-2018, are set forth in Table 20 in Appendix A. An outline of the key products and processes for this sector within the shale gas value chain is set forth in Appendix B.

⁴⁹ Belmont County Auditor (<http://oh-belmont-auditor.publicaccessnow.com/>). *See also*

<https://marcellusdrilling.com/2019/07/ptt-buying-homes-near-proposed-cracker-plant-in-belmont-county/>

⁵⁰ <http://pttgcbelmontcountyo.com/pttgca-reaches-agreement-with-environmental-organizations/>. *See also*.

<https://www.theintelligencer.net/news/top-headlines/2017/01/proposed-dilles-bottom-cracker-gets-water-permit-from-ohio-epa/>

⁵¹ *See* <https://www.spglobal.com/platts/en/market-insights/latest-news/oil/102519-refinery-news-roundup-husky-energy-says-lima-ohio-plant-offline-until-end-november-to-finish-expansion>. *See also*

<https://petminusa.com/>

⁵² *See* https://www.tenova.com/fileadmin/user_upload/HYL_News_-_December_2018.pdf. *See also* <https://petminusa.com/>. *See also* http://www.millennium-steel.com/wp-content/uploads/2017/05/pp024-030_ms17.pdf

3. CONCLUSION

Upstream shale investment in Ohio continued to be active, with 117 new wells being developed in the second half of 2018. Sustained production growth in the third and fourth quarters was likely encouraged by what the EIA characterized as natural gas prices that exceeded previous market expectations during the study period.⁵³ While operators are drilling fewer wells, longer laterals (greater than 12,500 on average throughout the Utica) are resulting in higher production and increased investment per well, with total upstream spending in the second half of 2018 exceeding that for the first by around \$173.4 million.

A pause in new major pipeline, processing, and petrochemical project construction during the study period led to a drop in midstream and downstream investments from the first half of 2018. Overall midstream spending of \$231.8 million was primarily focused on gathering system buildout, while new CHP Plants constituted the majority of the \$48 million spent on downstream projects. An uptick in midstream and downstream investment is anticipated in the near-term, though, given the billions of dollars in projects for these sectors that are either in the late planning stages (i.e. fully permitted and fully financed) or broke ground as of 2019.

Total shale related investment in Ohio for the second half of 2018, including upstream, midstream and downstream, was around \$3.82 Billion. Total investment from 2011-2018 is around \$77.7 billion.

⁵³ See <https://www.eia.gov/todayinenergy/detail.php?id=37713>

About the Study Team

Andrew R. Thomas, J.D.

Andrew Thomas directs the Energy Policy Center in the Maxine Goodman Levin College of Urban Affairs of Cleveland State University, where he conducts research on oil and gas, electricity and transportation policy. He teaches oil and gas contracting courses internationally and is an Ohio oil and gas commissioner. a.r.thomas99@csuohio.edu, 216-687-9304.

Mark Henning, M.S.

Mark Henning is a research associate in the Energy Policy Center at Cleveland State University. He holds a Master of Public Administration, and an M.S. in Mathematics with a specialization in Applied Statistics, both from Cleveland State University. m.d.henning@csuohio.edu.

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/>.

4. APPENDICES

APPENDIX A. CUMULATIVE OHIO SHALE INVESTMENT

Figure 5: Total Utica Production in Bcfe (Gas Equivalence) by County through Dec. 2018

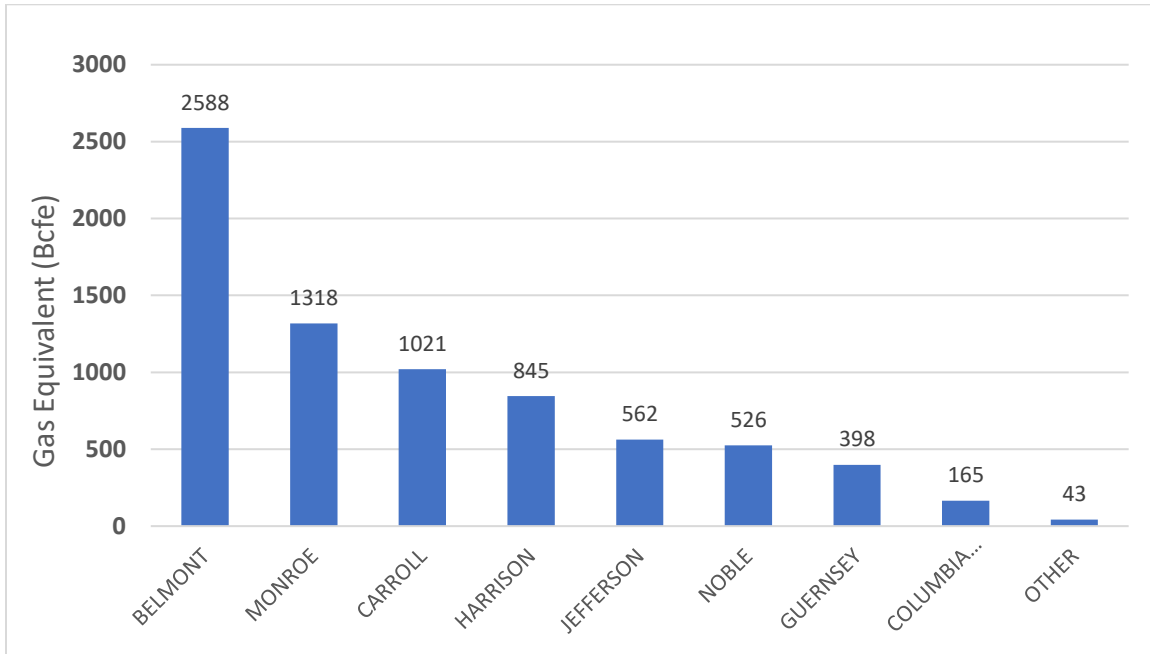


Figure 6: Total Utica Production in Bcfe by Operator through December 2018

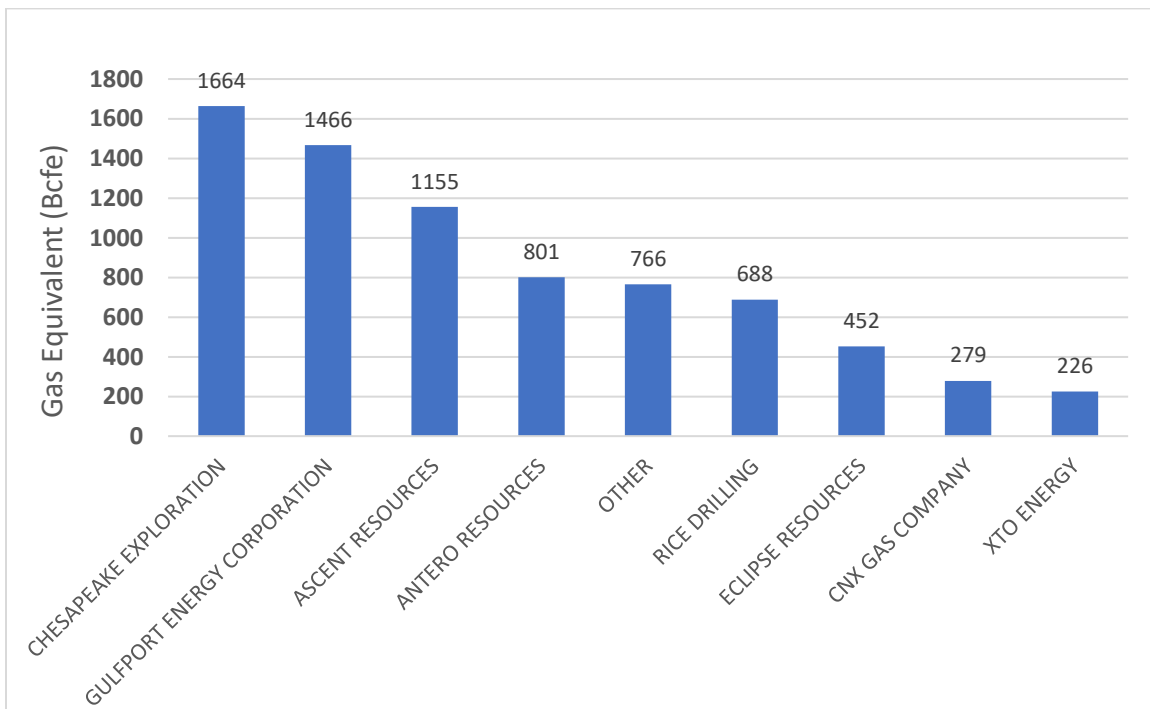
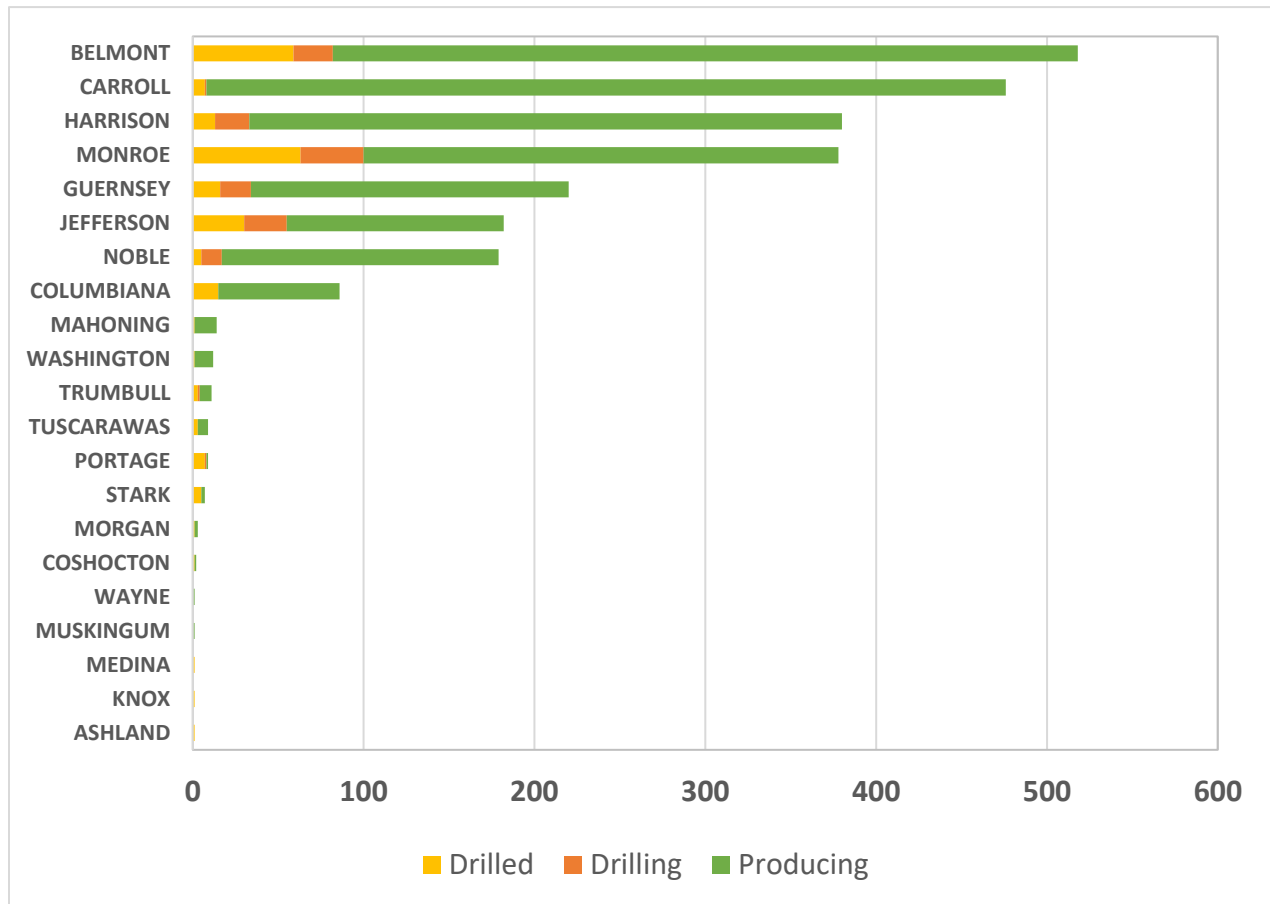
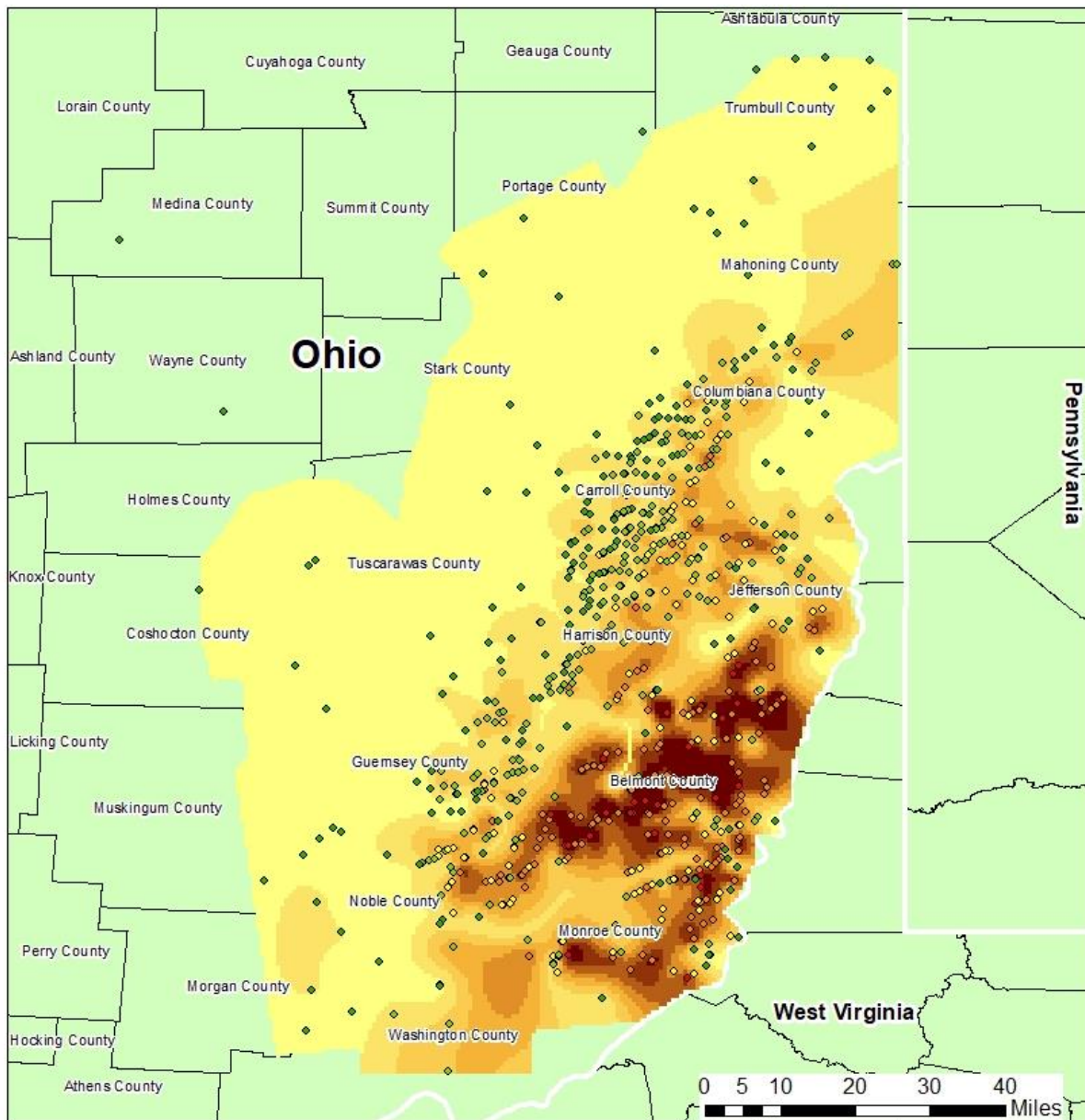


Figure 7: Cumulative Number of Wells by County



Source: Ohio Department of Natural Resources (December 2018)

Figure 8: Distribution of Gas Equivalent Production for 2011 through December 2018



**Cumulative
Production
2011 - 2018**

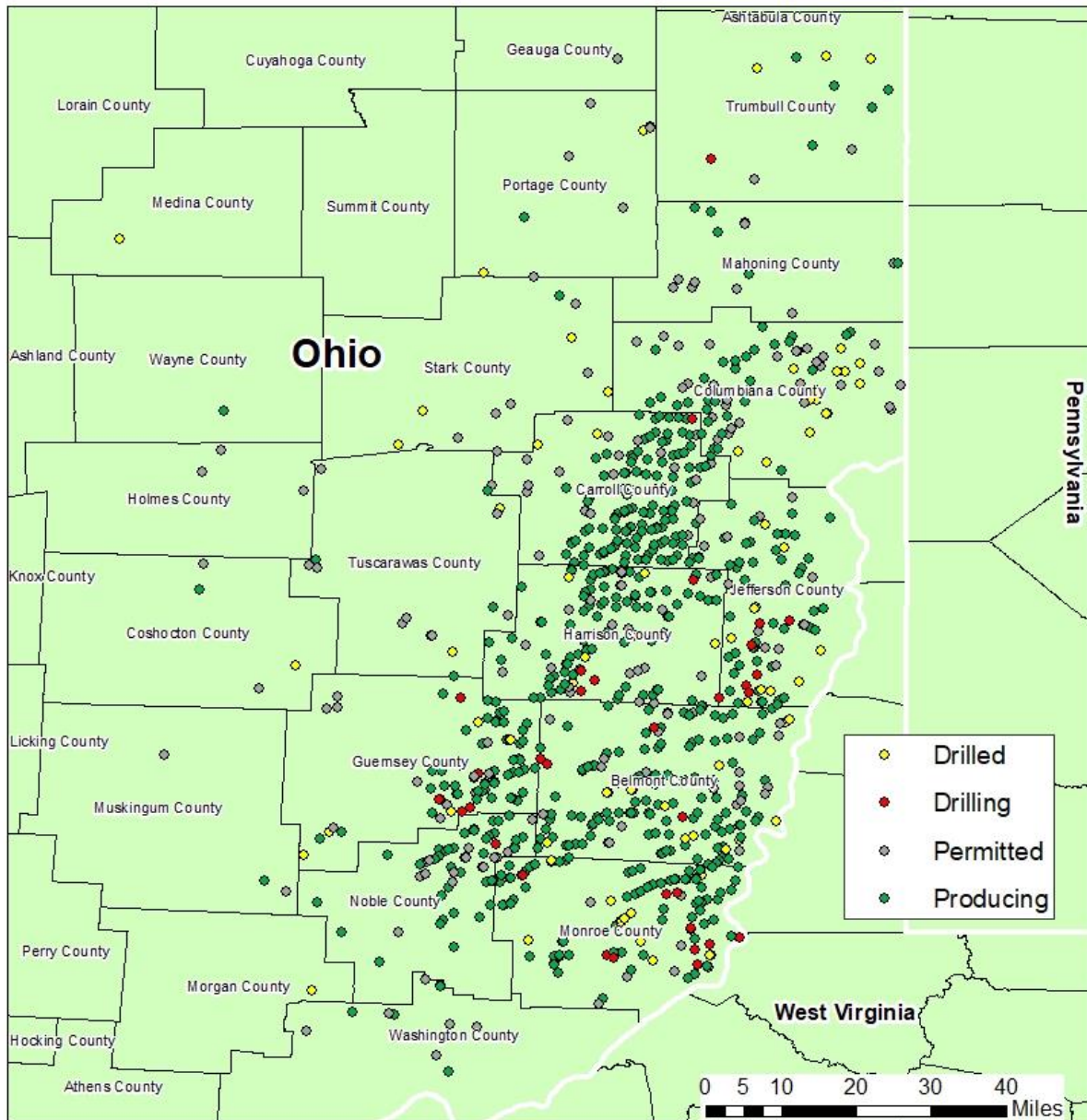
BCF of Gas Equivalent per Well



Producing Wells



Figure 9: Distribution of Utica Wells by Status as of December 2018



Cumulative Well Status December 2018

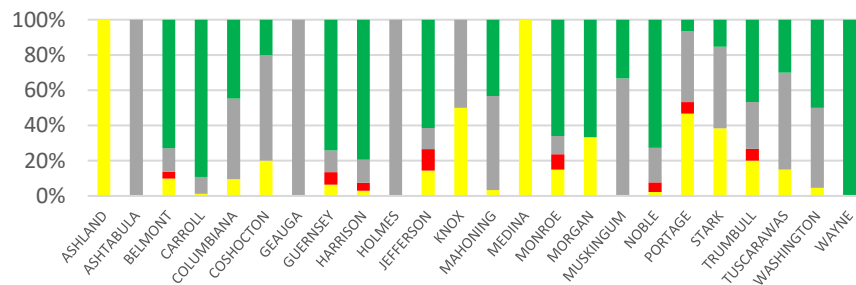


Table 16: Utica Upstream Companies Drilling in Ohio

Company	Cumulative No. of Wells
CHESAPEAKE EXPLORATION LLC ⁵⁴	729
ASCENT RESOURCES UTICA LLC	477
GULFPORT ENERGY CORPORATION	365
ANTERO RESOURCES CORPORATION	239
ECLIPSE RESOURCES I LP	155
RICE DRILLING D LLC	125
XTO ENERGY INC.	54
EAP OHIO LLC	46
CNX GAS COMPANY LLC	40
PENNENERGY RESOURCES LLC	40
UTICA RESOURCE OPERATING LLC	34
EQUINOR USA ONSHORE PROPERTIES INC.	30
TRIAD HUNTER LLC	20
GULFPORT APPALACHIA LLC	18
HILCORP ENERGY COMPANY	16
EM ENERGY OHIO LLC	16
PIN OAK ENERGY PARTNERS LLC	13
ATLAS NOBLE LLC	12
CHEVRON APPALACHIA LLC	8
ARTEX OIL COMPANY	7
ENERVEST OPERATING LLC	6
ARSENAL RESOURCES LLC	6
NORTHWOOD ENERGY CORP	6
STATOIL USA ONSHORE PROPERTIES INC	5
HG ENERGY LLC	5
GEOPETRO LLC	5
DEVON ENERGY PRODUCTION CO LP	3
EQT PRODUCTION COMPANY	2
BRAMMER ENGINEERING INC	2
R E GAS DEVELOPMENT LLC	1
PDC ENERGY INC	1
AMERICAN ENERGY UTICA LLC	1
PROTEGE ENERGY III LLC	1
BP AMERICA PRODUCTION COMPANY	1
CHESAPEAKE APPALACHIA LLC	1
M & R INVESTMENTS OHIO LLC	1
Total	2,491

Note: Cumulative Number of Wells are calculated based upon the total numbers of Drilled, Drilling, and Producing. Source: ODNR (December 30, 2018).

⁵⁴ As previously noted, Chesapeake sold its Ohio assets to Encino Acquisition Partners near the end of 2018.

**Table 17: Total Lease Operating Expenses through December 2018
(in millions of dollars)**

Year	Period	Production Wells	Lease Operating Expenses for Period (\$mm)
2018	Q3 and Q4	2200	231.0
2018	Q1 and Q2	1874	191.15
2017	Q3 and Q4	1818	121.8
2017	Q1 and Q2	1588	141.3
2016	Q3 and Q4	1467	101.2
2016	Q1 and Q2	1355	97.6
2015	Annual	1034	148.9
2014	Annual	612	88.1
2013	Annual	237	34.1
2012	Annual	82	30
2011	Annual	9	3
		Total	957.2

Table 18: Cumulative Utica-Related Upstream Investments in Ohio through Dec. 2018

Estimated Investments	Total Amount
Undeveloped Land	\$16,153,370,000
Developed Land	\$2,664,000,000
Lease Renewals	\$5,419,171,000
Drilling	\$22,450,700,000
Roads	\$1,063,300,000
Lease Operating Expenses	\$1,158,426,000
Royalties	\$4,892,510,000
Total	\$53,801,477,000

Table 19: Cumulative Utica-Related Midstream Investments in Ohio through Dec. 2018

Estimated Investments	Total Amount
Midstream Gathering	\$6,836,899,000
Processing Plants	\$1,538,600,000
Fractionation Plants	\$1,414,000,000
NGL Storage	\$241,000,000
Rail Loading Terminals	\$145,000,000
Transmission Pipelines	\$9,353,020,000
Total	\$19,528,519,000

Table 20: Cumulative Utica-Related Downstream Investments in Ohio through Dec. 2018

Estimated Investments	Total Amount
Petrochemical Plants and Refineries	\$551,425,000
Other Industrial Plants	\$700,000,000
Natural Gas Refueling Stations	\$44,825,000
Natural Gas Power Plants	\$3,040,000,000
Combined Heat and Power (CHP) Plants	\$85,100,000
Total	\$4,421,350,000

APPENDIX B. METHODOLOGY

1. Upstream Methodology.

Investment into the upstream for this fourth report has been broken down into four categories.

a. Wells and Related Roads. The first category is investment into wells and includes one-time investments into drilling and road construction related to well development. They were estimated as:

- Drilling: Northern Counties - \$11.4 mm/well; Southern Counties - \$12.9 mm/well.⁵⁵
 - Equivalent true vertical depth (TVD) for wells in all counties.
 - Average drilling and completion costs of \$900 per lateral foot.⁵⁶
 - Average lateral length of 12,660 ft. for northern counties and 14,360 ft. for southern counties.⁵⁷
- Roads: average investments - approximately \$60,000 per well based on 2013 data from Carroll County Engineer's Office.⁵⁸

The number of new wells developed in the study period, used as a basis for these calculations, were accounted for by subtracting the number of wells in the drilled, drilling and producing categories as of July 1, 2018 from the number existent as of December 31, 2018. This information was downloaded from the ODNR Oil and Gas Well database.⁵⁹

b. Lease Operating Expense. The second estimated upstream cost identified by operators is the "lease operating expense." This includes post-production costs such as the storage, processing and disposal of produced water, among other expenses. Lease operating expenses for Utica wells were estimated to be around \$17,500/month, throughout the life of the well. This average expense was developed by the study team based on analysis of Ascent's and Gulfport's

⁵⁵ Previous shale reports distinguished between drilling costs for northern counties (Carroll, Harrison, Jefferson, Columbiana, Trumbull, Mahoning and Tuscarawas) and southern counties (Noble, Guernsey, Belmont, Monroe and Washington) based on the assumption that the Utica is deeper in the south, requiring more expensive drilling in over-pressured formations. The Study Team conducted a review of drilling surveys associated with ODNR completion reports for new wells and found a difference in mean true vertical depth between northern and southern counties of less than 500 ft., which would likely not lead to significant cost differences. However, the same review of drilling surveys indicated that laterals for new wells in southern counties were 1,700 feet longer on average than for those in the north. This difference in average lateral length is the basis for the difference in drilling cost between northern and southern counties.

⁵⁶ Based on Ascent Resources' estimated drilling costs per lateral foot in the Utica according to the company's chairman and CEO. Ascent is active in both northern and southern counties. See <https://oklahoman.com/article/5626621/ascent-resources-reports-growth-in-utica-shale-field-during-2018>

⁵⁷ Calculated using well completion reports obtained from the ODNR's *Ohio Oil & Gas Well Database*.

⁵⁸ See fn 7, *supra*.

⁵⁹ <http://oilandgas.ohiodnr.gov/well-information/oil-gas-well-database>

lease operating expenses for 2018, divided by the number of wells operated, as reported in their financial statements.⁶⁰

For purposes of estimating the lease operating expenses for Q3 and Q4 2018, the Study Team assumed that all wells listed as “producing” by the Ohio Department of Natural Resources on July 1, 2018 were incurring this cost and continued to do so through December 31, 2018.

c. Oil and Gas Production Royalties. A third area of upstream investment, royalty calculation, is more complicated. The estimate is based upon the total production over the six-month period and the likely price received for sales of the hydrocarbon during that same period. However, because much of the natural gas has been processed, Ohio Department of Natural Resources production records cannot be readily converted to royalty payments. Accordingly, a number of assumptions are required to estimate the royalties paid. These include estimating the local market conditions at the time hydrocarbons were sold. 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 based upon industry interviews, industry investor presentations, and Energy Information Agency reports:

- Production for each well was similar to that found in the wet gas region, and not the dry gas or condensate regions. This represents the average situation.
- The average production shrinkage after processing was 12%, thereby making the residue gas volume 88% of the total natural gas production.⁶¹
- The residue energy content was around 1.1 MMBtu/Mcf.⁶²
- Residue gas in the Utica was selling at an average price of \$2.74/MMBtu for Q3 and \$3.64/MMBtu for Q4.⁶³ This price for the Columbia-Appalachia hub was used to estimate royalties.
- Around 44 barrels of liquids were recovered per million cubic feet of gas produced.⁶⁴
- Natural gas liquids were selling for around 30% of the listed price for Marcellus-Utica light crude oil.⁶⁵
- Oil in the Utica region was selling for \$63.60 and \$52.82 per barrel during the third and the fourth quarter of 2018, respectively.⁶⁶

⁶⁰ See https://ascentresources.com/documents/4/Q4_2018_ARUH_External_Financials_FINAL.PDF. See also <https://ir.gulfportenergy.com/all-sec-filings/content/0001628280-19-002242/0001628280-19-002242.pdf>

⁶¹ Based on industry interviews, experts citing API 12.3, Manual of Petroleum Measurements and Standards

⁶² The EIA estimates that the average conversion should be 1.037 MMBtu/Mcf (see: www.eia.gov/tools/faqs/faq.php?id=45). However, industry interviews suggest 1.1 is closer to the average conversion for the Utica Shale.

⁶³ https://www.naturalgasintel.com/data/data_products/bidweek?region_id=appalachia&location_id=NEATCO. Hub prices reflect the delivered price of natural gas and so do not require further deductions for transportation costs. See <https://www.eia.gov/todayinenergy/detail.php?id=18391>

⁶⁴ Based on industry data.

⁶⁵ Based on industry interviews.

⁶⁶ See Marcellus/Utica prices for light crude at <http://ergon.com/prices>. More than 95% of Ohio oil production is light crude by API gravity. See <https://www.eia.gov/petroleum/production/xls/api-history.xlsx>

- Royalty rates are 20% of gross production.

d. New and Renewal Lease Bonuses. Finally, a fourth form of upstream investment was estimated: new and renewal lease bonuses. For this purpose, we assumed that the average new lease or renewal bonus paid was \$5000/acre, and that the typical lease has a five-year primary term. Accordingly, we have assumed that approximately 20% of the undeveloped acreage identified will need to be renewed each year or is otherwise new.⁶⁷ Since this Study covered six months, we assumed that half of this 20% was renewed or new during the Study period. However, this estimate is based upon total undeveloped acreage, and not allocated on a per well basis. This estimate may be high insofar as companies are not renewing all their acreage, and some acreage will be developed and not need renewal. However, it is also likely to be low insofar as the studies have only identified undeveloped acreage for the top six to nine operators in Ohio. Undeveloped acreage is typically reported in company 10-K and other financial statements.

2. Midstream Methodology.

Midstream investments include pipeline construction (intrastate, gathering lines and inter-state), processing plants (compression, dehydration, fractionation, and others), natural gas liquid storage facilities, and railroad terminals and transloading facilities. Midstream expenditures were estimated based upon a combination of midstream company investor reports, media reports, and industry “rules of thumb” obtained from 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.

a. Processing plants. Processing plant information was obtained by searching a wide range of resources including EPA permit databases, news agencies, and company web sites and presentations. For purposes of estimating the investments for midstream processing plants, rules of thumb were developed based upon facility throughput capacities. These rules of thumb were applied to the processing plants that have been built in Ohio, using the throughput capacity estimates cited in permit documents, or made available from public literature. Likewise, rules of thumb based upon throughput capacity were used to estimate investments downstream of the processing plants, such as storage facilities and loading terminals. Dehydration processing plants were estimated using average cost per Mcf capacity for similarly designed and recently built plants in the Appalachian region.

Compressor station investments were calculated based on the horsepower rating listed in Ohio EPA air permit data and estimated construction costs per horsepower of \$3,479 for the Midwest Region as obtained from the INGAA, as projected for 2018.⁶⁸

⁶⁷ This estimate was confirmed through industry interviews. New operator undeveloped acreage reports are likely to be made available over time that may suggest these estimates could be either too high or too low.

⁶⁸ *Id.*

The approximate capital cost for TEG dehydration units based on throughput was obtained from Carroll's *Natural Gas Hydrates: A Guide for Engineers* (2014, 3rd ed.). Facilities receiving a final permit-to-install or permit-to-install-and operate were assumed to be constructed during the same 6-month period in which the permit was issued by the Ohio EPA.

The following assumptions were used to estimate midstream-related investments:

- Processing Plants.
 - \$400,000 per MMcf/d throughput
 - \$80 MM per 200 MMcf/d plant (typical skid size)
- Fractionation Plants.
 - \$2800 per bbl/d
 - \$100 mm per 36000 bbl/d unit (typical size of plant)
- Storage Tankage: \$80 MM for 1 Bcf/d throughput
- Rail Loading Terminals: \$40 MM for 1 Bcf/d throughput

b. Pipelines. Pipeline investments were estimated by applying “inch-mile” cost estimates to known pipeline diameter and length for both inter- and intrastate projects. Interstate pipeline diameters and mileage can be determined from Federal Energy Regulatory Commission data these estimates were confirmed from investor presentations, when available. Intrastate mileage and diameter were determined using data for gathering system construction that was obtained from the Public Utilities Commission of Ohio.⁶⁹

For this report, up-to-date cost projections for natural gas transmission and gathering line pipelines, per inch-mile, was obtained from the Interstate Natural Gas Association of America (INGAA).⁷⁰ The estimated cost for natural gas pipelines for the Midwest Region as used in this analysis was \$183,457 per inch-mile, which included labor, raw materials, and permitting costs, as projected by the INGAA for 2018.

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. For pipelines carrying liquids, the investment assumption is that expenditures will be comparable to those seen for gas pipelines. These were also corroborated by industry investor reports.

⁶⁹ that the data currently used supersedes data used in previous reports for study periods through June 30, 2017. Newer data suggests that the previously used assumption of 4 miles of gathering line per well pad was about twice as high as what midstream companies actually deploy in the field on average. Additionally, oil and gas companies can accommodate more than three times the 3-wells-per-pad that the Study Team assumed in prior studies. Earlier iterations of this dashboard assumed companies would drill three wells per pad on average, move on to other locations, and then come back later to infill. As the Utica play becomes more mature, we can expect that there will be a greater number of wells per pad, and therefore fewer gathering pipeline miles per well.

⁷⁰ The INGAA Foundation, Inc. (2018). *North America Midstream Infrastructure through 2035*. <https://www.ingaa.org/File.aspx?id=34703>.

3. Downstream Methodology.

For estimating downstream expenditures, the Study Team relied upon publicly available reports gathered from news media, trade association publications, company websites and investor presentations. The Study Team also used interviews, and Ohio EPA permits and public notices to identify projects and support investment estimates. Search terms included identified company names, and key words associated with specific facility types and industries.

As of this report, downstream investment is categorized into eight categories:

- Natural Gas Power Plants
- Combined Heat and Power Plants
- Ethane Cracker Plants
- Methanol Plants
- Refineries
- Natural Gas refueling stations
- Petrochemical Plants
- Other industrial plants with natural gas inputs

NAICS codes used to generate keywords for searches included the following:

3251 – Basic Chemical Manufacturing

3252 – Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing

3253 – Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing

3255 – Paint, Coating, and Adhesive Manufacturing

3259 – Other Chemical Product and Preparation Manufacturing

3261 – Plastics Product Manufacturing

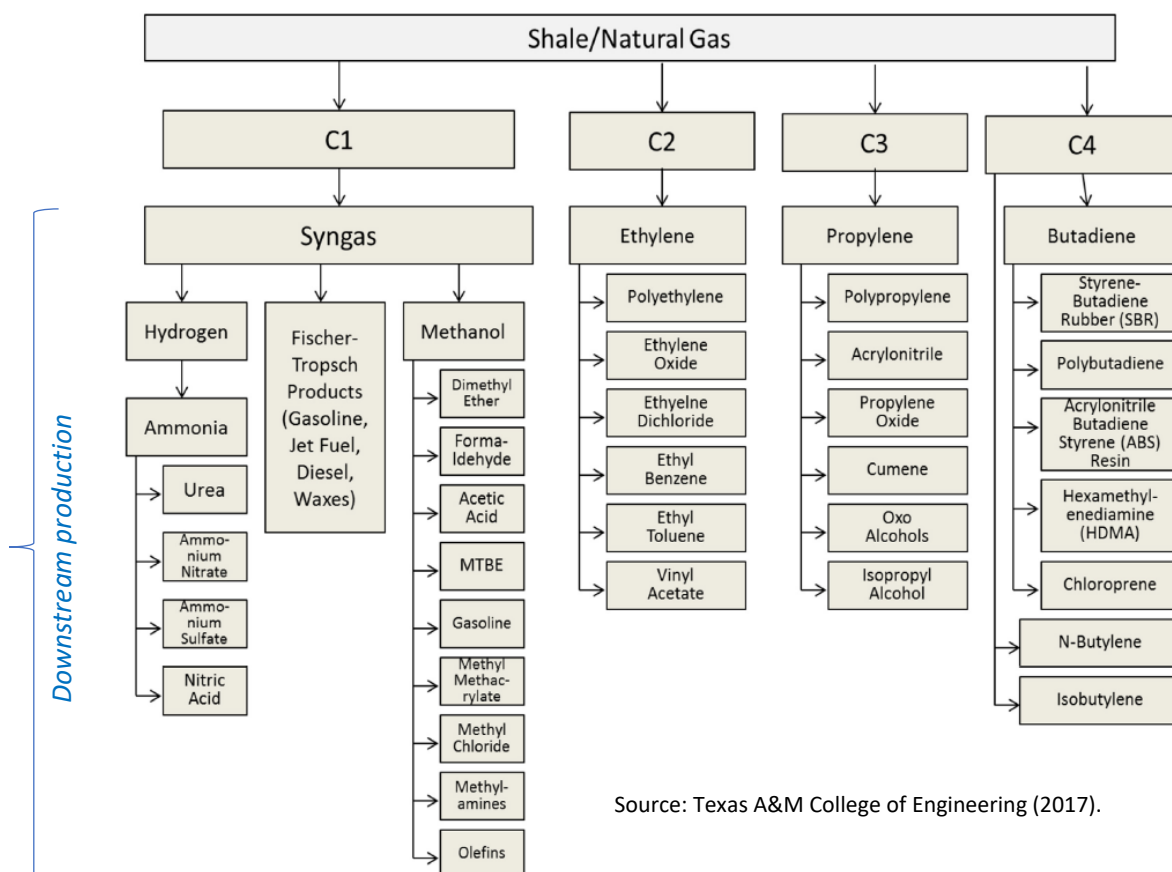
Downstream activities include the deployment of processes that turn hydrocarbons—particularly the light hydrocarbons methane (C1), ethane (C2), propane (C3), and the butanes (C4)—into higher-valued fuels and petrochemicals. Shale gas may be monetized into numerous resulting value-added products. Figure 10 shows the primary intermediates and products that can be manufactured from the main hydrocarbon components in shale gas as part of downstream production.⁷¹ At or near the top of this hierarchy are what have been called the four main “building blocks” for petrochemicals: ethylene, propylene, butadiene, and methanol.⁷² The processes currently available for producing these critical downstream links in the shale gas value chain are listed in Table 21.⁷³ All of the products and processes shown in Figure 10 and Table 21 form the basis for additional search terms to identify downstream investment during the study period.

⁷¹ See Al-Douri, A., Sengupta, D., & El-Halwagi, M. M. (2017). Shale gas monetization—A review of downstream processing to chemicals and fuels. *Journal of Natural Gas Science and Engineering*, 45, 436-455.

⁷² Al-Douri, A. F. (2016). *A systems framework for shale gas monetization* (Doctoral dissertation). <https://oaktrust.library.tamu.edu/handle/1969.1/156938>

⁷³ See Elbashir, N. O., El-Halwagi, M. M., Economou, I. G., & Hall, K. R. (Eds.). (2018). *Natural Gas Processing from Midstream to Downstream*. Wiley.

Figure 10. Shale/Natural Gas Value Chain for Petrochemicals



Source: Texas A&M College of Engineering (2017).

Table 21. Downstream Production Processes for Petrochemical Building Blocks

Petrochemical Building Block	Production Processes for Converting Shale Gas
Ethylene	<ul style="list-style-type: none"> steam cracking hydrocarbons (e.g. naphtha, ethane, propane, etc.) oxidative coupling of methane (OCM) methanol-to-olefins (MTO)
Propylene	<ul style="list-style-type: none"> by-product of ethylene manufacture from steam cracking hydrocarbons methanol-to-olefins (MTO) propane dehydrogenation (PDH)
Butadiene	<ul style="list-style-type: none"> by-product of ethylene manufacture from steam cracking hydrocarbons dehydrogenation of n-butane (Houdry process) oxidative dehydrogenation of n-butane (Oxo-D) biomass-to-butadiene
Methanol	Synthesis from syngas reformed via: <ul style="list-style-type: none"> partial oxidation (POX) steam methane reforming (SMR) auto-thermal reforming (ATR) combined reforming (CR)