Cost-Effectiveness of Comprehensive Oil and Gas Emissions Reduction Rules in New Mexico

Impacts of Reduced Methane and Volatile Organic Compound Emissions from the Oil and Gas Industry

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AUTHORS

Erin Camp, PhD
Nate Garner
Asa Hopkins, PhD

Synapse
Energy Economics, Inc.

485 Massachusetts Avenue, Suite 2
Cambridge, Massachusetts 02139

617.661.3248 | www.synapse-energy.com

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1. INTRODUCTION

Nationally leading, comprehensive oil and gas emissions reduction controls would require a set of actions to reduce pollutant emissions of methane and volatile organic compounds (VOCs) from the oil and gas industry in New Mexico. Methane emissions can occur in the production, processing, or delivery phases of the oil and gas supply chain. Proposed comprehensive controls outline the sources of emissions throughout the oil and gas production process in New Mexico and calculate a required level of emissions reductions for the industry.[1] The total cumulative methane emissions reduction realized by a set of comprehensive controls over a 10-year period (2020–2030) is 21.2 million tonnes. Similarly, the total cumulative VOC emissions reduction required by these controls is approximately 7 million tonnes. Though these comprehensive controls set specific requirements or performance standards intended to achieve emissions reductions, they do not specify a mitigation technology. Rather, by setting standards the proposed comprehensive controls allow for flexibility and encourage innovation in pollution control technologies.

Though reducing pollutant emissions has many benefits for the people of New Mexico, there are also costs to implementing the recommended standards. On behalf of Environmental Defense Fund (EDF), Synapse Energy Economics, Inc. (Synapse) performed a benefit-cost assessment of the proposed comprehensive controls for New Mexico. In developing the analysis presented in this report, Synapse relied upon calculations conducted by Spherical Analytics for emission reductions that would result from implementation of the recommended standards (see Appendix). The Synapse approach and results are presented in the sections below.

2. COST-EFFECTIVENESS EVALUATION

In order to determine the cost-effectiveness of the comprehensive controls, Synapse calculated the benefits of reducing methane and VOC emissions and the costs of reducing those emissions. Together, the benefits and costs come together to yield a benefit-cost ratio. First, we discuss the benefit types evaluated in this study, followed by the costs associated with the regulation. We then present a description of the three benefit-cost ratios used to evaluate the comprehensive emissions reduction rule for New Mexico.

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[1] The specified actions apply to the production, gathering, and boosting phase of the oil and gas supply chain. More details on these comprehensive controls can be found at: https://www.edf.org/nm-oil-gas/ComprehensiveControl.pdf

2.1. Benefits Estimation

Synapse quantified four categories of benefits from the proposed set of regulations: (1) the value of captured gas that would otherwise be vented or flared; (2) the human health benefits of reduced air pollution; (3) the reduced cost of compliance with federal ozone regulations; and (4) the global social benefit from the reduction in greenhouse gas emissions. We discuss the methodology for each category below.

Value of Captured Gas

Methane that is produced (either as the primary product or associated with oil production) can have one of three fates: (1) it is captured into the pipeline infrastructure and carried downstream to eventual customers; (2) it is lost or purposely emitted into the atmosphere; or (3) it is burned in a flare. One effect of the proposed regulations would be shifting methane that would have been emitted or flared into the captured category. Captured gas has economic value, so the increased capture results in an economic benefit attributable to the regulation.

Synapse calculated the value of the captured gas to gas producers in New Mexico using a method based on revealed market prices, combined with expert assessment of the impact of increased gas pipeline capacity. Gas prices paid to producers in New Mexico are lower than the Henry Hub price (the most common national benchmark for natural gas prices) because of the cost to transport gas to the national market. This difference between Henry Hub and New Mexico gas prices is called the “basis.”

In New Mexico, oil and gas is primarily produced in two locations: the Permian Basin (southeastern New Mexico) and the San Juan Basin (northwestern New Mexico). We used market forward prices from Natural Gas Intelligence for sale points in the Permian and San Juan areas to calibrate current expected basis estimates.[2,3] At the El Paso San Juan location, the forward basis for Winter 2019-2020 is approximately $0.40 per thousand cubic feet (mcf), increasing to about $0.70 per mcf for Summer 2020. At the El Paso Permian location, the forward basis for Winter 2019-2020 is approximately $0.72 per mcf, increasing to about $1.28 per mcf for Summer 2020. We assumed that the annual average basis for 2020 would be the average of the winter and summer forwards.

We used the market projections of the Henry Hub natural gas price as revealed in the price of market forward purchases on the NYMEX exchange.[4] These values tend to be lower than the U.S. Energy Information Administration’s projections from the Annual Energy Outlook, so the gas value reflected

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[2] Natural Gas Intelligence, “NGI Data: El Paso Permian.” Accessed August 5, 2019 at https://www.naturalgasintel.com/data/data_products/forward-contracts?region_id=west-texas/se-new-mexico&location_id=WTXEPP.

[3] Natural Gas Intelligence, “NGI Data: El Paso San Juan.” Accessed August 5, 2019 at https://www.naturalgasintel.com/data/data_products/forward-contracts?region_id=rocky-mountains&location_id=RMTEPSJ.

[4] CME Group, “Henry Hub Natural gas Futures Quotes.” Accessed August 5, 2019 at https://www.cmegroup.com/trading/energy/natural-gas/natural-gas.html.

using these prices is a conservative estimate. In 2018 dollars, the market projection of Henry Hub prices rises from $2.30 per mcf in 2020 to $2.74 per mcf in 2030.

Pipeline capacity out of both the Permian and San Juan production areas is currently constrained. This is demonstrated by the fact that the value of gas in New Mexico is substantially lower than the national Henry Hub price. Pipeline companies have begun substantial new investments in pipeline capacity to relieve these constraints. For example, the U.S. Energy Information Administration is tracking the progress of seven announced pipelines to transport gas from the Permian, totaling over 13.8 billion cubic feet (Bcf) per day. Additionally, the upcoming Double E Pipeline will transport 1.4 Bcf per day to better connect New Mexico production to the rest of the Permian pipeline network.[5] As these pipelines enter service, the basis should decline. McKinsey & Company estimates that the basis should shrink to $0.10 per mcf once the constraints are relieved.[6] This remaining cost reflects the continued cost of transporting the gas away from New Mexico to the national market. We assumed that this new equilibrium would be established by 2025, with the basis declining linearly to $0.10 per mcf between 2020 and 2025. Subtracting the basis projection from the Henry Hub projection results in a projected net value of gas to New Mexico producers, by region (Figure 1).

The State of New Mexico will see some direct fiscal benefit from the increased capture and sale of gas resulting from these regulations, including federal royalties that are returned to the state, state trust royalties, emergency school tax, severance tax, conservation tax, and ad valorem production tax.[7] These values were provided directly from Spherical Analytics. Though the fiscal benefit from increased royalties does not impact the benefit-cost ratios, we present the percentage of royalty benefit and absolute fiscal benefit by county in New Mexico.

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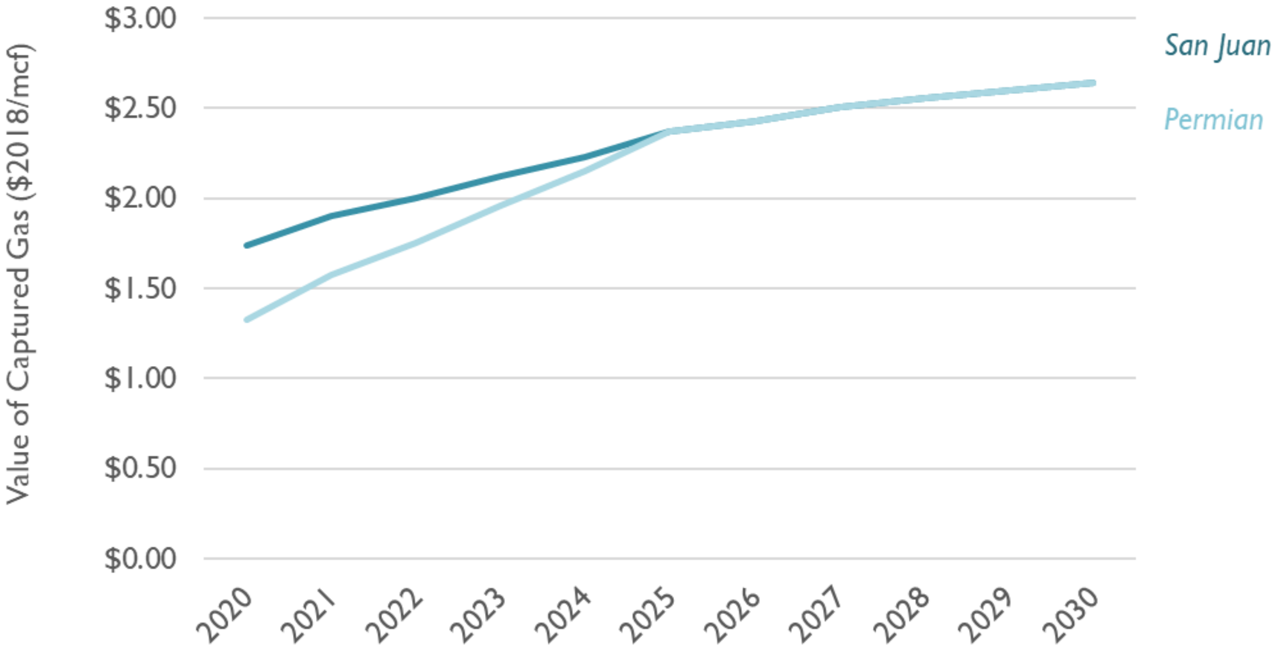
[5] U.S. Energy Information Administration, "Pipeline projects." Accessed August 22, 2019 at https://www.eia.gov/naturalgas/pipelines/EIA-NaturalGasPipelineProjects.xlsx.

[6] Brick, J. 2018. "Permian, we have a gas problem(s)." McKinsey & Company, July 1, 2018. https://www.mckinsey.com/industries/oil-and-gas/our-insights/petroleum-blog/permian-we-have-a-gas-problems.

[7] The tax calculations assume that 49 percent of federal royalties (a rate of 12.5 percent) are returned to the state of New Mexico; the state trust royalty tax rate is 19 percent; emergency school tax is 4 percent, severance tax is 3.75 percent; conservation tax is 0.19 percent; and the ad valorem tax varies by land type (ranging from 0.82 percent on tribal land to 1.39 percent on private land).

Figure 1. Projected value of captured gas in the San Juan and Permian regions, 2020-2030



Source: Synapse calculations based on EIA projections for Henry Hub natural gas prices.

Human Health Benefits

Exposure to air pollution from fossil-fuel based energy can exacerbate human respiratory disease, cause heart attacks, and lead to premature death. Illnesses from air pollution can also result in other costs to society, such as medical costs and lost wages to treat and recover from the illness. Oil and gas operations are associated with forms of air pollution during the fuel extraction process, including methane gas flared into the atmosphere (i.e., burned and converted into carbon dioxide and other compounds). Furthermore, VOCs released during oil and gas production can react with existing nitrogen oxides (NO_x) in the atmosphere to form ground-level ozone, which can lead to respiratory diseases.[8]

Synapse utilized U.S. Environmental Protection Agency's (EPA) CO-Benefits Risk Assessment (COBRA) tool to quantify a portion of the human health benefits of reduced emissions associated with the proposed comprehensive controls.[9] COBRA estimates both health and health-related economic impacts of changes in pollutant emissions for a given geography. This analysis reports results on the county level.

COBRA quantifies human health impacts from reductions of the following air pollutants: $PM_{2.5}$, sulfur dioxide (SO_2), NO_x, ammonia (NH_3), and VOCs. In order to quantify the impacts from reduced methane

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[8] U.S. EPA, Health Effects of Ozone Pollution. Available at: https://www.epa.gov/ground-level-ozone-pollution/health-effects-ozone-pollution.

[9] U.S. EPA, CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool. Available at: https://www.epa.gov/statelocalenergy/co-benefits-risk-assessment-cobra-health-impacts-screening-and-mapping-tool.

flaring, Synapse converted the methane reductions into quantities of SO_2 and NO_x reductions using conversion rates from methane flaring literature.[10]

Conversions rates for $PM_{2.5}$ associated with methane flaring were not available and were therefore excluded from this analysis. Health impacts of reduced ground-level ozone (smog) were also excluded due to the complexity of the process by which ozone is created in the atmosphere. Nonetheless, as the following section on ozone air quality regulations indicates, the comprehensive controls would have a substantial positive effect on human health from the reduction in ground-level ozone exposure. Because $PM_{2.5}$ and ozone were excluded from the health impacts analysis, we consider our calculation of the benefits associated with the proposed comprehensive controls to be conservative. Actual benefits are likely to be greater than estimated in this report.

Avoided NAAQS Nonattainment Costs

Atmospheric concentrations of ozone in the state of New Mexico have been rising rapidly in recent years, increasing the risk of violating the U.S. EPA's National Ambient Air Quality Standards (NAAQS) for ground-level ozone. Many of the increases in ozone are concentrated in areas of increasing oil and gas production and, therefore, increasing air pollution. VOCs react with NO_x to generate ozone, so regulatory actions to limit VOC emissions from the oil and gas industry should reduce ozone concentrations, all else being equal. Failure of a county to meet the EPA's ozone threshold of 70 parts per billion (ppb) results in both direct and indirect economic costs on residents and businesses in the area (in addition to the human health costs discussed above). For example, once an area is in nonattainment (i.e., has exceeded the ozone threshold), new potential sources of emissions must be reviewed through a permitting process and various programs related to transportation emissions become required. If emissions are not brought down quickly, further measures may be imposed. These measures can impede economic development by requiring greater investment in pollution controls for expanded or new facilities. This process creates localized costs of doing business that could encourage development to happen elsewhere—in a different county of New Mexico or in another state entirely.

Nonattainment is classified in multiple levels of severity depending on ozone concentration. Each level has its own requirements that become more severe and require more time for remediation at higher ozone concentration levels. In our analysis, we examined data from the five counties in New Mexico with EPA air monitoring stations that overlapped with our emissions data.[11] Nonattainment classification is based on the "design value," which is the three-year average of the monitor's fourth highest eight-hour average ozone reading in each year. Among the five oil and gas producing counties, only Eddy County has locations with design values that are currently above the nonattainment threshold. Given the rate of design value ozone increase over the past three years, however, it is highly likely that all five counties may reach some level of nonattainment within the next several years if they

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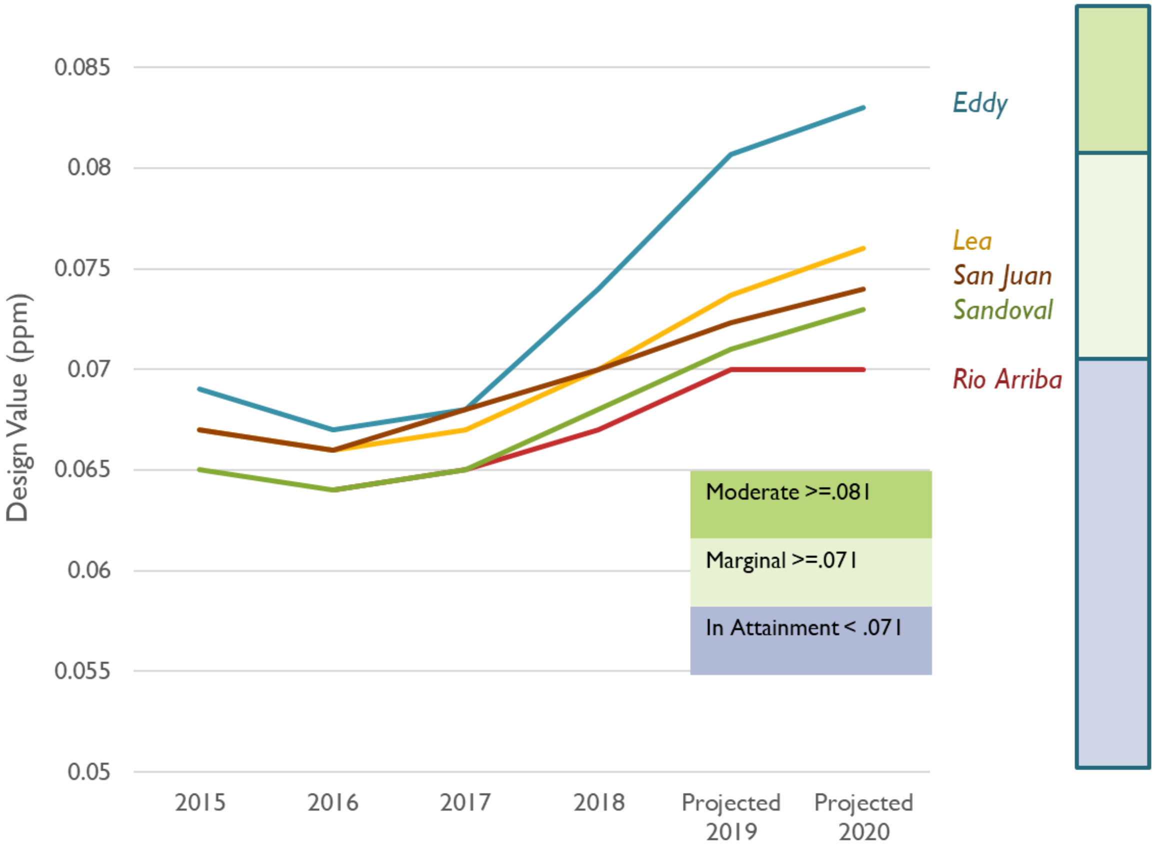
[10] Umukoro, G., and Ismail, O. 2017. Modelling emissions from natural gas flaring. Journal of King Saud University – Engineering Sciences. Available at: https://www.sciencedirect.com/science/article/pii/S1018363915000203.

[11] Other counties may have poor or worsening air quality but are not monitored.

do not take action. It is impossible to determine exactly how severe future ozone design values will be, but an estimate can be obtained through historical growth rates in annual fourth-worst ozone values. Figure 2 shows this increase in ozone design values (three-year average) between 2015–2020, with 2019 and 2020 representing projected values. Assuming a very conservative no-growth assumption in the fourth highest ozone value from 2018, all but one of these counties fall into nonattainment by 2020. While Rio Arriba's design value under these assumptions would be 70 ppb and thus technically in attainment, any increase in the annual fourth-worst ozone value would push that county into nonattainment as well.

Figure 2. Projected ozone design values to 2020



Source: Synapse calculations based on EPA historical design values.

Our projection supports the idea that nonattainment is an imminent threat and the resulting regulatory costs are highly probable in the near term unless actions are taken. Once a county falls into a nonattainment status of moderate or above, the state must file a state implementation plan (SIP) that outlines its path to compliance. At the moderate nonattainment level, the SIP must include developing a major emissions statement, conducting a transportation conformity demonstration including a motor vehicle emissions budget. Furthermore, all major emissions sources greater than 100 metric tonnes per year must go through new source review and permitting. These major emissions sources are also required to purchase offset credits to ensure there is no increase in emissions. At the moderate level, there is also the requirement to impose reasonably available control technology on all major emitting sources, reduce VOC emissions by 15 percent of the county's baseline, and impose a vehicle inspection and maintenance program.

For our analysis, we modeled avoided costs based on a moderate nonattainment level using information from two reports from Texas, one developed by the Capital Area Council of Governments (CAPCOG) and the other conducted for the Alamo Area Council of Governments focusing on the San Antonio metropolitan area.[12,13] These studies occurred after NAAQS standards were made more stringent—decreasing from 75 ppb to 70 ppb in 2015—after which a number of counties fell into nonattainment, including those outlined in these reports. It is difficult to quantify the specific costs of compliance actions because, while there are general benchmarks that must be met, how a state decides to meet them can be very different. Our analysis attempted to quantify the hard costs associated with nonattainment, including permitting, offsets, and vehicle inspection and maintenance. Because our analysis is forward-looking, we could not reasonably estimate some of the softer costs associated with nonattainment, such as the loss of business expansion due to permitting costs.

Overall, the most significant costs identified in our nonattainment analysis stem from increased permitting costs and the cost of offset purchases. These costs are incurred because any new major emitting source above 100 tonnes per year of NO_x or VOCs that is built in the state under nonattainment must go through a special permitting process. In addition, any new emissions source must purchase offset credits equal to 1.15 times the tonnes per year amount in the permit. Using data from the New Mexico Environment Department Air Quality Bureau, we were able to approximate the size and quantity of permits by county. We took offset prices from 2017 California Air Resources Board (CARB) data and used them to determine total offset cost.[14] The costs of vehicle inspection and maintenance programs were calculated using inspection and repair costs outlined in the Texas reports multiplied by the number of vehicles in New Mexico. We calculated this using populations by county and motor vehicle registrations in the state to determine vehicles per county. Finally, the cost of a 15 percent reduction in VOCs was calculated using EPA data of VOC emissions in the state of New Mexico and CAPCOG's estimate of the cost per tonne of VOC reduction.[15]

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[12] CAPCOG. 2015. *The Potential Costs of Ozone Nonattainment Designation to Central Texas*. Available at: http://www.capcog.org/documents/airquality/reports/2015/Potential_Costs_of_a_Nonattainment_Designation_09-17-15.pdf.

[13] Navin, S. et al. 2017. *Potential Cost of Nonattainment in the San Antonio Metropolitan Area*. Available at: https://www.tceq.texas.gov/assets/public/agency/nc/air/Appendix-B-for-EPA-HQ-OAR-2018-0635.pdf.

[14] California Air Resources Board, New Source Review - Emission Reduction Credit Offsets. Available at: https://ww3.arb.ca.gov/nsr/erco/erc17.pdf.

[15] CAPCOG. 2015. *The Potential Costs of Ozone Nonattainment Designation to Central Texas*. Pg. 77. Available at: http://www.capcog.org/documents/airquality/reports/2015/Potential_Costs_of_a_Nonattainment_Designation_09-17-15.pdf.

Avoided Greenhouse Gas Costs

Synapse quantified the impact that reducing methane emissions has on mitigating climate change, including reducing damages associated with the spread of disease, coastal destruction, and decreased food security. We applied the societal cost of methane calculated by the U.S. Government Interagency Working Group (IWG) in 2016, as calculated using a 3 percent real discount rate.[16] The 3 percent discount rate was selected for this analysis because the IWG considers it a central estimate based on average climate outcomes. This cost is equivalent to $1,431 per tonne of methane in 2020 and escalates to $1,908 per tonne in 2030 (2018 dollars).

2.2. Costs Estimation

Oil and gas producers in New Mexico will incur costs in order to comply with the comprehensive controls. Synapse researched and compiled compliance costs by source of methane on a dollar per mcf and dollar per metric tonne basis. We then calculated total costs by county using annual methane and VOC emissions reduction potential provided by Spherical Analytics.

The 15 emissions sources outlined in our study can be broadly classified in two categories: vented and fugitive emissions. Vented emissions are the intentional release of gases, while fugitive emissions are the result of unintentional gas leaks from various valves, pumps, and other equipment throughout the production, gathering, and boosting processes. Reductions in vented emissions are primarily accomplished through increasing gas capture with vapor recovery units (VRU) and zero-emissions equipment. Reductions in fugitive emissions come from quarterly leak detection and repair (LDAR).

Fugitive emission reduction has the greatest methane and VOC emissions reduction potential of all actions evaluated in this analysis. Reducing fugitive emissions can reduce 88 percent of existing methane emissions and 74 percent of existing VOC emissions in the state. Within the category of fugitive emissions, the largest methane reduction potential comes from equipment malfunctions (i.e., “abnormal emissions”), which represent 72 percent of the total methane emission reduction potential and 61 percent of VOC reduction. Abnormal emissions are measured by comparing the difference between top-down site level measurements and bottom-up aggregation of source level emissions.[17]

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[16] Interagency Working Group on Social Cost of Greenhouse Gases. 2016. Addendum to Technical Support Document on Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866: Application of the Methodology to Estimate the Social Cost of Methane and the Social Cost of Nitrous Oxide. Available at: https://19january2017snapshot.epa.gov/sites/production/files/2016-12/documents/addendum_to_sc-ghg_tsd_august_2016.pdf.

[17] Zavala-Araiza, D. et al. 2017. *Super-emitters in natural gas infrastructure are caused by abnormal process conditions*. Available at: https://www.nature.com/articles/ncomms14012. We have adopted a definition of abnormal emissions, aligned with Spherical’s calculations, wherein abnormal emissions are those from abnormal processes (e.g., equipment malfunctions) measured by comparing the difference between top-down site level measurements and bottom-up aggregation of source level emissions.

Total site emissions can be calculated by using optical gas-imaging cameras downwind of production facilities.[18]

Table 1. Emissions sources and corresponding abatement technology and unit cost

Emission Source	Technology	Unit Cost ($/mcf of reduced methane)	Unit Cost ($/tonne of reduced methane)	Source
Abnormal Emissions	*Existing quarterly LDAR**	$0.00	$0.00	ICF, 2015
Associated gas flaring	VRU	$4.18	$217.36	CARB, 2017
Associated gas venting	VRU	$4.18	$217.36	CARB, 2017
Centrifugal compressors	Wet Seal Degassing Recovery System for Centrifugal Compressors	$0.82	$42.64	CARB, 2017
Dehydrators	VRU	$4.18	$217.36	CARB, 2017
Gathering station blowdowns	Transmission Station Venting -Redesign Blowdown Systems /ESD Practices	$3.84	$199.68	ICF, 2016
Gathering stations	LDAR (weighted average)	$7.35	$382.20	ICF, 2015
High-bleed pneumatic controller	High-bleed to zero-bleed pneumatic controller	$7.89	$410.14	Carbon Limits, 2016
Leaks	LDAR (weighted average)	$7.35	$382.20	ICF, 2015
Liquids unloading	Liquid Unloading - Install Plunger Lift Systems in Gas Wells	$5.03	$261.56	ICF, 2016
Low-bleed pneumatic controller	Low-bleed to zero-bleed pneumatic controller	$49.30	$2,563.40	Carbon Limits, 2016
Malfunctioning pneumatic controllers	*Existing quarterly LDAR**	$0.00	$0.00	ICF, 2015
Oil and condensate tanks	VRU	$4.18	$217.36	CARB, 2017
Pneumatic pump	Solar electric pneumatic pump replacement	$4.86	$217.36	ICF, 2016
Reciprocating compressors	Replacement of Reciprocating Compressor Rod Packing Systems	$1.83	$95.16	CARB, 2017

Note: Abnormal emissions and malfunctioning pneumatic controllers are addressed by quarterly LDAR for leaks and gathering stations, therefore their costs are not repeated.

All types of fugitive emissions can be mitigated through LDAR. LDAR is one of the most common emission mediation methods and is relatively inexpensive to implement on a cost-per-volume basis. The cost of LDAR is primarily associated with the labor cost of sending a technician to the site. We assume that all abnormal emissions (including those from malfunctioning pneumatics) will be identified and

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[18] EDF Methodology. Available at: https://www.edf.org/nm-oil-gas/methodology/.

addressed as part of the quarterly LDAR process. Therefore, we conclude that there is no additional cost associated with those two source categories.

Retrofitting high- and low-bleed pneumatic controllers with zero-bleed alternatives represents the second-largest emissions reduction category (7.6 percent). Pneumatic controllers are also the most significant cost driver, as there is a higher capital cost relative to the volume of gas savings. It should be noted that all costs per unit of emissions reduction are variable, and this is particularly true for zero-bleed systems. In the face of this variability we have taken a conservative approach which likely over-represents these costs.

Sources of Cost Data

Synapse compiled abatement technology cost data from several sources. Given that LDAR makes up a substantial portion of the emissions reductions in this analysis, we utilized a source specific to LDAR that calculated costs using facility models and Monte Carlo simulations.[19] Zero-bleed pneumatic controller costs were calculated using a Carbon Limits tool developed for the Clean Air Task Force.[20] For the remaining technologies, we use a 2017 CARB report for the costs it contains (including VRU, wet seal degassing, and reciprocating compressors) because it was the most recent source of methane abatement technology costs.[21] The remainder of costs that were not covered by other more recent sources were sourced from two reports by ICF, one prepared for EDF in 2014 and the other prepared for One Future, Inc. in 2016.[22] In all cost categories for which we relied on an ICF report, the two reports agreed and we have cited the 2016 report. Table 1 summarizes each emissions source analyzed by Spherical, the technology used, and the cost of emissions reduction on a dollar per mcf and dollar per tonne basis.

2.3. Benefit-Cost Ratios

Comparing the benefits and costs described above yields a benefit-cost ratio (BCR), with the discounted benefits in the numerator and the discounted costs in the denominator. A BCR above 1 indicates that the program is cost-effective because the total lifetime benefits outweigh the total lifetime costs of the regulation. In contrast, a BCR below 1 indicates that the program is not cost-effective because the costs are higher than the benefits. All costs and benefits in this analysis were discounted at a rate of 3 percent

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[19] ICF. 2015. *Leak Detection and Repair Cost-Effectiveness Analysis* (Revised 2016). Available at: https://www.edf.org/sites/default/files/content/edf_ldar_analysis_120415_v7.pdf.

[20] Carbon Limits. 2016. *Zero emission technologies for pneumatic controllers in the USA*. Available at: https://www.ourenergypolicy.org/wp-content/uploads/2014/04/epa-devices.pdf.

[21] California Air Resources Board. 2017. Regulation for greenhouse gas emission standards for crude oil and natural gas facilities, Attachment 2. Available at: https://ww3.arb.ca.gov/regact/2016/oilandgas2016/oilgasatt2.pdf

[22] ICF. 2014. Available at: https://www.edf.org/sites/default/files/methane_cost_curve_report.pdf; ICF. 2016. Available at: http://onefuture.us/wp-content/uploads/2018/05/ONE-Future-MAC-Final-6-1.pdf

and in constant 2018 dollars. Synapse calculated three distinct BCRs, each different in which benefits are included in the numerator of the ratio:

1. **Primary BCR**: This ratio includes only the benefits of captured gas and avoided health impacts. These benefit streams are the two most tangible benefits to New Mexicans.
2. **Secondary BCR**: In addition to the benefits of the Primary BCR, this ratio also includes the value of avoided NAAQS nonattainment. This benefit is included secondarily given the uncertainty with the estimation of the value of avoiding nonattainment.
3. **Global BCR**: In addition to the benefits of the Secondary BCR, this ratio also includes the greenhouse gas benefit. This benefit is only included in the Global BCR because the value will accrue to the benefit of people around the world, rather than just to New Mexicans.

3. BENEFIT-COST RESULTS

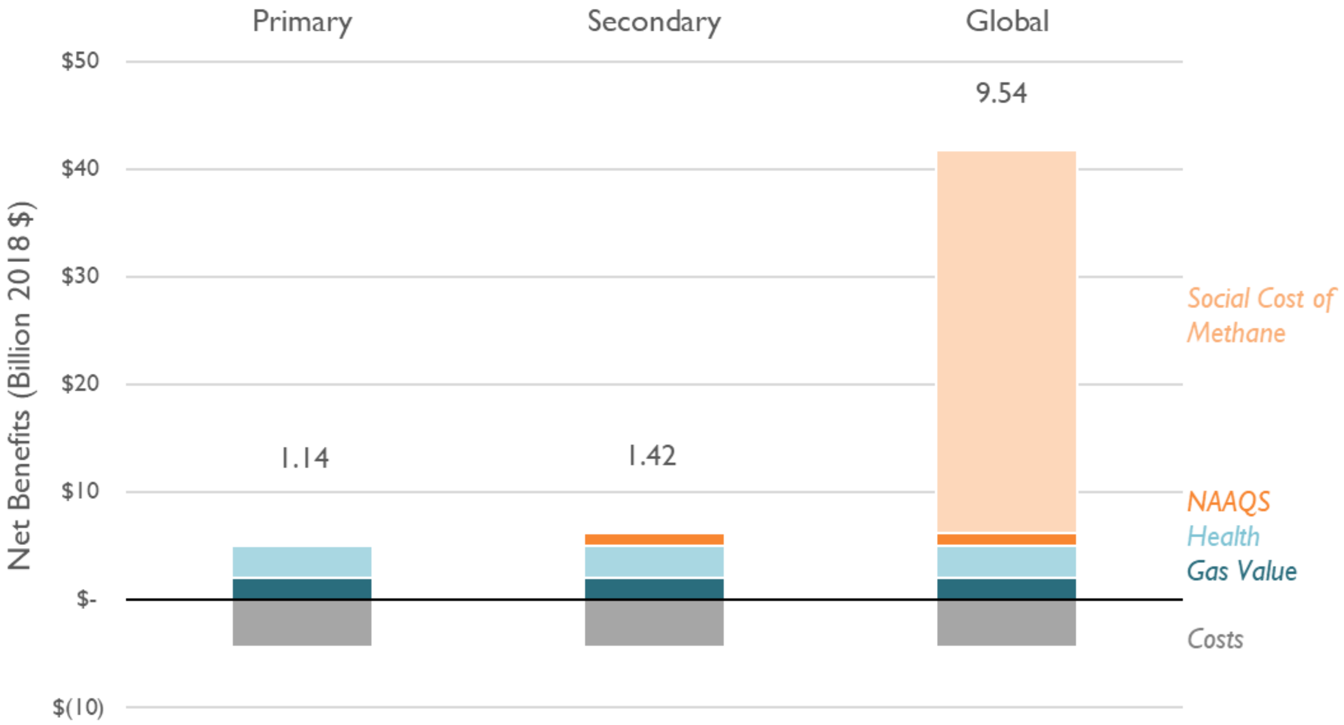
3.1. Overview

The comprehensive oil and gas emission reduction rules were found to be cost-effective to New Mexicans across all three BCRs. The Primary BCR, which is considered the most conservative ratio, is 1.14 over the ten-year study period. Based on this perspective, for every $1 million dollars of costs associated with the comprehensive controls, New Mexico residents and firms are expected to benefit by $1.14 million dollars from captured gas revenue and reduced health-related costs. This translates to a net benefit of $0.56 per mcf of recovered methane.

The Secondary BCR, which also includes the avoided costs associated with compliance with federal ozone regulations, is 1.42 over the ten-year study period. In this case, for every $1 million dollars of costs associated with the comprehensive controls, New Mexico is expected to benefit by $1.42 million dollars of from captured gas revenue, reduced health-related costs, and reduced ozone regulation compliance costs. This translates to a net benefit of $1.55 per mcf of recovered methane.

Finally, the Global BCR—which includes all benefits from the Secondary BCR, plus the avoided social cost of methane—is 9.54 over the ten-year study period. For every $1 million dollars of costs associated with the comprehensive controls, we calculate a global benefit of $9.54 million dollars of from captured gas revenue, reduced health-related costs, reduced ozone regulation compliance costs, and mitigation of climate change. This translates to a net benefit of $33.62 per mcf of recovered methane.

Figure 3. Net benefits and benefit-cost ratios for the comprehensive controls in New Mexico



Source: Synapse calculations.

3.2. Cost Summary

In total, the comprehensive controls are expected to achieve a 1.2 billion mcf reduction in methane emissions and nearly 7 million tonnes reduction of VOCs from 2020–2030. The total compliance cost of $5.2 billion translates to $4.71 per mcf of methane reduced or $244.50 per tonne of methane gas emissions reduced, in 2018 dollars. Furthermore, this translates to $1,100 per tonne of VOC reduced. More than 82 percent of the cost is associated with zero-bleed controllers.

Table 2. Total cost of methane and VOC reduction by emissions source

Emission Source	Methane Reduction (million mcf)	VOC Reduction (thousand tonnes)	Total Cost (2018$ millions)
Abnormal Emissions	794	4,296	$0.0
Associated gas flaring	9	53	$42.9
Associated gas venting	8	41	$37.1
Centrifugal Compressors	1	3	$0.4
Dehydrators	1	3	$3.2
Gathering Station Blowdowns	9	49	$36.8
Gathering Stations	32	182	$260.4
High-Bleed Pneumatic Controller	6	29	$49.4
Leaks	45	203	$366.3
Liquids Unloading	7	25	$37.3
Low-bleed Pneumatic Controller	79	327	$4,302.0
Malfunctioning Pneumatic Controllers	104	435	$0.0
Oil and Condensate Tanks	11	129	$48.4
Pneumatic Pump	3	14	$17.0
Reciprocating Compressors	1	3	$1.3
Total	**1,199**	**6,959**	**$5,204.9**

Source: Spherical Analytics (emissions reductions) and Synapse calculations (costs).

3.3. Benefits Summary

Value of Captured Gas

The value of captured gas from the comprehensive controls over the period of 2020 to 2030 varies greatly by county, from about $1 million (McKinley) to nearly $700 million (Eddy). This variation is due in large part to the volume of captured gas in each county and in small part to the difference in gas value between the Permian and San Juan Basins. The total discounted value of captured gas from the comprehensive controls over the 10-year study period is just over $2 billion (Table 3). Of this value, approximately 14 percent ($270 million) is expected to be realized by the state of New Mexico in gas royalties.

Table 3. Discounted value of captured gas and royalty revenues for 2020–2030, by county

County	Discounted NPV (Millions 2018$)	Royalty Revenue (Millions 2018$)	Percent of Revenue for Royalties
Chaves	$83.6	$10.9	13%
Colfax	$23.6	$2.2	9%
Eddy	$696.9	$97.3	14%
Lea	$650.2	$86.0	13%
McKinley	$1.0	$0.2	15%
Rio Arriba	$231.8	$32.4	14%
Roosevelt	$6.7	$0.6	10%
San Juan	$314.8	$43.8	14%
Sandoval	$9.2	$1.4	15%
All	**$2,017.8**	**$274.2**	**14%**

Source: Synapse calculations (discounted NPV) and Spherical Analytics calculations (royalty percentages).

In a similar analysis, the Colorado Division of Public Health and Environment (CDPHE) conducted a cost-benefit analysis of emissions regulations that aligned with our findings, also concluding that the comprehensive controls are cost-effective.[23] Furthermore, CDPHE found total annual costs of $59.2 million compared to $16.8 million in captured gas value, representing 28 percent of cost recovery. In our analysis we calculated 10-year costs at $6.4 billion and a value of captured gas of roughly $2 billion, or 31 percent of total costs. In its analysis, CDPHE found that the costs to oil and gas companies only represented 0.4 percent of their annual revenues and that regulations would be unlikely to cause price impacts to consumers. In fact, major oil and gas companies in Colorado supported these regulations.

Human Health

Reduced VOC emissions and methane flaring (resulting in a reduction in nitric oxide, nitrogen dioxide, and SO_2 emissions) leads to lower human mortality, illnesses, and associated detriment to the economy. The total discounted value of these human health benefits amounts to nearly $3 billion over the 2020–2030 study period (Table 4). Colfax County would experience the least of these benefits ($56 million), while Eddy County would experience the greatest of these benefits ($638 million).

Note that these benefits do not include those associated with reduced ground-level ozone (resulting from reduced VOC emissions). As such, we consider this category of benefits to be conservative. Actual benefits are likely to be higher than what is estimated in this report.

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[23] Colorado Department of Public Health and Environment. 2014. *Cost Benefit Analysis*. Available at: http://www.ematrix.erg.com/files/control/BP%20Doc%20Colorado%201.pdf.

Table 4. Discounted value of human health benefits for 2020-2030, by county

County	Discounted NPV (Millions 2018$)
Chaves	$515.7
Colfax	$56.3
Eddy	$638.3
Lea	$405.8
McKinley	$186.8
Rio Arriba	$153.1
Roosevelt	$62.1
San Juan	$564.1
Sandoval	$399.3
ALL	**$2,981.5**

Source: Synapse calculations.

NAAQS Avoided Nonattainment Costs

In total we found moderate nonattainment would cost the five New Mexico counties a total of $1.2 billion (over a six-year nonattainment time period at a 3 percent discount rate), but we expect the actual impact could be much higher. This analysis excludes costs associated with project delays, decreases in gross regional product (GRP) due to loss of business expansion, and costs of point source emissions reductions through reasonably available control technology.[24] While more localized to individual businesses, the softer costs of nonattainment may have large effects on the local economy. These localized impacts were outside the scope of this analysis. Therefore, we note that our estimate of avoided nonattainment benefits is very conservative, and the Secondary and Global BCRs are likely higher than calculated in this report.

Table 5. Present value of cost of moderate nonattainment

Measure	Cost (Millions 2018$)
NSR Permitting	$23.0
Offset	$644.9
Transportation Conformity	$0.04
Vehicle I-M	$9.9
15% VOC RFP	$539.3
Total	**$1,217.2**

Source: Synapse calculations.

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[24] Both Texas studies were able to approximate these costs, finding tens of billions of dollars in losses in GRP.

Examining each county individually, we found that the total costs at risk range from $62 million in Sandoval County to $415 million in San Juan County (Table 6).

Table 6. Discounted value of avoided NAAQS nonattainment costs for 2020–2030, by county

County	Discounted NPV (Millions 2018$)
Chaves	-
Colfax	-
Eddy	$235.7
Lea	$368.2
McKinley	-
Rio Arriba	$137.1
Roosevelt	-
San Juan	$414.5
Sandoval	$61.7
All	**$1,217.2**

Source: Synapse calculations. Note: Chaves, Colfax, McKinley, and Roosevelt Counties do not have air quality monitoring stations; therefore, the analysis could not be conducted for those four counties.

Avoided Greenhouse Gas Costs

Reducing methane emissions has a long-term global benefit: mitigating the costly effects of climate change (e.g., sea-level rise and property damage, increased transfer of illnesses, ecological damage). The total discounted value of this global benefit amounts to $35.5 billion over the 2020–2030 study period (Table 7). McKinley County would generate the least of these benefits ($17 million), while Eddy County would generate the greatest of these benefits ($12.5 billion).

Table 7. Discounted value of avoided social cost of methane for 2020-2030, by county

County	Discounted NPV (Millions 2018$)
Chaves	$1,497
Colfax	$399
Eddy	$12,476
Lea	$11,639
McKinley	$17
Rio Arriba	$3,921
Roosevelt	$120
San Juan	$5,324
Sandoval	$156
All	**$35,548**

Source: Synapse calculations.

4. CONCLUSIONS

To calculate the cost-effectiveness of the comprehensive oil and gas emission rules in New Mexico, Synapse evaluated three BCRs of the regulation for 2020 through 2030, each with different combinations of benefit streams but the same cost assumptions. Where cost choices were available, higher technology cost assumptions were chosen to be as conservative as possible. These ratios range from conservative to comprehensive and are termed the Primary, Secondary, and Global BCRs. A BCR greater than 1 is considered cost-effective because the total benefits over the study period are greater than the total costs. Based on this analysis, we determined that the comprehensive controls are cost-effective regardless of which of the three sets of benefits and costs is used.

Synapse considers the Primary BCR the most conservative ratio, inclusive of benefit streams that are readily quantifiable and have a direct and tangible impact on New Mexicans. The benefits calculated as part of the Primary BCR include only the avoided human health costs (due to reduced air pollution) and the value of captured (i.e., non-leaked or non-vented) methane that supports the state's economy. The resulting Primary BCR was 1.14.

The Secondary BCR includes a broader set of benefits than the Primary. In addition to avoided human health costs and the value of captured methane, the Secondary BCR also includes the avoided costs associated with nonattainment of the federal NAAQS ground-level ozone regulations. Though nonattainment has both direct and indirect costs, Synapse limited the analysis to the direct costs, including permit and transportation programmatic costs. The resulting Secondary BCR was also found to be cost-effective with a ratio of 1.42.

Finally, the Global BCR takes the most comprehensive view of benefits, including long-term climate benefits to the global population—not just to New Mexicans. The Global BCR includes all benefits from the Secondary BCR, plus the avoided social cost of methane associated with methane's greenhouse gas effect on climate change. The resulting Global BCR was found to be highly cost-effective with a ratio of 9.54.

This study illustrates that, regardless of the perspective of benefits, the comprehensive oil and gas emissions rules are cost-effective in New Mexico.

Appendix A. COST CALCULATIONS

Controllers

The Carbon Limits tool used in this analysis estimated methane abatement costs by calculating 10-year lifetime capital costs of the project and emissions reductions from a zero-bleed controller. Key inputs and assumptions that affected the final cost in dollars per tonne of methane emissions avoided include the number of controllers at a site, the emissions factor of a high- and low-bleed controller in cubic feet per hour, and the capital costs of the project. Included in the capital cost are the controllers, control panel, solar panel, battery backup, as well as replacement batteries and labor over the lifetime of the project. We made a conservative assumption that there is no electric connection at these sites to power the controllers and that all devices are paired with solar and battery storage. Upfront capital costs for the project totaled $35,640 for an average site retrofit with six continuous bleed controllers (Table 8). Additional operating costs include $1,200 every four years for battery replacement and $480 annually for labor cost.

Table 8. Upfront capital cost of an average zero bleed controller retrofit

Type	Unit Cost	Units	Total Cost
Continuous Controller	4,000	6	$24,000
Control Panel	4,000	1	$4,000
Solar Panel	500	1	$500
Battery	400	3	$1,200
Installation Cost		20% of CAPEX	$5,940
Total			**$35,640**

The largest driver of the abatement cost for zero-bleed controllers was the emissions rate. Additionally, capital costs were the same between high- and low-bleed retrofits, therefore high-bleed devices had a much lower cost per mcf of methane emissions avoided comparative to low-bleed because their emissions reduction potential is greater. We used EPA's reported emissions rate of 13.75 standard cubic feet per hour (scfh) for high-bleed devices and 2.17 scfh for low-bleed.[25] Controllers per site was taken from a University of Texas at Austin study that sampled the number of controllers at 65 sites throughout

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[25] EPA. 2014. *Oil and Natural Gas Sector Pneumatic Devices*. High and low bleed available in table 2-4 at: https://www.ourenergypolicy.org/wp-content/uploads/2014/04/epa-devices.pdf

the United States.[26] Overall, high-bleed controllers had an abatement cost of $7.89 per mcf of methane compared to a low-bleed retrofit at $49.3 per mcf.

Other

For other cost calculations including LDAR, wet seal degassing for centrifugal compressors and replacement of reciprocating compressor rod packing systems, we utilized values from a CARB proposed regulation.[27] CARB reported emissions reductions in metric tonnes of carbon dioxide equivalent (CO2e) which we converted to tonnes of methane by dividing by IPCC's global warming potential for methane.[28] We then multiplied by 52 to convert tonnes to mcf.[29]

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[26] Allen, D. et al. 2014. *Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Pneumatic Controllers*. Available at: https://pubs.acs.org/doi/pdf/10.1021/es5040156?rand=pedkv1qx

[27] California Air Resources Board. 2017. *Regulation for greenhouse gas emission standards for crude oil and natural gas facilities, Attachment 2*. Available at: https://ww3.arb.ca.gov/regact/2016/oilandgas2016/oilgasatt2.pdf

[28] Using 100-year global warming potential (25) for methane from IPCC Annual Report 4. Chapter 2 table 2.14. Changes in Atmospheric Constituents and in Radiative Forcing. Available at: https://wg1.ipcc.ch/publications/wg1-ar4/ar4-wg1-chapter2.pdf

[29] Using a calculated tonnes to cubic feet conversion. Available at: https://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_energy/Infographic-Climate-Risks-of-Natural-Gas-Fugitive-Emissions-Methodology-and-Assumptions.pdf

Appendix B. **NAAQS – NONATTAINMENT**

Nonattainment costs are composed of offset trading, 15 percent baseline VOC reduction, vehicle inspection and maintenance, new source review and permitting, and transportation conformity costs. Costs were dominated by offsets and VOC reduction which together accounted for 97 percent of the total.

We approximated air permitting and offset costs using publicly available data sources through the New Mexico Environment Department Air Quality Bureau. For permitting cost, we used the annual number of new permits by county and cost per permit. First, we found the percentage of total Title V permits (major emissions sources >100 tonnes per year) by county by taking total permits by county divided by the total permits in the state from the “Permitted Facilities Lat Long” dataset.[30] Then, annual permitting data between 2016 and 2018 was used to calculate the average number of new permits by year in the state of New Mexico.[31] Between 2016 and 2018 there were 31 new Title V permits on average. To find new permits by county we multiplied the county level distribution percentage by the annual average number of Title V permits in the state of New Mexico. S. Navin, et al. estimated permitting costs between $100,000 and $250,000; therefore, we used the average for our cost and multiplied by annual permit count to get total cost (Table 9).[32]

Table 9. Average Title-V permitting distribution and cost by county

County	Title-V (%)	Annual Permit Count	Average Permit Cost	Total Permit Cost
Eddy	20.9	6	$175,000	$1,050,000
Lea	18	6	$175,000	$1,050,000
Rio Arriba	7.6	2	$175,000	$350,000
Sandoval	21.5	7	$175,000	$175,000
San Juan	2.9	1	$175,000	$1,225,000
ALL	**70.9**	**22**	**$175,000**	**$3,850,000**

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[30] At the time of our analysis we used the file “Permitted Facilities Lat Long as of 07/01/19.” Current version is as of 09/03/19. Available at: https://www.env.nm.gov/air-quality/aqb-p_current_permitting_activites/

[31] Monthly Report of Title V Permitting Activities Fiscal Year 2016-2018. Available at: https://www.env.nm.gov/air-quality/monthly-report-of-permitting-statistics/

[32] Navin, S. et al. 2017. *Potential Cost of Nonattainment in the San Antonio Metropolitan Area*. Available at: https://www.tceq.texas.gov/assets/public/agency/nc/air/Appendix-B-for-EPA-HQ-OAR-2018-0635.pdf.

Source: Synapse calculations

Under moderate nonattainment, any new major emissions source must also supply an offset equal to 1.15 times the amount specified in their permit. For offset cost we multiplied the annual number of permits filed by county and the average permit size in tonnes of both NO_x and VOC that we calculated from our initial "Permitted Facilities Lat Long" dataset. We used the maximum value between VOC and NO_x to calculate the total required offset amount. Offset costs were taken from CARB offset transactions from 2017 for both NO_x and VOCs. Average NO_x offset costs per tonne were $13,883 and VOC were $6,242 per tonne. We used the average of the two offset costs (Table 10).[33]

Table 10. Average Title-V emissions and offset costs by county

County	NO_x (tonnes/year)	VOC (tonnes/year)	Offset Amount (tonnes)	Offset Cost ($/tonne)	Total Offset Cost
Eddy	176.6	197.1	1360.1	10,062.5	$13,686,078
Lea	587.6	134.4	4054.6	10,062.5	$40,799,348
Rio Arriba	188.2	200.6	461.3	10,062.5	$4,641,746
Sandoval	82.1	53.3	94.4	10,062.5	$950,051
San Juan	589.5	164.3	4745.3	10,062.5	$47,749,655
ALL	**1,624.0**	**749.7**	**10,715.7**	**10,062.5**	**$107,826,877**

Source: Synapse calculations

We calculated costs associated with 15 percent VOC reductions by using EPA National Emissions Inventory Data VOCs from 2014 and CAPCOG's cost in dollars per tonne of VOC emission reductions (Table 11).[34]

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[33] California Air Resources Board. 2017. New Source Review – Emissions Reduction Credit Offsets. Available at: https://ww3.arb.ca.gov/nsr/erco/erc17.pdf

[34] EPA National Emissions Inventory Data 2014. https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data

Table 11. Estimation of 15% VOC reduction costs by county

County	VOC Baseline (tonnes)	Reduction (tonnes)	VOC Reduction $/ton	Total Cost
Eddy	122,785.6	18,417.8	7,965	$146,698,099
Lea	97,680.2	14,652.0	7,965	$116,703,437
Rio Arriba	89,329.0	13,399.3	7,965	$106,725,791
Sandoval	43,329.6	6,499.4	7,965	$51,768,018
San Juan	99,706.6	14,956.0	7,965	$119,124,406
All	**452,831.0**	**67,924.5**	**7,965**	**$541,019,751**

Source: Synapse calculations

The remainder of costs were relatively small in comparison to offsets and VOC reduction represented just 3 percent of total costs. A transportation conformity analysis estimated at $0.10 per person by CAPCOG was multiplied by county level census data to get total costs.[35] Similarly, vehicle inspection and maintenance was calculated using county level population data in addition to vehicle registration data and CAPCOG cost estimations. CAPCOG estimated inspection and repair costs as well as the percentage of vehicles that would require repair of the total vehicles inspected. From their estimations, we calculated an average cost per vehicle at $26.26 which includes initial inspection and a percentage of total vehicles that would require a secondary inspection and repair. Using total New Mexico vehicle registrations, we determined a statewide vehicles per person based on state population. This ratio of .87 vehicles per person was multiplied by total population by county and finally by the cost of $26.26 per vehicle for a total shown in Table 12.

Table 12. Vehicle inspection and maintenance and transportation conformity costs based on county population

County	Population	Vehicles	I-M Cost	Transportation Conformity Cost
Eddy	57,900	50,385	$1,323,061	$5,790
Lea	69,611	60,576	$1,590,667	$6,961
Rio Arriba	39,006	33,943	$891,318	$3,901
Sandoval	145,179	126,335	$3,317,455	$14,518
San Juan	125,043	108,813	$2,857,332	$12,504
All	**436,739**	**380,051**	**$9,979,833**	**$43,674**

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[35] County level population data taken from U.S. Census Bureau. https://www.census.gov/