METHANE REDUCTION TECHNOLOGY ELECTRICITY AND ABATEMENT COSTS

The Cost to Power Zero-Emission Pneumatic Controllers and Pumps in Grid-Connected and Remote Locations

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May 6, 2022

Acknowledgments

This is an independent study prepared at the request of Environmental Defense Fund by a team at Analysis Group led by Paul Hibbard. Our work benefitted significantly from assistance by Scott Ario and Elisa Gan at Analysis Group, and from the input and comment received from Environmental Defense Fund.

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About Analysis Group

Analysis Group is one of the largest international economics consulting firms, with over 1,000 professionals across 14 offices in North America, Europe, and Asia. Since 1981, Analysis Group has provided expertise in economics, finance, analytics, and strategy to top law firms, Fortune Global 500 companies, government agencies, and other clients. The firm's energy and environment practice area is distinguished by its expertise in economics, finance, market modeling and analysis, regulatory and policy analysis, and infrastructure development. Analysis Group's consultants have worked for a wide variety of clients, including energy suppliers, energy consumers, utilities, regulatory commissions, other federal and state agencies, tribal governments, power system operators, foundations, financial institutions, start-up companies, and others.

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I. Summary

In November 2021, EPA proposed new regulations to implement new source performance standards and emissions guidelines for existing sources to significantly reduce methane emissions in the exploration, production, processing and transport of oil and natural gas. EPA's proposed rule, when finalized and implemented, will achieve major reductions in methane and other harmful air pollution from both new and existing oil and natural gas sources. For some portions of the oil and natural gas fuel cycles, new and emerging emission control technologies operating on electricity offer opportunities to achieve significant reductions at a reasonable cost. In this report we focus on one of these categories proposed in the EPA rule - zero-emitting technologies for pneumatic controllers and pumps - and evaluate the overall cost and potential incremental cost of electricity to install and/or operate them at oil and natural gas production, processing and transmission and storage sites.

We expect that operators will largely utilize electric controllers and pumps or electric air compressors to comply with these rules. EPA considered several combinations of technologies for complying with the rules, including electronic controllers and pumps powered by on-site solar/battery systems, electronic controllers and pumps powered by the grid or other on-site generation, and compressed air systems powered from the grid or other on-site generation. In the case of electric controllers powered by onsite solar/battery systems, EPA's cost estimates include the costs of the solar/battery system. We note that, based on the remoteness of many oil and gas sites and the relatively low annualized costs of electronic controller systems that include solar/battery power systems, these systems are expected to be a very common tool for compliance with these rules. However, for cases where power comes from the grid or other (non-solar) onsite power generation, EPA did not include the costs of obtaining this power in their cost estimates.

The method of supplying electricity and the cost of electricity to operate this equipment can vary significantly from site to site as a function of the prevailing cost of electricity, how many facilities are in nearby operation in an area, whether the location has an existing connection to the local electric distribution system, whether it is reasonably close to the distribution system, or whether the location is fully remote. Our analysis seeks to answer the following question relevant to EPA's consideration of methane emission reduction technologies at oil and natural gas sites: What would be the electricity, total annualized, and abatement costs to operate zero-emission technologies for pumps and controllers at locations covered by EPA's proposed rule?

Therefore, for situations where operators do not use solar/battery systems, this report provides estimates of the cost of electric power that are not included in EPA's analysis. For situations utilizing solar/battery systems, this report provides an independent, up-to-date assessment of such costs.

There is a great diversity of oil and natural gas site technologies, locations, and sizes across the country. The EPA studied two types of non-emitting technologies – electronic controllers and pumps (powered by grid access and solar) and instrument air controllers and pumps. In this analysis, to help determine the feasibility of those technologies, we evaluate electricity, equipment and maintenance costs under three different scenarios:

- Grid Electricity: Locations that have grid electricity supply on-site;
- Service Extension: Locations that do not have electricity supply on-site, but are located close enough to the local electric distribution system to consider developing a line extension from the closest spot on the grid; and

- Off-Grid: Locations that are clearly too far away from the electric distribution system to consider a line extension, and thus must rely on off-the-grid technologies (in this case, a combination of solar and storage).

Our estimates track EPA's definition of "Model Plants" (small, medium, and large), which vary by the number of controllers and pumps used on site. The key inputs to our analysis are emissions reductions per technology as estimated by the EPA, estimates of the equipment and maintenance costs and nature and quantity of electricity required to operate the technologies needed at each site, and the geographic location relative to oil and natural gas production regions. For simplicity we study four main regions - the Mid-West/Mid-Atlantic, the South, the Rocky Mountains, and Alaska. We thus develop our estimates of the incremental electricity and annualized cost for methane emission abatement technologies at locations as a function of (a) three different technologies[1], (b) four regions, (c) three model plant sizes, and (d) three electricity connection scenarios. Data for the analysis are all from public sources, including the U.S. Energy Information Administration (EIA), National Renewable Energy Lab (NREL), Bureau of Labor Statistics (BLS), Lawrence Berkeley Lab (LBL), Edison Electric Institute (EEI), Lazard, and Carbon Limits.

The results vary significantly across the different technology, geographic, and electricity connection scenarios evaluated. Based on our analysis, we come to several observations:

- The sources reviewed for this report suggest that zero-emission technologies for controlling methane emissions from pumps and controllers at oil and natural gas sites are available today, in circumstances where there is electricity already available on site, and where there is not.
- The electricity demand for pneumatic devices is low, meaning that the total incremental cost of electricity to use these devices at well sites is also low. The electricity demand for, and electricity cost of, instrument air devices is significantly higher and, as noted by EPA, would likely be used only in larger facilities.[2]
- While there is significant range in the cost of achieving zero emissions, depending on location and degree of electricity service, the magnitude of annualized costs in every region and for nearly every technology studied is vastly exceeded by the estimated benefit of curtailing methane emissions at oil and natural gas sites, including production, transmission and storage, and natural gas processing facilities. In other words, for every region and nearly every technology, the cost of methane abatement (in dollars per ton) - including the cost of electricity - remains well below estimated benefits of reducing methane, in this case

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[1] The three technologies considered are grid-powered electronic devices, solar-powered electronic devices, and instrument air devices. Where pneumatic devices send a pneumatic signal to a pneumatic actuator or positioner, electronic devices (grid-powered and solar-powered) adjust the position of the end-device by sending an electric signal to an electric actuator or positioner. Instrument air devices use compressed air as an energy source and signaling mechanism. All three technologies do not require the use of natural gas. Each technology is considered in each region except for solar in Alaska due to uncertainty over solar output and battery capacity during the Arctic winter.

[2] Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Review, Background Technical Support Document, EPA, October 2021, pp. 8-8 and 8-9, available at https://www.regulations.gov/document/EPA-HQ-OAR-2021-0317-0166.

the social cost of methane (SC-CH_4) and EPA's other cost-effectiveness benchmarks.[3] When natural gas savings are accounted for at production sites and natural gas processing plants, the cost of methane abatement is even lower. See Tables ES-1, ES-2, ES-3, ES-4 and ES-5. In particular:

  - In the case of production sites that have access to grid electricity, the abatement costs including our estimated cost of electricity range from $231 to $675 dollars per ton, compared to the estimate of benefits of methane reduction of $1,361 per ton. Thus, the cost of device installation *plus* electricity use continues to result in cost effective methane abatement.
  - In the case of production sites that can build a distribution line to connect to the grid, the abatement costs for this approach, including our estimated cost of electricity range from $484 to $891 dollars per ton, compared to EPA's estimate of benefits of methane reduction of $1,361 per ton. Thus, the cost of constructing a distribution line *plus* electricity use continues to result in cost effective methane abatement.
  - In the case of production sites that are remote, and must install solar/storage systems, the abatement costs including our estimated cost of electricity range from $238 to $444 dollars per ton, compared to EPA's estimate of methane reduction of $1,361 per ton. Thus, the cost of device installation *plus* investment in solar and storage on site continues to result in cost effective methane abatement.[4]
- In addition to being cost-effective purely on the basis of methane reductions, the use of non-emitting technologies to replace venting gas-driven pneumatics controllers and pumps will have the additional benefit of significantly reducing VOC emissions. While EPA generally found that its proposed rules for pneumatics are cost-effective as a means of VOC reductions, such estimates are beyond the scope of this report.
- In short, for the vast majority of oil and natural gas sites in the U.S., the cost of electricity to operate zero-emission pneumatic controllers and pumps should not be a deterrent to establishing these technologies as

[3] In the proposed rule, EPA presents a social cost of methane at $1,500 per metric ton of CH_4 ($1,361 per short ton), which is associated with the average social cost of methane at a 3% discount rate. EPA does not have a single central social cost of methane point estimate and emphasizes the importance and value in considering the benefits calculated using all four social cost of methane estimates (model average at 2.5%, 3%, and 5% discount rates; 95th percentile at 3% discount rate). Using the alternative estimates, the social cost of methane (per short ton) ranges from $608 to $3,538. EPA estimated the global social benefits of CH_4 emission reductions using the estimates presented in the Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under EO 13990 (IWG, 2021), available at https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf?source=email. In addition, EPA notes additional non-monetized climate and ozone health benefits from methane reduction not included in the social cost of methane estimates. Separately, EPA presents cost-effectiveness values of $1,800 to $2,185 per short ton of methane reduction to be reasonable for controls that are identified as BSER in the proposal. Cost-effectiveness refers to the annualized cost to implement an emission control option divided by the amount of annual emission reductions. This comparison is not intended to be a cost-benefit analysis, but rather a metric to compare the relative costs and emission impacts of various control options. See Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Review, Proposed Rules, EPA, November 2021, available at https://www.regulations.gov/document/EPA-HQ-OAR-2021-0317-0001. Our report shows that the majority of scenarios produce cost-effectiveness results within the lower half of the social cost of methane range and that all produce cost-effectiveness results below EPA's $1,800 cost-effectiveness benchmark. See Tables ES-1 to ES-5.

[4] In comparing abatement costs, solar/storage systems at small production, transmission and storage sites result in more cost-effective methane abatement than sites with access to grid electricity. This is because EPA's estimates of capital costs for connecting electronic controllers and pumps to the grid (including equipment, engineering, and installation costs) are more than the equivalent costs to set up a solar/storage system to power the devices.

cost-effective approaches to reducing methane emissions at such locations. This is true when a grid connection exists on site, when a service line is required, and when the site is off-grid and requires the installation of solar and storage technologies.

Table ES-1
Cost Effectiveness for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Production Sites (Without Savings)

Scenario	Cost Effectiveness ($/ton of Methane)		
Model Plant Size	**Small**	**Medium**	**Large**
Grid Electricity, Existing Service (Electronic Devices)			
South	$451	$412	N/A
Rocky Mountains	$451	$412	N/A
Mid-West / Mid-Atlantic	$451	$412	N/A
Alaska	$452	$413	N/A
Grid Electricity, Existing Service (Instrument Air Devices)			
South	N/A	N/A	$601
Rocky Mountains	N/A	N/A	$603
Mid-West / Mid-Atlantic	N/A	N/A	$606
Alaska	N/A	N/A	$675
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)			
South	$890	$665	N/A
Rocky Mountains	$890	$665	N/A
Mid-West / Mid-Atlantic	$890	$665	N/A
Alaska	$891	$666	N/A
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)			
South	N/A	N/A	$725
Rocky Mountains	N/A	N/A	$727
Mid-West / Mid-Atlantic	N/A	N/A	$730
Alaska	N/A	N/A	$799
Off-Grid (Solar-Powered Devices)			
South	$438	$420	N/A
Rocky Mountains	$436	$419	N/A
Mid-West / Mid-Atlantic	$444	$425	N/A
Alaska	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Methane reductions for each scenario are based off EPA emission reduction estimates from the Technical Support Document (TSD).

[3] Costs for electronic devices include initial capital expenditures for the equipment, the engineering and installation costs, and the operating costs for electrical energy. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to determine total costs.

[4] Costs for instrument air devices include initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to determine total costs.

[5] Costs for off-grid solar powered devices include initial capital expenditures for the controller/pump equipment and the engineering and installation costs, which are all based off EPA cost estimates (TSD) and assumed to be the same for each region. The regional levelized costs of solar plus storage from Table 1 are added to determine total costs.

[6] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table ES-2
Cost Effectiveness for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Production Sites (With Savings)

Scenario	Cost Effectiveness ($/ton of Methane)		
Model Plant Size	**Small**	**Medium**	**Large**
Grid Electricity, Existing Service (Electronic Devices)			
South	$269	$231	N/A
Rocky Mountains	$269	$231	N/A
Mid-West / Mid-Atlantic	$269	$231	N/A
Alaska	$270	$232	N/A
Grid Electricity, Existing Service (Instrument Air Devices)			
South	N/A	N/A	$421
Rocky Mountains	N/A	N/A	$423
Mid-West / Mid-Atlantic	N/A	N/A	$426
Alaska	N/A	N/A	$495
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)			
South	$709	$484	N/A
Rocky Mountains	$709	$484	N/A
Mid-West / Mid-Atlantic	$709	$484	N/A
Alaska	$710	$485	N/A
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)			
South	N/A	N/A	$545
Rocky Mountains	N/A	N/A	$547
Mid-West / Mid-Atlantic	N/A	N/A	$550
Alaska	N/A	N/A	$619
Off-Grid (Solar-Powered Devices)			
South	$256	$239	N/A
Rocky Mountains	$255	$238	N/A
Mid-West / Mid-Atlantic	$262	$244	N/A
Alaska	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Methane reductions for each scenario are based off EPA emission reduction estimates from the Technical Support Document (TSD).

[3] Costs for electronic devices include a natural gas savings of $3.13 per Mcf, initial capital expenditures for the equipment, the engineering and installation costs, and the operating costs for electrical energy. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to determine total costs.

[4] Costs for instrument air devices include a natural gas savings of $3.13 per Mcf, initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to determine total costs.

[5] Costs for off-grid solar powered devices include a natural gas savings of $3.13 per Mcf. initial capital expenditures for the controller/pump equipment and the engineering and installation costs, which are all based off EPA cost estimates (TSD) and assumed to be the same for each region. The regional levelized costs of solar plus storage from Table 1 are added to determine total costs.

[6] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table ES-3
Cost Effectiveness for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Transmission and Storage Sites (Without Savings)

Scenario	Cost Effectiveness ($/ton of Methane)		
Model Plant Size	**Small**	**Medium**	**Large**
Grid Electricity, Existing Service (Electronic Devices)			
South	$565	$710	N/A
Rocky Mountains	$566	$710	N/A
Mid-West / Mid-Atlantic	$566	$710	N/A
Alaska	$567	$712	N/A
Grid Electricity, Existing Service (Instrument Air Devices)			
South	N/A	N/A	$1,304
Rocky Mountains	N/A	N/A	$1,318
Mid-West / Mid-Atlantic	N/A	N/A	$1,318
Alaska	N/A	N/A	$1,501
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)			
South	$1,117	$1,147	N/A
Rocky Mountains	$1,117	$1,147	N/A
Mid-West / Mid-Atlantic	$1,117	$1,147	N/A
Alaska	$1,119	$1,148	N/A
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)			
South	N/A	N/A	$1,584
Rocky Mountains	N/A	N/A	$1,597
Mid-West / Mid-Atlantic	N/A	N/A	$1,598
Alaska	N/A	N/A	$1,781
Off-Grid (Solar-Powered Devices)			
South	$549	$725	N/A
Rocky Mountains	$548	$723	N/A
Mid-West / Mid-Atlantic	$557	$734	N/A
Alaska	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Methane reductions for each scenario are based off EPA emission reduction estimates from the Technical Support Document (TSD).

[3] Costs for electronic devices include initial capital expenditures for the equipment, the engineering and installation costs, and the operating costs for electrical energy. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 2 are added to determine total costs.

[4] Costs for instrument air devices include initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 2 are added to determine total costs.

[5] Costs for off-grid solar powered devices include initial capital expenditures for the controller/pump equipment and the engineering and installation costs, which are all based off EPA cost estimates (TSD) and assumed to be the same for each region. The regional levelized costs of solar plus storage from Table 2 are added to determine total costs.

[6] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table ES-4
Cost Effectiveness for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Natural Gas Processing Plants (Without Savings)

Scenario	Cost Effectiveness ($/ton of Methane)		
Model Plant Size	**Small**	**Medium**	**Large**
Grid Electricity, Existing Service (Instrument Air Devices)			
South	$911	$633	$456
Rocky Mountains	$921	$637	$459
Mid-West / Mid-Atlantic	$921	$637	$459
Alaska	$1,049	$699	$506
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)			
South	$1,108	$684	$475
Rocky Mountains	$1,117	$689	$478
Mid-West / Mid-Atlantic	$1,118	$689	$478
Alaska	$1,246	$750	$525

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Methane reductions for each scenario are based off EPA emission reduction estimates from the Technical Support Document (TSD).

[3] Costs for instrument air devices include initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 3 are added to determine total costs.

[4] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table ES-5
Cost Effectiveness for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Natural Gas Processing Plants (With Savings)

Scenario	Cost Effectiveness ($/ton of Methane)		
Model Plant Size	**Small**	**Medium**	**Large**
Grid Electricity, Existing Service (Instrument Air Devices)			
South	$750	$457	$276
Rocky Mountains	$760	$461	$280
Mid-West / Mid-Atlantic	$760	$461	$280
Alaska	$888	$523	$326
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)			
South	$947	$508	$295
Rocky Mountains	$956	$512	$298
Mid-West / Mid-Atlantic	$957	$512	$299
Alaska	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Methane reductions for each scenario are based off EPA emission reduction estimates from the Technical Support Document (TSD).

[3] Costs for instrument air devices include a natural gas savings of $3.13 per Mcf, initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 3 are added to determine total costs.

[4] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

II. Introduction

In November 2021, EPA proposed new regulations to implement new source performance standards and emissions guidelines for existing sources to significantly reduce methane emissions in the exploration, production, processing and transport of oil and natural gas. EPA's proposed rule, when finalized and implemented, will achieve major reductions in methane and other harmful air pollution from both new and existing oil and natural gas sources. The rule would enhance emissions reduction requirements that are in place for some sources and would require that states implement regulations to achieve reductions from a wide array of previously unregulated sources.

In this report, we focus on one of the categories proposed in the EPA rule - zero-emitting pneumatic technologies. EPA provides a full assessment of the costs, emission reduction potential, and benefits of requiring zero-emission technologies at oil and natural gas production, processing, transmission and storage sites, including the cost of systems using solar power. These zero-emission technologies require electricity for operation, and the method of supplying electricity and cost of electricity can vary significantly from site to site. Variations in electricity consumption and cost depend on, for example, how many wells are in nearby operation in an area, whether the location has an existing connection to the local electric distribution system, whether it is reasonably close to the distribution system, or whether the site is fully remote.

The purpose of the analysis is to test the feasibility and estimate the cost of providing electricity for zero-emitting technologies in various locations of oil and natural gas facilities around the country that may be subject to EPA's proposed rules. To do this, we estimate the potential range of electricity costs associated with operating zero-emitting pneumatics in grid-connected, grid-proximate, and remote locations. We first describe the scenarios analyzed, and the analytic method for estimating annual electricity costs under each scenario. Next, we present the results, and provide observations based on the analysis relevant to EPA's ongoing consideration of these technologies.

III.Analytic Method and Scenarios Analyzed

Our analysis seeks to answer the following question relevant to EPA's consideration of methane emission reduction technologies at oil and natural gas sites: What would be the electricity and abatement cost to operate zero-emission pneumatic technologies (pumps and controllers) at well locations covered by EPA's proposed rule?

We develop our estimates of the added electricity cost and abatement cost for zero-emission technologies at oil and natural gas locations as a function of (a) three different technologies[5], (b) four regions, (c) three model plant sizes (for oil and natural gas production and transmission/storage, and separately for natural gas processing) [6], (d) three electricity connection scenarios, (e) emission reductions, and (f) natural gas savings assumptions.

In the following section, the first subsection discusses the general inputs used for each interconnection scenario, and the second subsection explains methodological considerations and data sources used uniquely for each interconnection scenario.

General Scenario Inputs and Technology Types

The key inputs to our analysis used for each interconnection scenario consider the nature and quantity of electricity required to operate the technologies needed at each well site. These inputs vary by technology (instrument air devices, grid-powered electronic devices, or solar-powered electronic devices), by the plant size and/or number of facilities, by the type of facility, and by location. In our analysis, we separately review electricity demand and cost for each technology. Cost-effectiveness also depends on emissions reductions and natural gas savings, which are based on EPA's assumptions for each type of site.

The following subsections review the methodology and sources for each input.

(a) Electricity Demand by Technology

Annual electricity demand for electronic controllers/pumps and instrument air controllers/pumps is based on the November 2021 Carbon Limits Report on costs for zero-emitting pneumatic devices.[7] Electricity demand for grid-

[5] The three technologies considered are grid-powered electronic devices, solar-powered electronic devices, and instrument air devices. Where pneumatic devices send a pneumatic signal to a pneumatic actuator or positioner, electronic devices (grid-powered and solar-powered) adjust the position of the end-device by sending an electric signal to an electric actuator or positioner. Instrument air devices use compressed air as an energy source and signaling mechanism. All three technologies do not require the use of natural gas. Each technology is considered in each region except for solar in Alaska due to uncertainty over solar output and battery capacity during the Arctic winter.

[6] The Appendix includes additional sensitivity scenarios for an extra-large plant size, which includes 100 continuous bleed controllers, 100 intermittent vent controllers, and 1 pneumatic pump. The annual grid electricity needed to power the electronic controllers and pump at an extra-large plant is less than 2 MWh (and much lower for the EPA model plant sizes).

[7] Note that this data is referenced as the primary source for cost estimates in EPA's Technical Support Document . See the full report at Zero emission technologies for pneumatic controllers in the USA: Updated applicability and cost effectiveness, November 2021, available at https://www.catf.us/resource/zero-emission-technologies-for-pneumatic-controllers-usa/.

connected electronic devices is calculated using amps per device, system voltage, and hours in a year. Electricity demand for instrument air devices is calculated by translating the amount of compressed air needed to power the device into a quantity of electricity assuming operation every hour of the year. This electricity need is supplied by either a grid connection or on-site solar panels.

(b) Location

The cost of electricity can vary meaningfully as a function not only of whether or not the site has an existing grid connection, but also as a function of location. For example, the cost of grid-based electricity in Texas is very different from the cost of grid-based electricity in Pennsylvania; and the productivity (and thus levelized cost of electricity) of solar panels is different in Montana than it is in Louisiana. In this analysis, we broadly group well locations into four separate regions, and use averages of electricity prices and/or solar levelized costs of electricity within each region to develop cost estimates:[8]

- South: Alabama, Texas, Louisiana, Arkansas, Kansas, Mississippi, New Mexico, and Oklahoma;
- Rocky Mountains: North Dakota, Colorado, Wyoming, Utah, and Montana;
- Mid-West / Mid-Atlantic: Ohio, West Virginia, Pennsylvania, and Michigan; and
- Alaska.

(c) Plant Size & Facility Types

In order to keep the number of scenarios manageable, we need to create categories that describe the number of controllers and type of zero-emitting technologies at each site. For consistency and simplicity, we adopt EPA's method on model plant sizes and also consider an additional extra-large plant size for production and transmission/storage sites in the Appendix. While there could be specific variations across the full universe of oil and natural gas sites across the country, these categories should capture the full range of possible electricity costs and have the benefit of generating results that can be consistently interpreted within EPA's other estimates of benefits and costs.[9] EPA doesn't specify the number of pneumatic pumps at a model plant, so our analysis

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[8] Our model is able to estimate costs on a state-by-state basis. However, given rough similarities in cost results across neighboring states, the geographic groupings used in this report provide close approximations to the costs within each state inside of a given region.

[9] EPA notes, "While individual natural gas-driven pneumatic controllers can be switched to other types of natural-gas driven pneumatic controllers (e.g., high bleed to low bleed types), the implementation of some options requires equipment that is used for all the controllers at the site. For example, in order to utilize instrument air driven controllers, a compressor and related equipment would need to be installed. The EPA does not believe that a compressor would be installed for a single controller, but rather to provide compressed air to all the controllers at the site. Therefore, to adequately account for the costs of the system, including the controllers and the common equipment, we developed "model" plants. The model plants were developed based on information reported in several studies suggesting that most well sites have less than 10 pneumatic controllers (45-50 percent have 1-3 pneumatic controllers, 35-45 percent have 4-10 pneumatic controllers, 7-10 percent have 11-20 PCs, < 10 percent have 20+." See Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Review, Background Technical Support Document, EPA, October 2021, pp. 8-8 and 8-9, available at https://www.regulations.gov/document/EPA-HQ-OAR-2021-0317-0166.

assumes 1 pneumatic pump at each site based on further review of the literature. Specifically, we model the following plant categories for production and transmission/storage sites:

- Small: 2 continuous bleed controllers, 2 intermittent vent controllers, 1 pneumatic pump;
- Medium: 2 continuous bleed controllers, 6 intermittent vent controllers, 1 pneumatic pump; and
- Large: 5 continuous bleed controllers, 15 intermittent vent controllers, 1 pneumatic pump.
- Extra-Large: 100 continuous bleed controllers, 100 intermittent vent controllers, 1 pneumatic pump.

For natural gas processing sites, the following model plants are used:

- Small: 7 continuous bleed controllers, 8 intermittent vent controllers, 1 pneumatic pump;
- Medium: 31 continuous bleed controllers, 32 intermittent vent controllers, 1 pneumatic pump; and
- Large: 87 continuous bleed controllers, 88 intermittent vent controllers, 1 pneumatic pump.

We also present results to align with EPA's guidance on the technologies they evaluated at each type of facility (production, transmission and storage, and natural gas processing) and model plant size (small, medium, and large). The electricity demand for, and electricity cost of, instrument air controllers is significantly higher and, as noted by EPA, would likely be used only in larger facilities.[10] For small and medium production, transmission, and storage facilities, we present costs for grid-powered and solar-powered electronic controllers and pumps. For large production, transmission and storage, and all natural gas processing facilities, we present costs for instrument air powered electronic controllers and pumps. In the Appendix, we present additional results for all technologies at each type of facility and model plant size (including extra-large plants for production and transmission/storage sites.)

(d) Emissions

The cost-effectiveness of each emission control technology is partly based on total costs and associated emission reductions. We present our results to align with EPA's methodology on calculating the emission reductions that would occur from replacing gas-powered pneumatic devices with zero-emitting pneumatic devices. Specifically, EPA estimates current methane emissions at production, transmission and storage, and natural gas processing facilities for different model plant sizes (small, medium, and large).[11] Methane reduction estimates for each type of facility, emission reduction technology, and model plant size are presented in the Appendix.

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[10] Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Review, Background Technical Support Document, EPA, October 2021, pp. 8-8 and 8-9, available at https://www.regulations.gov/document/EPA-HQ-OAR-2021-0317-0166.

[11] See Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Review, Background Technical Support Document, EPA, October 2021, pp. 8-8, 8-9, and 9-8.

(e) Natural Gas Savings Assumptions

The cost-effectiveness of each emission control technology is also based on assumptions surrounding the total cost of natural gas savings. We present our cost-effectiveness results with and without natural gas savings for production and natural gas processing facilities to align with EPA's methodology. For transmission and storage facilities, EPA assumes the facilities do not own the natural gas so revenues from decreasing the amount of natural gas emitted were not considered. The Appendix also presents additional results for total annualized costs including natural gas savings for production and natural gas processing facilities. EPA assumes that natural gas savings are $3.13 per Mcf, which reflects the forecasted Henry Hub price for 2022.

Unique Methods and Data Sources for Each Interconnection Scenario

There is a great diversity of oil and natural gas facility types, technologies, locations, and sizes across the country. The sheer number of sites is enormous, ruling out a specific site-by-site analysis of current or potential electricity demand or cost. Moreover, it is not easy to identify exactly which locations are connected to the electric grid or not. Nevertheless, it is possible to estimate the cost of electricity to operate these technologies as a function of their interconnection status. That is, we bucket expected electricity and abatement costs as a function of three different circumstances for locations across the country:

- Grid Electricity: Locations that have electricity supply on-site;
- Service Extension: Locations that do not have electricity supply on-site, but are located close enough to the local electric distribution system to consider developing a line extension from the closest spot on the grid; and
- Off-Grid: Locations that are clearly too far away from the electric distribution system to consider a line extension, and thus must rely on off-the-grid technologies (in this case, a combination of solar and storage).

We estimate an annualized cost of electricity for each of the scenarios defined by category selections above (e.g., pneumatic controller at a small model plant, and connected to the grid in the South Region). Data for the analysis are all from public sources, including the U.S. Energy Information Administration (EIA), National Renewable Energy Lab (NREL), Bureau of Labor Statistics (BLS), Lawrence Berkeley Lab (LBL), Edison Electric Institute (EEI), Lazard, and Carbon Limits. Here, we provide a high-level summary of the analytic approach and data sources. The Appendix includes additional tables to illustrate the differences between our analysis and EPA's cost-effectiveness calculations.

Grid-Connected Sites

For locations with an existing connection to the electric grid, we estimate the cost of delivered electricity as the average of state prices for electricity to ultimate customers from EIA.[12] For production sites, the average prices for the commercial sector are applied. For storage and transmission sites and natural gas processing plants, the average prices for the industrial sector are applied. To estimate the cost of delivered electricity for each grouped geographic region, we use the average of the delivered electricity across all states, weighted by each state's consumption. The regional cost of delivered electricity ($/kWh) is then multiplied by the electricity demand by technology type (kWh) from the Carbon Limits Report to estimate the total electricity cost for locations with an existing grid connection.[13]

Service Extension Sites

For locations proximate to the electric distribution system (but not connected to it), we estimate an *additional* cost (on top of the cost of delivered electricity) to fund a line extension, which can vary by the assumed distance between the grid and the well location. In the results below we assume a distance of 0.5 miles.[14] Initial line extension capital costs are from EEI, assuming the distribution lines are overhead and in rural areas.[15] Total capital cost is then translated to an annualized cost per mile using typical utility assumptions for depreciation period and cost of capital.[16]

Off-Grid (Solar)

For off-grid locations, we assume the combination of solar photovoltaic and energy storage capacity. As described below, the analysis considers the oversizing of the solar array and battery storage necessary to ensure sufficient

[12] Table 5.6.A. Average Price of Electricity to Ultimate Customers by End-Use Sector (October 2021 and 2020), EIA Electric Power Monthly, available at https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a. The underlying source of this table is Form EIA-861M (formerly EIA-826).

[13] Zero Emission Technologies for Pneumatic Controllers in the USA: Updated Applicability and Cost Effectiveness, November 2021, Carbon Limits (Carbon Limits Report).

[14] Our model allows estimates to vary by distance from the electric grid. We include only a representative distance for comparison in this report, since the additional cost of a distribution service extension becomes uneconomic (compared to on-site distributed generation) at relatively short distances.

[15] Distribution line capital costs are estimated based on averages of a utility's typical construction approach.[15] There are many different variables to contend with including customer density, soil conditions (sandy to rocky), labor costs, construction techniques, vegetation, and voltage levels. Customer density is defined as urban (150+ customers per square mile), suburban (51 to 149 customers per square mile), or rural (50 or fewer customers per square mile). The analysis assumes an initial capital cost of $86,700 per mile ($2012), which is escalated to $100,000 per mile ($2021) using an average inflation rate from the Bureau of Labor Statistics. Initial capital cost estimate available at Out of Sight Out of Mind 2012, Electric Edison Institute, available at https://www.eei.org/issuesandpolicy/electricreliability/undergrounding/documents/undergroundreport.pdf.

[16] Distribution line service life from USAID, Depreciation Expense: A Primer for Utility Regulators, p. 46, available at https://pubs.naruc.org/pub.cfm?id=6ADEB9EF-1866-DAAC-99FB-DBB28B7DF4FB. WACC from EPA, Utility Financial Assumptions, p. 10-6, available at https://www.epa.gov/sites/default/files/2019-03/documents/chapter_10.pdf.

generation to power the controllers. The annual solar generation needed to power the battery and electronic devices follows the approach used in the November 2021 Carbon Limits Report.[17] Specifically, the daily load is calculated based on total amps and system voltage required for the number of controllers and pumps in each model plant scenario. The size of the photovoltaic array is then calculated based on daily load, average battery efficiency, average hours of peak sun per day, and required oversizing of the solar panel. The required battery bank and daily solar generation is then calculated assuming 10 days of energy storage at a maximum depth of discharge of 80%. The annual solar generation (kWh) is then combined with a levelized cost of solar and storage ($/kWh), independently calculated by Analysis Group, to estimate annual cost for the off-grid technology. A baseline estimate of the levelized cost of electricity (LCOE) is developed for the combined solar/storage system using NREL and Lazard estimates for a 0.5 MW / 2 MWh battery paired with 1 MW of Solar Photovoltaic for a commercial/industrial location in California. The LCOE cost components include capital ($259/MWh), charging ($0/MWh), O&M ($50/MWh), taxes ($11/MWh), and other ($14/MWh).[18] NREL estimates that a 1 MW PV and 600 kW battery storage AC-coupled system includes similar capital costs for the PV array and battery system.[19] The regional LCOE estimates are derived by adjusting the baseline cost estimate for differences in solar capacity factors relative to those built into the baseline estimate. For example, the Mid-West / Mid-Atlantic region has a weighted-average capacity factor of 18.7% while California has an average capacity factor of 28.5%.[20] A solar capacity factor is the average hourly solar output relative to full capacity output. Therefore, solar in the Mid-West / Mid-Atlantic region generates less electricity than California on average. The baseline solar capital component is adjusted upwards based on this difference, and this approach is used to estimate regionally specific LCOEs for the combined solar/storage technologies.

[17] Zero Emission Technologies for Pneumatic Controllers in the USA: Updated Applicability and Cost Effectiveness, November 2021, Carbon Limits.

[18] Lazard's Levelized Cost of Storage Analysis Version 7.0, Lazard, pp. 15, 21, available at https://www.lazard.com/media/451882/lazards-levelized-cost-of-storage-version-70-vf.pdf.

[19] Commercial Battery Storage, NREL, available at https://atb.nrel.gov/electricity/2021/commercial_battery_storage.

[20] PV Capacity Factors, LBNL, available at https://emp.lbl.gov/pv-capacity-factors. Regional weighted-average capacity factors are weighted by state-level oil and gas consumption using a similar methodology to our regional electricity prices.

IV. Results and Observations

This report provides estimates of the overall cost, abatement cost, and cost of electricity required to operate certain zero-emission technologies at oil and natural gas locations across the U.S. The analytic method and model can generate state-specific results where needed; however, for the purpose of our analysis we grouped states into broad categories roughly approximating the major producing regions, and averaged results across those regions. The results are presented for three different scenarios that vary by the proximity of facility locations to electricity supply, and for different assumed sizes/groupings of oil and natural gas production, transmission and storage, and natural gas processing sites consistent with EPA's model plant methodology. Our observations are presented in 11 tables:

- Tables 1-3: Annualized electricity costs;
- Tables 4-6: Total costs (without natural gas savings);
- Tables 7-9: Abatement costs (without natural gas savings); and
- Tables 10-11: Abatement costs (with natural gas savings).

The results for annualized electricity costs vary significantly across the different technology, geography, and electricity connection scenarios evaluated.

For production sites, as Table 1 demonstrates, the total annualized electricity cost to use zero-emission pneumatic devices varies between $7 and $7,144 per year, with costs increasing by size (small to large model plants), increasing as you go from regions with lower delivered electricity prices to those with higher delivered electricity prices, increasing as you move from grid-supplied electricity to remote, off-grid sources, and increasing to the extent construction of service extensions from the grid is required. For transmission and storage sites, the total annualized electricity cost to use zero-emission pneumatic devices varies between $5 and $6,890. For natural gas processing plants, the total annualized electricity cost to use zero-emission pneumatic devices varies between $1,214 and $16,758. Specific total annualized electricity costs for each scenario can be found in Tables 1-3.

Table 1
Electricity Costs for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Production Sites

Scenario	Total Annualized Electricity Cost (2021$)			Individual Pump Electricity Cost
Model Plant Size	Small	Medium	Large	
Grid Electricity, Existing Service (Electronic Devices)				
South	$7	$10	N/A	$4
Rocky Mountains	$7	$11	N/A	$4
Mid-West / Mid-Atlantic	$8	$11	N/A	$4
Alaska	$15	$22	N/A	$8
Grid Electricity, Existing Service (Instrument Air Devices)				
South	N/A	N/A	$1,837	$161
Rocky Mountains	N/A	N/A	$1,885	$165
Mid-West / Mid-Atlantic	N/A	N/A	$1,964	$172
Alaska	N/A	N/A	$3,817	$334
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)				
South	$3,334	$3,338	N/A	$4
Rocky Mountains	$3,335	$3,338	N/A	$4
Mid-West / Mid-Atlantic	$3,335	$3,338	N/A	$4
Alaska	$3,342	$3,349	N/A	$8
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)				
South	N/A	N/A	$5,164	$161
Rocky Mountains	N/A	N/A	$5,212	$165
Mid-West / Mid-Atlantic	N/A	N/A	$5,291	$172
Alaska	N/A	N/A	$7,144	$334
Off-Grid (Solar-Powered Devices)				
South	$334	$482	N/A	$186
Rocky Mountains	$324	$468	N/A	$180
Mid-West / Mid-Atlantic	$380	$550	N/A	$211
Alaska	N/A	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Electricity costs include costs for purchasing electricity if the site is grid-connected. If the site is not connected to a grid but close to an existing service, electricity costs additionally include the capital costs for building the distribution line. For sites that are off-grid, electricity costs include the costs to build a distributed energy system on site.

[3] For scenarios that use instrument air devices, the capital costs of compressors are included in the Total Annualized Electricity Cost and spread across controllers and pumps.

[4] For the Grid Electricity, Service Extension scenarios, the distance of distribution line to be built is assumed to be 0.5 mile.

[5] The Off-Grid scenario assumes that commercial/industrial PV plus storage are used to supply the electricity needed for Pneumatic Devices.

Table 2
Electricity Costs for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Transmission and Storage Sites

Scenario	Total Annualized Electricity Cost (2021$)			Individual Pump Electricity Cost
Model Plant Size	Small	Medium	Large	
Grid Electricity, Existing Service (Electronic Devices)				
South	$5	$7	N/A	$3
Rocky Mountains	$5	$8	N/A	$3
Mid-West / Mid-Atlantic	$5	$8	N/A	$3
Alaska	$14	$20	N/A	$8
Grid Electricity, Existing Service (Instrument Air Devices)				
South	N/A	N/A	$1,219	$107
Rocky Mountains	N/A	N/A	$1,378	$121
Mid-West / Mid-Atlantic	N/A	N/A	$1,385	$121
Alaska	N/A	N/A	$3,563	$312
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)				
South	$3,332	$3,334	N/A	$3
Rocky Mountains	$3,333	$3,335	N/A	$3
Mid-West / Mid-Atlantic	$3,333	$3,335	N/A	$3
Alaska	$3,341	$3,347	N/A	$8
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)				
South	N/A	N/A	$4,546	$107
Rocky Mountains	N/A	N/A	$4,705	$121
Mid-West / Mid-Atlantic	N/A	N/A	$4,713	$121
Alaska	N/A	N/A	$6,890	$312
Off-Grid (Solar-Powered Devices)				
South	$334	$482	N/A	$186
Rocky Mountains	$324	$468	N/A	$180
Mid-West / Mid-Atlantic	$380	$550	N/A	$211
Alaska	N/A	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Electricity costs include costs for purchasing electricity if the site is grid-connected. If the site is not connected to a grid but close to an existing service, electricity costs additionally include the capital costs for building the distribution line. For sites that are off-grid, electricity costs include the costs to build a distributed energy system on site.

[3] For scenarios that use instrument air devices, the capital costs of compressors are included in the Total Annualized Electricity Cost and spread across controllers and pumps.

[4] For the Grid Electricity, Service Extension scenarios, the distance of distribution line to be built is assumed to be 0.5 mile.

[5] The Off-Grid scenario assumes that commercial/industrial PV plus storage are used to supply the electricity needed for Pneumatic Devices.

Table 3
Electricity Costs for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Natural Gas Processing Plants

Scenario	Total Annualized Electricity Cost (2021$)			Individual Pump Electricity Cost
Model Plant Size	Small	Medium	Large	
Grid Electricity, Existing Service (Instrument Air Devices)				
South	$1,214	$2,229	$4,596	$37
Rocky Mountains	$1,372	$2,518	$5,193	$42
Mid-West / Mid-Atlantic	$1,380	$2,532	$5,222	$42
Alaska	$3,549	$6,513	$13,431	$108
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)				
South	$4,541	$5,556	$7,923	$37
Rocky Mountains	$4,699	$5,845	$8,520	$42
Mid-West / Mid-Atlantic	$4,707	$5,860	$8,549	$42
Alaska	$6,876	$9,840	$16,758	$108

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Electricity costs include costs for purchasing electricity if the site is grid-connected. If the site is not connected to a grid but close to an existing service, electricity costs additionally include the capital costs for building the distribution line. For sites that are off-grid, electricity costs include the costs to build a distributed energy system on site.

[3] For scenarios that use instrument air devices, the capital costs of compressors are included in the Total Annualized Electricity Cost and spread across controllers and pumps.

[4] For the Grid Electricity, Service Extension scenarios, the distance of distribution line to be built is assumed to be 0.5 mile.

The annual electricity cost to use zero-emission electronic controllers and pumps at production, transmission and storage sites that already have electricity service varies between $5 and $22 per year, with costs increasing by size (small to medium model plants) and increasing as you go from regions with lower delivered electricity prices to those with higher delivered electricity prices. These costs increase in price in off-grid locations due to the capital costs associated with installation of solar and battery storage technologies of sufficient size to meet the electricity demand requirements. Specifically, the costs range from $324 per year to roughly $550 dollars per year for the solar/storage solutions. Nevertheless, because the electricity *demand* is so low, the size of the installations required keeps the overall cost low, and still far below the social cost of methane (SC-CH_4).

Instrument air devices, generally used only at larger facilities with access to electricity, have considerably larger electricity demand requirements.[21] Consequently, the electricity costs associated with these devices is far greater than for electronic controllers/pumps. For production, transmission, and storage sites that already have electricity access, instrument air electricity costs vary from $1,219 for a large transmission and storage site in the south to $3,817 for a large production site in Alaska. For natural gas processing plants, instrument air electricity costs vary from $1,214 for a small model plant in the south to $13,431 for a large model plant in Alaska.

As noted, we also evaluated the annual cost of electricity for a site that is proximate to the electric grid, but currently has no electric service on site. The cost components for this category would include the delivered price of electricity, plus the annualized cost of completing a service extension from the electric grid to the well site. In Tables 1-3 we provide estimates of this for a service extension of just one-half mile. Under this scenario, the electricity cost is dominated by the annualized costs of construction of the service extension, which adds over $3,300 in annualized costs on top of delivered electricity price costs.

The focus of the report is on the different ways to supply electricity for zero-emitting technologies studied by EPA for eliminating methane leaks from oil and natural gas facilities across the U.S. These electricity costs are additive to the estimates developed by EPA for the installation, operation and maintenance of the devices themselves. Tables 4-6 present the total annualized costs for our model plants, including our electricity cost estimates, Carbon Limits' net maintenance costs[22] and EPA's device cost estimates without the natural gas savings.[23]

[21] EPA notes instrument air systems are generally installed at larger facilities with a high concentration of control valves where an operator is usually present to ensure the system is properly operating.

[22] Zero Emission Technologies for Pneumatic Controllers in the USA: Updated Applicability and Cost Effectiveness, November 2021, Carbon Limits. Also see the accompanying Abatement Cost Tool for the Carbon Limits report. Analysis Group's net maintenance costs include maintenance costs for zero-emission devices and subtract the maintenance costs of gas-driven controllers.

[23] The Appendix presents additional results for total annualized costs including natural gas savings. EPA assumes that natural gas savings are $3.13 per Mcf, which reflects the forecasted Henry Hub price for 2022. See Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Review, Background Technical Support Document, EPA, October 2021, p. 11-14.

As a final step, we calculate the new methane emission reduction cost effectiveness estimates inclusive of electricity costs and emissions reductions. Tables 7-11 provide results with and without natural gas savings.

Table 4
Total Costs for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Production Sites (Without Savings)

Scenario	Total Annualized Costs (2021$)		
Model Plant Size	**Small**	**Medium**	**Large**
Grid Electricity, Existing Service (Electronic Devices)			
South	$3,412	$5,414	N/A
Rocky Mountains	$3,412	$5,415	N/A
Mid-West / Mid-Atlantic	$3,413	$5,415	N/A
Alaska	$3,420	$5,426	N/A
Grid Electricity, Existing Service (Instrument Air Devices)			
South	N/A	N/A	$16,125
Rocky Mountains	N/A	N/A	$16,174
Mid-West / Mid-Atlantic	N/A	N/A	$16,252
Alaska	N/A	N/A	$18,105
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)			
South	$6,739	$8,742	N/A
Rocky Mountains	$6,740	$8,742	N/A
Mid-West / Mid-Atlantic	$6,740	$8,742	N/A
Alaska	$6,747	$8,753	N/A
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)			
South	N/A	N/A	$19,452
Rocky Mountains	N/A	N/A	$19,501
Mid-West / Mid-Atlantic	N/A	N/A	$19,580
Alaska	N/A	N/A	$21,432
Off-Grid (Solar-Powered Devices)			
South	$3,312	$5,523	N/A
Rocky Mountains	$3,302	$5,508	N/A
Mid-West / Mid-Atlantic	$3,359	$5,590	N/A
Alaska	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Costs for electronic devices include initial capital expenditures for the equipment, the engineering and installation costs, and the operating costs for electrical energy. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to determine total costs.

[3] Costs for instrument air devices include initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to determine total costs.

[4] Costs for off-grid solar powered devices include initial capital expenditures for the controller/pump equipment and the engineering and installation costs, which are all based off EPA cost estimates (TSD) and assumed to be the same for each region. The regional levelized costs of solar plus storage from Table 1 are added to determine total costs.

[5] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table 5
Total Costs for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Transmission and Storage Sites (Without Savings)

Scenario	Total Annualized Costs (2021$)		
Model Plant Size	Small	Medium	Large
Grid Electricity, Existing Service (Electronic Devices)			
South	$3,410	$5,411	N/A
Rocky Mountains	$3,410	$5,412	N/A
Mid-West / Mid-Atlantic	$3,410	$5,412	N/A
Alaska	$3,419	$5,424	N/A
Grid Electricity, Existing Service (Instrument Air Devices)			
South	N/A	N/A	$15,507
Rocky Mountains	N/A	N/A	$15,666
Mid-West / Mid-Atlantic	N/A	N/A	$15,674
Alaska	N/A	N/A	$17,851
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)			
South	$6,737	$8,738	N/A
Rocky Mountains	$6,738	$8,739	N/A
Mid-West / Mid-Atlantic	$6,738	$8,739	N/A
Alaska	$6,746	$8,751	N/A
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)			
South	N/A	N/A	$18,835
Rocky Mountains	N/A	N/A	$18,993
Mid-West / Mid-Atlantic	N/A	N/A	$19,001
Alaska	N/A	N/A	$21,178
Off-Grid (Solar-Powered Devices)			
South	$3,312	$5,523	N/A
Rocky Mountains	$3,302	$5,508	N/A
Mid-West / Mid-Atlantic	$3,359	$5,590	N/A
Alaska	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Costs for electronic devices include initial capital expenditures for the equipment, the engineering and installation costs, and the operating costs for electrical energy. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 2 are added to determine total costs.

[3] Costs for instrument air devices include initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 2 are added to determine total costs.

[4] Costs for off-grid solar powered devices include initial capital expenditures for the controller/pump equipment and the engineering and installation costs, which are all based off EPA cost estimates (TSD) and assumed to be the same for each region. The regional levelized costs of solar plus storage from Table 2 are added to determine total costs.

[5] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table 6
Total Costs for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Natural Gas Processing Plants (Without Savings)

Scenario	Total Annualized Costs (2021$)		
Model Plant Size	Small	Medium	Large
Grid Electricity, Existing Service (Instrument Air Devices)			
South	$15,421	$41,082	$80,645
Rocky Mountains	$15,579	$41,371	$81,242
Mid-West / Mid-Atlantic	$15,587	$41,386	$81,271
Alaska	$17,756	$45,366	$89,480
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)			
South	$18,749	$44,409	$83,972
Rocky Mountains	$18,906	$44,699	$84,569
Mid-West / Mid-Atlantic	$18,914	$44,713	$84,598
Alaska	$21,083	$48,694	$92,807

Notes:
[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Costs for instrument air devices include initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 3 are added to determine total costs.

[3] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table 7
Cost Effectiveness for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Production Sites (Without Savings)

Scenario	Cost Effectiveness ($/ton of Methane)		
Model Plant Size	**Small**	**Medium**	**Large**
Grid Electricity, Existing Service (Electronic Devices)			
South	$451	$412	N/A
Rocky Mountains	$451	$412	N/A
Mid-West / Mid-Atlantic	$451	$412	N/A
Alaska	$452	$413	N/A
Grid Electricity, Existing Service (Instrument Air Devices)			
South	N/A	N/A	$601
Rocky Mountains	N/A	N/A	$603
Mid-West / Mid-Atlantic	N/A	N/A	$606
Alaska	N/A	N/A	$675
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)			
South	$890	$665	N/A
Rocky Mountains	$890	$665	N/A
Mid-West / Mid-Atlantic	$890	$665	N/A
Alaska	$891	$666	N/A
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)			
South	N/A	N/A	$725
Rocky Mountains	N/A	N/A	$727
Mid-West / Mid-Atlantic	N/A	N/A	$730
Alaska	N/A	N/A	$799
Off-Grid (Solar-Powered Devices)			
South	$438	$420	N/A
Rocky Mountains	$436	$419	N/A
Mid-West / Mid-Atlantic	$444	$425	N/A
Alaska	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Methane reductions for each scenario are based off EPA emission reduction estimates from the Technical Support Document (TSD).

[3] Costs for electronic devices include initial capital expenditures for the equipment, the engineering and installation costs, and the operating costs for electrical energy. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to determine total costs.

[4] Costs for instrument air devices include initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to determine total costs.

[5] Costs for off-grid solar powered devices include initial capital expenditures for the controller/pump equipment and the engineering and installation costs, which are all based off EPA cost estimates (TSD) and assumed to be the same for each region. The regional levelized costs of solar plus storage from Table 1 are added to determine total costs.

[6] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table 8
Cost Effectiveness for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Transmission and Storage Sites (Without Savings)

Scenario	Cost Effectiveness ($/ton of Methane)		
Model Plant Size	**Small**	**Medium**	**Large**
Grid Electricity, Existing Service (Electronic Devices)			
South	$565	$710	N/A
Rocky Mountains	$566	$710	N/A
Mid-West / Mid-Atlantic	$566	$710	N/A
Alaska	$567	$712	N/A
Grid Electricity, Existing Service (Instrument Air Devices)			
South	N/A	N/A	$1,304
Rocky Mountains	N/A	N/A	$1,318
Mid-West / Mid-Atlantic	N/A	N/A	$1,318
Alaska	N/A	N/A	$1,501
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)			
South	$1,117	$1,147	N/A
Rocky Mountains	$1,117	$1,147	N/A
Mid-West / Mid-Atlantic	$1,117	$1,147	N/A
Alaska	$1,119	$1,148	N/A
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)			
South	N/A	N/A	$1,584
Rocky Mountains	N/A	N/A	$1,597
Mid-West / Mid-Atlantic	N/A	N/A	$1,598
Alaska	N/A	N/A	$1,781
Off-Grid (Solar-Powered Devices)			
South	$549	$725	N/A
Rocky Mountains	$548	$723	N/A
Mid-West / Mid-Atlantic	$557	$734	N/A
Alaska	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Methane reductions for each scenario are based off EPA emission reduction estimates from the Technical Support Document (TSD).

[3] Costs for electronic devices include initial capital expenditures for the equipment, the engineering and installation costs, and the operating costs for electrical energy. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 2 are added to determine total costs.

[4] Costs for instrument air devices include initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 2 are added to determine total costs.

[5] Costs for off-grid solar powered devices include initial capital expenditures for the controller/pump equipment and the engineering and installation costs, which are all based off EPA cost estimates (TSD) and assumed to be the same for each region. The regional levelized costs of solar plus storage from Table 2 are added to determine total costs.

[6] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table 9
Cost Effectiveness for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Natural Gas Processing Plants (Without Savings)

Scenario	Cost Effectiveness ($/ton of Methane)		
Model Plant Size	**Small**	**Medium**	**Large**
Grid Electricity, Existing Service (Instrument Air Devices)			
South	$911	$633	$456
Rocky Mountains	$921	$637	$459
Mid-West / Mid-Atlantic	$921	$637	$459
Alaska	$1,049	$699	$506
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)			
South	$1,108	$684	$475
Rocky Mountains	$1,117	$689	$478
Mid-West / Mid-Atlantic	$1,118	$689	$478
Alaska	$1,246	$750	$525

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Methane reductions for each scenario are based off EPA emission reduction estimates from the Technical Support Document (TSD).

[3] Costs for instrument air devices include initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 3 are added to determine total costs.

[4] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table 10
Cost Effectiveness for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Production Sites (With Savings)

Scenario	Cost Effectiveness ($/ton of Methane)		
Model Plant Size	**Small**	**Medium**	**Large**
Grid Electricity, Existing Service (Electronic Devices)			
South	$269	$231	N/A
Rocky Mountains	$269	$231	N/A
Mid-West / Mid-Atlantic	$269	$231	N/A
Alaska	$270	$232	N/A
Grid Electricity, Existing Service (Instrument Air Devices)			
South	N/A	N/A	$421
Rocky Mountains	N/A	N/A	$423
Mid-West / Mid-Atlantic	N/A	N/A	$426
Alaska	N/A	N/A	$495
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)			
South	$709	$484	N/A
Rocky Mountains	$709	$484	N/A
Mid-West / Mid-Atlantic	$709	$484	N/A
Alaska	$710	$485	N/A
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)			
South	N/A	N/A	$545
Rocky Mountains	N/A	N/A	$547
Mid-West / Mid-Atlantic	N/A	N/A	$550
Alaska	N/A	N/A	$619
Off-Grid (Solar-Powered Devices)			
South	$256	$239	N/A
Rocky Mountains	$255	$238	N/A
Mid-West / Mid-Atlantic	$262	$244	N/A
Alaska	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Methane reductions for each scenario are based off EPA emission reduction estimates from the Technical Support Document (TSD).

[3] Costs for electronic devices include a natural gas savings of $3.13 per Mcf, initial capital expenditures for the equipment, the engineering and installation costs, and the operating costs for electrical energy. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to determine total costs.

[4] Costs for instrument air devices include a natural gas savings of $3.13 per Mcf, initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to determine total costs.

[5] Costs for off-grid solar powered devices include a natural gas savings of $3.13 per Mcf. initial capital expenditures for the controller/pump equipment and the engineering and installation costs, which are all based off EPA cost estimates (TSD) and assumed to be the same for each region. The regional levelized costs of solar plus storage from Table 1 are added to determine total costs.

[6] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table 11
Cost Effectiveness for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Natural Gas Processing Plants (With Savings)

Scenario	Cost Effectiveness ($/ton of Methane)		
Model Plant Size	**Small**	**Medium**	**Large**
Grid Electricity, Existing Service (Instrument Air Devices)			
South	$750	$457	$276
Rocky Mountains	$760	$461	$280
Mid-West / Mid-Atlantic	$760	$461	$280
Alaska	$888	$523	$326
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)			
South	$947	$508	$295
Rocky Mountains	$956	$512	$298
Mid-West / Mid-Atlantic	$957	$512	$299
Alaska	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Methane reductions for each scenario are based off EPA emission reduction estimates from the Technical Support Document (TSD).

[3] Costs for instrument air devices include a natural gas savings of $3.13 per Mcf, initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 3 are added to determine total costs.

[4] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

There are several things to highlight with respect to electricity demand for zero-emission controllers and pumps, based on the analysis:

- The sources reviewed for this report demonstrate that zero-emission technologies for controlling methane emissions from pumps and controllers at oil and natural gas sites are available today, in circumstances where there is electricity already available on site, and where there is not.
- The electricity demand for pneumatic devices is low, meaning that the total incremental cost of electricity to use these devices at well sites is also low. The electricity demand for, and electricity cost of, instrument air controllers is significantly higher and, as noted by EPA, would likely be used only in larger facilities.[24]
- While there is significant range in the cost of achieving zero emissions, depending on location and degree of electricity service, the magnitude of annualized costs in every region and for nearly every technology studied are vastly exceeded by EPA's estimated net benefit of curtailing methane emissions at oil and natural gas sites, including production, transmission and storage, and natural gas processing facilities. In other words, in every region and for nearly every technology the cost of methane abatement (in dollars per ton) - including the cost of electricity - remains well below EPA's estimated benefits of reducing methane, in this case the social cost of methane (SC-CH_4).[25] When natural gas savings are accounted for at production and natural gas processing plants, the cost of methane abatement is even lower. See Tables 7-11. In particular:
    - In the case of production sites that have access to electricity, the abatement costs including our estimated cost of electricity range from $231 to $675 dollars per ton, compared to EPA's estimate of benefits of methane reduction of $1,361 per ton. Thus, the cost of device installation *plus* electricity use continues to result in cost effective methane abatement.
    - In the case of production sites that can build a distribution line to connect to the grid, the abatement costs including our estimated cost of electricity range from $484 to $891 dollars per ton, compared to EPA's estimate of benefits of methane reduction of $1,361 per ton. Thus, the

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[24] Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Review, Background Technical Support Document, EPA, October 2021, pp. 8-8 and 8-9, available at https://www.regulations.gov/document/EPA-HQ-OAR-2021-0317-0166.

[25] In the proposed rule, EPA presents a social cost of methane at $1,500 per metric ton of CH_4 ($1,361 per short ton), which is associated with the average social cost of methane at a 3% discount rate. EPA does not have a single central social cost of methane point estimate and emphasizes the importance and value in considering the benefits calculated using all four social cost of methane estimates (model average at 2.5%, 3%, and 5% discount rates; 95th percentile at 3% discount rate). Using the alternative estimates, the social cost of methane (per short ton) ranges from $608 to $3,538. EPA estimated the global social benefits of CH_4 emission reductions using the estimates presented in the Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under EO 13990 (IWG, 2021), available at https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf?source=email. In addition, EPA notes additional non-monetized climate and ozone health benefits from methane reduction not included in the social cost of methane estimates. Separately, EPA presents cost-effectiveness values of $1,800 to $2,185 per short ton of methane reduction to be reasonable for controls that are identified as BSER in the proposal. Cost-effectiveness refers to the annualized cost to implement an emission control option divided by the amount of annual emission reductions. This comparison is not intended to be a cost-benefit analysis, but rather a metric to compare the relative costs and emission impacts of various control options. See Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Review, Proposed Rules, EPA, November 2021, available at https://www.regulations.gov/document/EPA-HQ-OAR-2021-0317-0001.

cost of constructing a distribution line *plus* electricity use continues to result in cost effective methane abatement.

    - In the case of production sites that are remote, and must install solar/storage systems, the abatement costs including our estimated cost of electricity range from $238 to $444 dollars per ton, compared to EPA's estimate of methane reduction of $1,361 per ton. Thus, the cost of device installation *plus* investment in solar and storage on site continues to result in cost effective methane abatement. [26]

- In short, for the vast majority of oil and natural gas sites in the U.S., the cost of electricity to operate zero-emission pneumatic controllers and pumps should not be a deterrent to establishing these technologies as cost-effective approaches to reducing methane emissions at such locations. This is true when a grid connection exists on site, when a service line is required, and when the site is off-grid and requires the installation of solar and storage technologies.

[26] In comparing abatement costs, solar/storage systems at small production, transmission and storage sites result in more cost-effective methane abatement than sites with access to grid electricity. This is because EPA's estimates of capital costs for connecting electronic controllers and pumps to the grid (including equipment, engineering, and installation costs) are more than the equivalent costs to set up a solar/storage system to power the devices.

V. Appendix: Supplementary Tables

Table A1

Weighted Average Costs of Delivered Electricity for Industrial and Commercial Customers, 2021

Region	Industrial Customer ($/kWh)	Commercial Customer ($/kWh)
South	0.064	0.096
Rocky Mountains	0.072	0.098
Mid-West / Mid-Atlantic	0.072	0.102
Alaska	0.186	0.199

Notes:

[1] The Weighted Average Costs of Delivered Electricity for a region is calculated by weighting the state average electricity price to industrial or commercial customers within that region by electric consumption among industrial or commercial customers. The Average Costs of Delivered Electricity for a state is simply the state average electricity price without weighting.

[2] The state average electricity price to industrial or commercial consumers represents the cost per unit of electricity sold and is calculated by dividing electric revenue from ultimate industrial or commercial consumers by the corresponding sales of electricity. The electric revenue is the operating revenue reported by the electric power industry participant. Operating revenue includes energy charges, demand charges, consumer service charges, environmental surcharges, fuel adjustments, and other miscellaneous charges. Electric power industry participant operating revenues also include State and Federal income taxes and other taxes paid by the utility.

Sources:

[1] Table 5.6.A - Average Price of Electricity to Ultimate Customers by End-Use Sector by October 2021, EIA Electric Power Monthly, available at https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a.

[2] Table T5.c - Industrial Average Monthly Bill by Census Division, and State in 2020, EIA, released on October 7, 2021, available at https://www.eia.gov/electricity/sales_revenue_price/.

Table A2
Commercial and Industrial PV & Storage Levelized Cost

Region / State	Average Capacity Factor for Solar PV	LCOS Cost Components ($/MWh)						
		Capital (PV)	Capital (Battery)	Charging	Other	O&M	Taxes	Value
Lazard Base Case (CA)	28.5%	129.5	129.5	0	50	14	11	334
Region								
South	24.9%	148.51	129.50	0.00	50.00	14.00	11.00	353.01
Rocky Mountains	26.8%	137.68	129.50	0.00	50.00	14.00	11.00	342.18
Mid-West / Mid-Atlantic	18.7%	197.68	129.50	0.00	50.00	14.00	11.00	402.18

Notes:

[1] Base case is a 0.5 MW / 2 MWh Battery, paired with 1 MW of Solar PV for a commercial/industrial location in San Francisco, California. Average PV capacity factor is estimated for California. Capital cost component is assumed to be split 50-50 between PV array and battery based on NREL capital cost breakdown of PV plus storage system.

[2] The weighted average capacity factor for a region is calculated by weighting the state average capacity factor within that region by electric consumption among industrial customers. The Average Capacity Factor for a state is simply the state average capacity factor price without weighting.

[3] The capacity factor data is for 752 PV projects totaling 28,652 MW-AC, which represents 92% of all utility-scale PV capacity operating at the end of 2019 (CF data are not available yet for projects built in 2020). CF is based on AC capacity. State-average CF is weighted by AC capacity.

Sources:

[1] Lazard's Levelized Cost of Storage Analysis - Version 7.0, Lazard, October 28, 2021, available at https://www.lazard.com/media/451882/lazards-levelized-cost-of-storage-version-70-vf.pdf.

[2] Commercial Battery Storage, NREL Annual Technology Baseline, available at https://atb.nrel.gov/electricity/2021/commercial_battery_storage.

[3] PV Capacity Factors from Utility Scale Solar 2021 - Performance by State, Berkeley Lab, available at https://emp.lbl.gov/pv-capacity-factors.

[4] Table T5.c - Industrial Average Monthly Bill by Census Division, and State in 2020, EIA, released on October 7, 2021, available at https://www.eia.gov/electricity/sales_revenue_price/.

Table A3
Electricity Costs for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Production Sites

Scenario	Total Annualized Electricity Cost (2021$)				Individual Pump
Model Plant Size	Small	Medium	Large	Extra Large	Electricity Cost
Grid Electricity, Existing Service (Electronic Devices)					
South	$7	$10	$20	$165	$4
Rocky Mountains	$7	$11	$21	$169	$4
Mid-West / Mid-Atlantic	$8	$11	$22	$176	$4
Alaska	$15	$22	$42	$343	$8
Grid Electricity, Existing Service (Instrument Air Devices)					
South	$1,496	$1,556	$1,837	$7,738	$161
Rocky Mountains	$1,535	$1,597	$1,885	$7,941	$165
Mid-West / Mid-Atlantic	$1,600	$1,664	$1,964	$8,273	$172
Alaska	$3,108	$3,233	$3,817	$16,075	$334
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)					
South	$3,334	$3,338	$3,347	$3,492	$4
Rocky Mountains	$3,335	$3,338	$3,348	$3,496	$4
Mid-West / Mid-Atlantic	$3,335	$3,338	$3,349	$3,503	$4
Alaska	$3,342	$3,349	$3,369	$3,670	$8
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)					
South	$4,823	$4,883	$5,164	$11,065	$161
Rocky Mountains	$4,863	$4,924	$5,212	$11,268	$165
Mid-West / Mid-Atlantic	$4,927	$4,991	$5,291	$11,600	$172
Alaska	$6,435	$6,560	$7,144	$19,402	$334
Off-Grid (Solar-Powered Devices)					
South	$334	$482	$928	$7,607	$186
Rocky Mountains	$324	$468	$899	$7,374	$180
Mid-West / Mid-Atlantic	$380	$550	$1,057	$8,667	$211
Alaska	N/A	N/A	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Electricity costs include costs for purchasing electricity if the site is grid-connected. If the site is not connected to a grid but close to an existing service, electricity costs additionally include the capital costs for building the distribution line. For sites that are off-grid, electricity costs include the costs to build a distributed energy system on site.

[3] For scenarios that use instrument air devices, the capital costs of compressors are included in the Total Annualized Electricity Cost and spread across controllers and pumps.

[4] For the Grid Electricity, Service Extension scenarios, the distance of distribution line to be built is assumed to be 0.5 mile.

[5] The Off-Grid scenario assumes that commercial/industrial PV plus storage are used to supply the electricity needed for Pneumatic Devices.

Table A4
Electricity Costs for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Transmission and Storage Sites

Scenario	Total Annualized Electricity Cost (2021$)				Individual Pump Electricity Cost
Model Plant Size	Small	Medium	Large	Extra Large	
Grid Electricity, Existing Service (Electronic Devices)					
South	$5	$7	$13	$109	$3
Rocky Mountains	$5	$8	$15	$124	$3
Mid-West / Mid-Atlantic	$5	$8	$15	$124	$3
Alaska	$14	$20	$39	$320	$8
Grid Electricity, Existing Service (Instrument Air Devices)					
South	$993	$1,033	$1,219	$5,135	$107
Rocky Mountains	$1,122	$1,167	$1,378	$5,802	$121
Mid-West / Mid-Atlantic	$1,128	$1,174	$1,385	$5,835	$121
Alaska	$2,902	$3,018	$3,563	$15,007	$312
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)					
South	$3,332	$3,334	$3,340	$3,437	$3
Rocky Mountains	$3,333	$3,335	$3,342	$3,451	$3
Mid-West / Mid-Atlantic	$3,333	$3,335	$3,342	$3,452	$3
Alaska	$3,341	$3,347	$3,366	$3,647	$8
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)					
South	$4,320	$4,360	$4,546	$8,462	$107
Rocky Mountains	$4,449	$4,494	$4,705	$9,130	$121
Mid-West / Mid-Atlantic	$4,455	$4,501	$4,713	$9,162	$121
Alaska	$6,229	$6,345	$6,890	$18,335	$312
Off-Grid (Solar-Powered Devices)					
South	$334	$482	$928	$7,607	$186
Rocky Mountains	$324	$468	$899	$7,374	$180
Mid-West / Mid-Atlantic	$380	$550	$1,057	$8,667	$211
Alaska	N/A	N/A	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Electricity costs include costs for purchasing electricity if the site is grid-connected. If the site is not connected to a grid but close to an existing service, electricity costs additionally include the capital costs for building the distribution line. For sites that are off-grid, electricity costs include the costs to build a distributed energy system on site.

[3] For scenarios that use instrument air devices, the capital costs of compressors are included in the Total Annualized Electricity Cost and spread across controllers and pumps.

[4] For the Grid Electricity, Service Extension scenarios, the distance of distribution line to be built is assumed to be 0.5 mile.

[5] The Off-Grid scenario assumes that commercial/industrial PV plus storage are used to supply the electricity needed for Pneumatic Devices.

Table A5
Electricity Costs for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Natural Gas Processing Plants

Scenario	Total Annualized Electricity Cost (2021$)			Individual Pump Electricity Cost
Model Plant Size	Small	Medium	Large	
Grid Electricity, Existing Service (Electronic Devices)				
South	$11	$36	$96	$3
Rocky Mountains	$12	$41	$109	$3
Mid-West / Mid-Atlantic	$12	$41	$109	$3
Alaska	$31	$106	$281	$8
Grid Electricity, Existing Service (Instrument Air Devices)				
South	$1,214	$2,229	$4,596	$37
Rocky Mountains	$1,372	$2,518	$5,193	$42
Mid-West / Mid-Atlantic	$1,380	$2,532	$5,222	$42
Alaska	$3,549	$6,513	$13,431	$108
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)				
South	$3,338	$3,363	$3,423	$3
Rocky Mountains	$3,339	$3,368	$3,436	$3
Mid-West / Mid-Atlantic	$3,339	$3,368	$3,436	$3
Alaska	$3,358	$3,433	$3,608	$8
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)				
South	$4,541	$5,556	$7,923	$37
Rocky Mountains	$4,699	$5,845	$8,520	$42
Mid-West / Mid-Atlantic	$4,707	$5,860	$8,549	$42
Alaska	$6,876	$9,840	$16,758	$108
Off-Grid (Solar Powered Devices)				
South	$742	$2,523	$6,680	$186
Rocky Mountains	$719	$2,446	$6,475	$180
Mid-West / Mid-Atlantic	$846	$2,875	$7,610	$211
Alaska	N/A	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Electricity costs include costs for purchasing electricity if the site is grid-connected. If the site is not connected to a grid but close to an existing service, electricity costs additionally include the capital costs for building the distribution line. For sites that are off-grid, electricity costs include the costs to build a distributed energy system on site.

[3] For scenarios that use instrument air devices, the capital costs of compressors are included in the Total Annualized Electricity Cost and spread across controllers and pumps.

[4] For the Grid Electricity, Service Extension scenarios, the distance of distribution line to be built is assumed to be 0.5 mile.

[5] The Off-Grid scenario assumes that commercial/industrial PV plus storage are used to supply the electricity needed for Pneumatic Devices.

Table A6
Total Costs for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Production Sites (With Savings)

Scenario	Total Annualized Costs (2021$)			
Model Plant Size	**Small**	**Medium**	**Large**	**Extra Large**
Grid Electricity, Existing Service (Electronic Devices)				
South	$2,039	$3,032	N/A	N/A
Rocky Mountains	$2,039	$3,033	N/A	N/A
Mid-West / Mid-Atlantic	$2,040	$3,033	N/A	N/A
Alaska	$2,047	$3,044	N/A	N/A
Grid Electricity, Existing Service (Instrument Air Devices)				
South	N/A	N/A	$11,296	$78,810
Rocky Mountains	N/A	N/A	$11,344	$79,013
Mid-West / Mid-Atlantic	N/A	N/A	$11,423	$79,345
Alaska	N/A	N/A	$13,276	$87,147
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)				
South	$5,366	$6,360	N/A	N/A
Rocky Mountains	$5,367	$6,360	N/A	N/A
Mid-West / Mid-Atlantic	$5,367	$6,360	N/A	N/A
Alaska	$5,374	$6,371	N/A	N/A
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)				
South	N/A	N/A	$14,623	$82,137
Rocky Mountains	N/A	N/A	$14,672	$82,340
Mid-West / Mid-Atlantic	N/A	N/A	$14,750	$82,673
Alaska	N/A	N/A	$16,603	$90,474
Off-Grid (Solar-Powered Devices)				
South	$1,939	$3,141	N/A	N/A
Rocky Mountains	$1,929	$3,126	N/A	N/A
Mid-West / Mid-Atlantic	$1,986	$3,208	N/A	N/A
Alaska	N/A	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Costs for electronic devices include initial capital expenditures for the equipment, the engineering and installation costs, and the operating costs for electrical energy. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to determine total costs.

[3] Costs for instrument air devices include initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to determine total costs.

[4] Costs for off-grid solar powered devices include initial capital expenditures for the controller/pump equipment and the engineering and installation costs, which are all based off EPA cost estimates (TSD) and assumed to be the same for each region. The regional levelized costs of solar plus storage from Table 1 are added to determine total costs.

[5] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table A7
Total Costs for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Natural Gas Processing Plants (With Savings)

Scenario	Total Annualized Costs (2021$)		
Model Plant Size	**Small**	**Medium**	**Large**
Grid Electricity, Existing Service (Instrument Air Devices)			
South	$12,697	$29,640	$48,863
Rocky Mountains	$12,855	$29,929	$49,460
Mid-West / Mid-Atlantic	$12,863	$29,944	$49,489
Alaska	$15,032	$33,924	$57,698
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)			
South	$16,025	$32,967	$52,190
Rocky Mountains	$16,182	$33,257	$52,787
Mid-West / Mid-Atlantic	$16,190	$33,271	$52,816
Alaska	$18,359	$37,252	$61,025

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Costs for instrument air devices include initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 3 are added to determine total costs.

[3] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table A8
Cost Effectiveness for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Production Sites (Without Savings)

Scenario	Cost Effectiveness ($/ton of Methane)			
Model Plant Size	**Small**	**Medium**	**Large**	**Extra Large**
Grid Electricity, Existing Service (Electronic Devices)				
South	$451	$412	N/A	N/A
Rocky Mountains	$451	$412	N/A	N/A
Mid-West / Mid-Atlantic	$451	$412	N/A	N/A
Alaska	$452	$413	N/A	N/A
Grid Electricity, Existing Service (Instrument Air Devices)				
South	N/A	N/A	$601	$691
Rocky Mountains	N/A	N/A	$603	$692
Mid-West / Mid-Atlantic	N/A	N/A	$606	$694
Alaska	N/A	N/A	$675	$737
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)				
South	$890	$665	N/A	N/A
Rocky Mountains	$890	$665	N/A	N/A
Mid-West / Mid-Atlantic	$890	$665	N/A	N/A
Alaska	$891	$666	N/A	N/A
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)				
South	N/A	N/A	$725	$709
Rocky Mountains	N/A	N/A	$727	$710
Mid-West / Mid-Atlantic	N/A	N/A	$730	$712
Alaska	N/A	N/A	$799	$756
Off-Grid (Solar-Powered Devices)				
South	$438	$420	N/A	N/A
Rocky Mountains	$436	$419	N/A	N/A
Mid-West / Mid-Atlantic	$444	$425	N/A	N/A
Alaska	N/A	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Methane reductions for each scenario are based off EPA emission reduction estimates from the Technical Support Document (TSD).

[3] Costs for electronic devices include initial capital expenditures for the equipment, the engineering and installation costs, and the operating costs for electrical energy. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to determine total costs.

[4] Costs for instrument air devices include initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to determine total costs.

[5] Costs for off-grid solar powered devices include initial capital expenditures for the controller/pump equipment and the engineering and installation costs, which are all based off EPA cost estimates (TSD) and assumed to be the same for each region. The regional levelized costs of solar plus storage from Table 1 are added to determine total costs.

[6] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table A9
Cost Effectiveness for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Production Sites (With Savings)

Scenario	Cost Effectiveness ($/ton of Methane)			
Model Plant Size	**Small**	**Medium**	**Large**	**Extra Large**
Grid Electricity, Existing Service (Electronic Devices)				
South	$269	$231	N/A	N/A
Rocky Mountains	$269	$231	N/A	N/A
Mid-West / Mid-Atlantic	$269	$231	N/A	N/A
Alaska	$270	$232	N/A	N/A
Grid Electricity, Existing Service (Instrument Air Devices)				
South	N/A	N/A	$421	$438
Rocky Mountains	N/A	N/A	$423	$439
Mid-West / Mid-Atlantic	N/A	N/A	$426	$441
Alaska	N/A	N/A	$495	$484
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)				
South	$709	$484	N/A	N/A
Rocky Mountains	$709	$484	N/A	N/A
Mid-West / Mid-Atlantic	$709	$484	N/A	N/A
Alaska	$710	$485	N/A	N/A
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)				
South	N/A	N/A	$545	$457
Rocky Mountains	N/A	N/A	$547	$458
Mid-West / Mid-Atlantic	N/A	N/A	$550	$459
Alaska	N/A	N/A	$619	$503
Off-Grid (Solar-Powered Devices)				
South	$256	$239	N/A	N/A
Rocky Mountains	$255	$238	N/A	N/A
Mid-West / Mid-Atlantic	$262	$244	N/A	N/A
Alaska	N/A	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Methane reductions for each scenario are based off EPA emission reduction estimates from the Technical Support Document (TSD).

[3] Costs for electronic devices include a natural gas savings of $3.13 per Mcf, initial capital expenditures for the equipment, the engineering and installation costs, and the operating costs for electrical energy. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to determine

[4] Costs for instrument air devices include a natural gas savings of $3.13 per Mcf, initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 1 are added to

[5] Costs for off-grid solar powered devices include a natural gas savings of $3.13 per Mcf. initial capital expenditures for the controller/pump equipment and the engineering and installation costs, which are all based off EPA cost estimates (TSD) and assumed to be the same for each region. The regional levelized costs of solar plus storage from Table 1 are added to determine total costs.

[6] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table A10
Cost Effectiveness for Zero-Emission Pneumatic Devices Under Different Locational Scenarios
Transmission and Storage Sites (Without Savings)

Scenario	Cost Effectiveness ($/ton of Methane)			
Model Plant Size	**Small**	**Medium**	**Large**	**Extra Large**
Grid Electricity, Existing Service (Electronic Devices)				
South	$565	$710	N/A	N/A
Rocky Mountains	$566	$710	N/A	N/A
Mid-West / Mid-Atlantic	$566	$710	N/A	N/A
Alaska	$567	$712	N/A	N/A
Grid Electricity, Existing Service (Instrument Air Devices)				
South	N/A	N/A	$1,304	$1,875
Rocky Mountains	N/A	N/A	$1,318	$1,885
Mid-West / Mid-Atlantic	N/A	N/A	$1,318	$1,885
Alaska	N/A	N/A	$1,501	$2,027
Grid Electricity, Service Extension (Electronic Devices, 0.5 Mile)				
South	$1,117	$1,147	N/A	N/A
Rocky Mountains	$1,117	$1,147	N/A	N/A
Mid-West / Mid-Atlantic	$1,117	$1,147	N/A	N/A
Alaska	$1,119	$1,148	N/A	N/A
Grid Electricity, Service Extension (Instrument Air Devices, 0.5 Mile)				
South	N/A	N/A	$1,584	$1,926
Rocky Mountains	N/A	N/A	$1,597	$1,936
Mid-West / Mid-Atlantic	N/A	N/A	$1,598	$1,937
Alaska	N/A	N/A	$1,781	$2,078
Off-Grid (Solar-Powered Devices)				
South	$549	$725	N/A	N/A
Rocky Mountains	$548	$723	N/A	N/A
Mid-West / Mid-Atlantic	$557	$734	N/A	N/A
Alaska	N/A	N/A	N/A	N/A

Notes:

[1] Please see Section III for states included in each region and details on data sources and calculations.

[2] Methane reductions for each scenario are based off EPA emission reduction estimates from the Technical Support Document (TSD).

[3] Costs for electronic devices include initial capital expenditures for the equipment, the engineering and installation costs, and the operating costs for electrical energy. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 2 are added to determine total costs.

[4] Costs for instrument air devices include initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. These are based off EPA cost estimates (TSD) and assumed to be the same for each region. The delivered electricity and service line extension costs from Table 2 are added to determine total costs.

[5] Costs for off-grid solar powered devices include initial capital expenditures for the controller/pump equipment and the engineering and installation costs, which are all based off EPA cost estimates (TSD) and assumed to be the same for each region. The regional levelized costs of solar plus storage from Table 2 are added to determine total costs.

[6] Total costs include the net maintenance costs of zero-emission controllers relative to gas-driven controllers. The maintenance cost estimates are derived from the Carbon Limits Report.

Table A11
Methane Reduction for Zero-Emission Pneumatic Devices by Plant Size and Type
Tons Per Year

Scenario	Small			Medium		
	Production	Transmission and Storage	Natural Gas Processing	Production	Transmission and Storage	Natural Gas Processing
Grid Electricity, Existing and New Service (Electronic Controllers)	7.57	6.03	N/A	13.14	7.62	N/A
Grid Electricity, Existing Service (Instrument Air Controllers)	N/A	N/A	N/A	N/A	N/A	N/A
Grid Electricity, New Service (Instrument Air Controllers)	N/A	N/A	16.92	N/A	N/A	64.92
Off-Grid (Solar Powered Devices)	7.57	6.03	N/A	13.14	7.62	N/A

Scenario	Large			Extra Large		
	Production	Transmission and Storage	Natural Gas Processing	Production	Transmission and Storage	Natural Gas Processing
Grid Electricity, Existing and New Service (Electronic Controllers)	N/A	N/A	N/A	N/A	N/A	N/A
Grid Electricity, Existing Service (Instrument Air Controllers)	26.83	11.89	N/A	179.92	64.92	N/A
Grid Electricity, New Service (Instrument Air Controllers)	26.83	11.89	176.92	179.92	64.92	N/A
Off-Grid (Solar Powered Devices)	N/A	N/A	N/A	N/A	N/A	N/A

Notes:

[1] Individual controller emissions (tons per year) from the production segment are 2.48 (low-bleed controllers), 1.39 (high bleed controllers), 0.05 (intermittent vent controllers), and 0.39 (properly operating intermittent vent controllers).

[2] Individual controller emissions (tons per year) from the transmission and storage segment are 0.23 (low-bleed controllers), 3.08 (high bleed controllers), 0.40 (intermittent vent controllers), and 0.02 (properly operating intermittent vent controllers).

[3] Individual control loop emissions (tons per year) from the natural gas processing segment are 1 tpy.

[4] Individual pump emissions (tons per year) are 3.46 (diaphragm pump) and 0.38 (piston pump). EPA assumes a 50-50 split in pump types so average emission reductions are 1.92 tpy.

Table A12
EPA v. Analysis Group Cost Analyses - Electronic Devices (Grid or Power On-Site)

	Natural Gas and Oil Segments Analyzed	Plant Sizes Analyzed[1]	Cost Components[2]	Annualized Total Costs for System (Without Savings) [3]	Methane Emissions Mitigated per System (tpy)[4]	Cost-Effectiveness for System (Without Savings) ($/ton)
EPA	Production	Small	1) Capital expenditures for equipment (controllers, control panel) 2) Engineering and installation costs (assumed to be 20% of equipment costs) 3) Operating costs for electrical energy	$2,799	5.65	$495
		Medium		$5,038	11.22	$449
	Transmission and Storage	Small		$2,799	4.11	$682
		Medium		$5,038	5.70	$884
AG	Production	Small	1) Adjusted capital expenditures for equipment (controllers, control panel, and individual pump) 2) Engineering and installation costs (assumed to be 20% of equipment costs) 3) Operating costs for electrical energy 4) Electricity costs by region 5) Net maintenance costs	$3,412 - $3,420	7.57	$451 - $452
		Medium		$5,414 - $5,426	13.14	$412 - $413
	Transmission and Storage	Small		$3,410 - $3,419	6.03	$565 - $567
		Medium		$5,411 - $5,424	7.62	$710 - $712

Notes:

[1] Per Table 8-4, a small plant has 2 continuous bleed controllers and 2 intermittent vent controllers, and a medium plant has 2 continous bleed controllers and 6 intermittent vent controllers. While electronic controllers can be used at any location where pneumatic controllers or alternative types of controllers are needed, it is assumed that only locations with a low number of pneumatic control valves (less than 20) and without the presence of an operator would install electronic controllers. Therefore, the analysis is focus on small and medium-sized production and transmission and storage sites.

[2] EPA costs are based on those found in reviewed literature and are principally based on those found in a report prepared by Carbon Limits for the Clean Air Act Task Force. AG costs include the same capital, engineering, installation, and electricity operating costs for electronic controllers. AG adds the initial capital expenditures, installation and ongoing operation and maintenance for an individual pump at each site based on EPA's cost estimates from the Natural Gas STAR document, "PRO Fact Sheet: Convert Natural Gas-Driven Chemical Pumps." In addition, AG adds regional delivered electricity costs (EIA) based on annual electricity demand needed to power the controllers and pump. EPA did not consider costs of the power supply based on an assumption that electrical supply is already on site. AG also adds the net maintenance costs of zero-emission controllers relative to gas-driven controllers.

[3] EPA total costs are annualized assuming a 7 percent interest rate and a 15-year equipment life for controllers/10-year equipment life for pumps. AG total costs vary based on region and electricity rate class (industrial or commercial).

[4] Mitigated methane emissions are based on EPA emission estimates for pneumatic controllers and pumps from Table's 8-12 and 9-9.

Table A13
EPA v. Analysis Group Cost Analyses - Electronic Devices (Solar and Storage)

	Natural Gas and Oil Segments Analyzed	Plant Sizes Analyzed[1]	Cost Components[2]	Annualized Total Costs for System (Without Savings) [3]	Methane Emissions Mitigated per System (tpy)[4]	Cost-Effectiveness for System (Without Savings) ($/ton)
EPA	Production	Small	1) Capital expenditures for equipment (controllers, control panel, solar panels, batteries) 2) Engineering and installation costs (assumed to be 20% of equipment costs)	$3,093	5.65	$547
		Medium		$5,626	11.22	$502
	Transmission and Storage	Small		$3,093	4.11	$753
		Medium		$5,626	5.70	$988
AG	Production	Small	1) Adjusted capital expenditures for equipment (controllers, control panel, solar panels, batteries, and individual pump) 2) Engineering and installation costs (assumed to be 20% of equipment costs) 3) Net maintenance costs	$3,302 - $3,359	7.57	$436 - $444
		Medium		$5,508 - $5,590	13.14	$419 - $425
	Transmission and Storage	Small		$3,302 - $3,359	6.03	$548 - $557
		Medium		$5,508 - $5,590	7.62	$433 - $441

Notes:

[1] Per Table 8-4, a small plant has 2 continuous bleed controllers and 2 intermittent vent controllers, and a medium plant has 2 continous bleed controllers and 6 intermittent vent controllers. While electronic controllers can be used at any location where pneumatic controllers or alternative types of controllers are needed, it is assumed that only locations with a low number of pneumatic control valves (less than 20) and without the presence of an operator would install electronic controllers. Therefore, the analysis is focus on small and medium-sized production and transmission and storage sites.

[2] EPA costs are based on those found in reviewed literature and are principally based on those found in a report prepared by Carbon Limits for the Clean Air Act Task Force. AG costs include the same capital, engineering, and installation costs for the electronic controllers and control panel. AG adds the initial capital expenditures, installation and ongoing operation and maintenance for an individual pump at each site based on EPA's cost estimates from the Natural Gas STAR document, "PRO Fact Sheet: Convert Natural Gas-Driven Chemical Pumps." In addition, AG adjusts EPA national cost estimates for solar panels and batteries based on regional differences in weather that impact solar panel output and battery capacity. AG also adds the net maintenance costs of zero-emission controllers relative to gas-driven controllers.

[3] EPA total costs are annualized assuming a 7 percent interest rate and a 15-year equipment life for controllers/10-year equipment life for pumps. AG total costs vary based on region.

[4] Mitigated methane emissions are based on EPA emission estimates for pneumatic controllers and pumps from Table's 8-13 and 9-9.

Table A14
EPA v. Analysis Group Cost Analyses - Instrument Air Devices

	Natural Gas and Oil Segments Analyzed	Plant Sizes Analyzed[1]	Cost Components[2]	Annualized Total Costs for System (Without Savings) [3]	Methane Emissions Mitigated per System (tpy)[4]	Cost-Effectiveness for System (Without Savings) ($/ton)
EPA	Production	Large	1) Capital expenditures for equipment (compressors, related equipment) 2) Operating costs for electrical energy	$13,995	24.91	$562
	Transmission and Storage	Large		$13,995	9.97	$1,404
	Natural Gas Processing	Small		$13,214	15.00	$881
		Medium		$43,940	63.00	$697
		Large		$95,936	175.00	$548
AG	Production	Large	1) Adjusted capital expenditures for equipment (compressors, related equipment and individual pump) 2) Operating costs for electrical energy 3) Electricity costs by region 4) Net maintenance costs	$16,125 - $18,105	26.83	$601 - $675
	Transmission and Storage	Large		$15,507 - $17,851	11.89	$1,304 - $1,501
	Natural Gas Processing	Small		$15,421 - $17,756	16.90	$911 - $1,049
		Medium		$41,082 - $45,366	64.90	$633 - $699
		Large		$80,645 - $89,480	176.90	$456 - $506

Notes:

[1] Per Table 8-4, a large production or transmission and storage plant has 5 continuous bleed controllers and 15 intermittent vent controllers. Per Table 8-5, a small natural gas processing plant has 15 controllers, a medium plan has 63 controllers, and a large plant has 175 controllers. EPA assumes that only locations with a high concentration of pneumatic control valves and the presence of an operator would install an instrument air system. Therefore, EPA has assumed that all natural gas processing plants and only large production or transmission and storage sites would fit this description.

[2] For natural gas processing plants, EPA costs are updated from the 2011 NSPS TSD to 2019 dollars using the Federal Reserve Economic Data GDP Price Deflator. The 2011 NSPS TSD data was based largely on information in the Natural Gas STAR Lessons Learned document, "Lessons Learned: Convert Gas Pneumatic Controllers to Instrument Air." For production and transmission/storage plants, cost data is based on reviewed literature and principally based on the 2016 Carbon Limits report. AG costs include the same capital and electricity operating costs for compressors. AG adds the initial capital expenditures, installation and ongoing operation and maintenance for an individual pump at each site based on EPA's cost estimates from the Natural Gas STAR document, "PRO Fact Sheet: Convert Natural Gas-Driven Chemical Pumps." In addition, AG adds regional delivered electricity costs (EIA) based on annual electricity demand needed to power the controllers and pump. EPA did not consider costs of the power supply based on an assumption that electrical supply is already on site. AG also adds the net maintenance costs of zero-emission controllers relative to gas-driven controllers.

[3] EPA total costs are annualized assuming a 7 percent interest rate and a 15-year equipment life for controllers/10-year equipment life for pumps. AG total costs vary based on region and electricity rate class (industrial or commercial).

[4] Mitigated methane emissions are based on EPA emission estimates for pneumatic controllers and pumps from Table's 8-9, 8-10, 8-11 and 9-9.