Appendix B:
Economic Analysis

Proposed Amendments to the Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities

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I. Introduction

Chapter VIII of the Initial Statement of Reasons (ISOR) provides an overview of the costs of the Proposed Amendments. This appendix describes in more detail the methodology used to determine the costs, both first year and ongoing, of the Proposed Amendments to impacted businesses. The costs presented here are only the incremental costs for new provisions and requirements and are presented in 2021$.

II. Methodology to Determine Costs of the Proposed Amendments

A. Summary of First Year and Subsequent Annual Costs by Provision

Total first-year costs for the Proposed Amendments are estimated at $2,249,702 and total annual costs for each year thereafter are estimated at $1,096,472 (see Table 1 in Chapter VIII of the ISOR). These first year and annual costs are approximately 0.03 percent and 0.01 percent, respectively, of the total combined annual economic output generated by the regulated industries ($7.99 billion for Oil and Gas Extraction and $554 million for Pipeline Transportation of Natural Gas).[1]

Using an analysis time horizon of five years, the total statewide cost over that period is estimated at $6,635,591. Staff chose a five-year time horizon for this analysis because performance testing for vapor control devices occurs on a five-year cycle, while all other costs occur either in the first year only or annually.

The remainder of this section details assumptions, costs broken down by provision, and share of costs by industry.

B. General Assumptions

1. Number of Impacted Businesses

In 2021, there were a total of 227 owners and operators reporting for the Regulation through the electronic reporting tool Cal e-GGRT. Based on cross referencing data from the South Coast Air Quality Management District, CARB staff estimate that there are an additional 75 owners or operators subject to the regulation but not yet using the electronic reporting tool. Thus, staff estimate that there are 302 businesses subject to the regulation, all of which are located in California.

Of these 302 businesses, there are 294 in the NAICS code 2111 (Oil and Gas Extraction) and 8 in the NAICS code 4862 (Pipeline Transportation of Natural Gas). No small businesses are directly subject to the Regulation because oil and natural gas companies cannot be considered small businesses per California Government Code 11342.610(b).

Some businesses could be indirectly impacted by the Proposed Amendments such as those that provide leak detection and repair (LDAR) services, develop LDAR plans, provide chemical analysis of samples, service or test vapor collection or controls systems, and perform vapor collection or control system design analysis. Some of the businesses indirectly

[1]These are California industry-level gross domestic product from US BEA 2023.

affected in these ancillary sectors may be small businesses. Fuel purchasers, as subsequent businesses in the oil and gas supply chain, could be indirectly impacted if the direct costs or cost savings of the proposed amendments are passed on. However, staff expect any impacts on fuel purchasers to be negligible because the costs of the Proposed Amendments are very small in comparison to the total output of the affected industries.

2. Number of Impacted Equipment Pieces

Staff used mostly 2019 data reported pursuant to the Regulation to estimate the number of pieces of each type of equipment, number of facilities, number of operators, or number of leaks that are expected to be impacted by each regulatory provision. Data from 2019 were used because it was the most recent data that had been verified at the time of the calculations. Those counts are listed along with the calculations later in this section.

3. Labor Cost

As noted in Chapter VIII, labor costs are a major factor for many of the proposed provisions. Projected increases in labor requirements were assumed to cost $68.79 per hour, obtained from the technical support document for a 2021 US EPA rule exploration (US EPA 2021) for similar activities in the oil and gas sector and adjusted for inflation from 2019$ to 2021$.[2] Deviations from this labor rate and the sources of such figures are identified in the calculations.

C. Cost Calculations

1. Pneumatic Controller and Pneumatic Pump Tagging and Recordkeeping

The Proposed Amendments will require continuous low-bleed pneumatic controllers to be physically tagged with the month and year of installation and other information to enable traceability. Staff estimate that the additional labor time required for this tagging is 2 hours per controller based on the time to generate each tag and to visit sites where the controllers are located. Staff estimate the material cost of the tags at $0.26 per tag (adjusted to 2021$, as described previously), based on an estimate of tag costs for gas processing plants from the US EPA 2021 TSD (US EPA 2021). Regulatory reporting showed that 60 controllers of this type were in operation in 2019. At the hourly rate of $68.79, this tagging requirement is expected to cost $8,271 in the first year including both the labor and tag material costs (2 hr/controller x 60 controllers x $68.79/hr + $0.26 per controller x 60 controllers).

In addition to physical tagging, operators will be required to maintain records of the locations and manufacturer's specification for each continuous bleed pneumatic controller and each pneumatic pump. Regulatory reporting showed 91 pneumatic pumps in 2019. Staff estimate that this additional record keeping requirement will take 1 hour of labor time per controller or pump. This labor time was estimated as an average keeping in mind that manufacturer's specifications may need to be looked up and collected or organized.

[2] Using a scale up-factor of 1.060 based on the change in the California Consumer Price Index for "All Urban Consumers" from 2019 to 2021. Data from DIR 2022.

New uncontrolled continuous bleed pneumatic controllers and new uncontrolled pneumatic pumps are not allowed to be installed. Thus, staff assume that this recordkeeping will be a one-time process in the first year. Including both continuous bleed pneumatic controllers and pneumatic pumps subject to this requirement, 151 hours of labor is estimated to be spent on this task in the first year ([60 controllers + 91 pumps] x 1 hr/device). At the hourly labor rate of $68.79, this requirement is expected to cost $10,387 (151 hr x $68.79/hr).

2. Leak Detection and Repair (LDAR) Plans

Under the Proposed Amendments, operators will be required to develop detailed plans for how LDAR activities will be carried out. These include procedures for conducting surveys, sitemaps, lists of equipment and components to be monitored, lists of equipment and components designated as "inaccessible" or "unsafe to monitor", the frequency of inspection for each piece of equipment, and the repair timeframes based on leak size for each type of equipment. A separate plan is needed for each facility. In addition to developing the plans, operators need to document deviations from the plan when they occur.

Regulatory reporting from 2019 shows that there were 380 facilities and 94 operators that would be affected by this requirement. Staff estimated the time required to develop LDAR plans based on a US EPA estimate for producing LDAR plans in a technical support document for a 2022 rule proposal[3] (a supplemental update to the 2021 rule exploration cited previously, henceforth the "US EPA 2022 TSD") (US EPA 2022c). US EPA estimated 40 hours of labor to develop a "company-wide fugitives monitoring plan" for a "company-defined area." The requirements of the LDAR plans as estimated by the US EPA are based on 40 CFR 60.5397a, which has similar requirements to the plans in the Proposed Amendments. Based on the elements required in the plans, staff estimate that half of this time is for aspects of a plan that each operator would only need to complete once for the Proposed Amendments (e.g., methodology for monitoring, developing a plan reporting format, etc.) and that half of that time would be for tasks specific to each facility. Therefore, staff estimate 20 hours per operator and an additional 20 hours per facility, both as one-time costs, for developing LDAR plans. Based on the hourly labor rate, number of facilities and operators, and labor time requirement, development of LDAR plans is expected to cost $652,129 in the first year ([380 facilities x 20 hr/facility + 94 operators x 20 hr/operator] x $68.79/hr).

Staff estimate ongoing costs for labor for documenting deviations from the plan at 2 hours per facility per year and labor to update the plans periodically as equipment changes at 2 hours per facility per year. Staff do not expect that regular updates will need to be made to the components of the plans that are assigned a labor cost per operator. Combined with the hourly labor rate, this requirement is expected to cost $104,561 per year in ongoing costs (including in the first year) (4 hr/facility x 380 facilities x $68.79/hr). Of this cost, documentation of deviations constitutes recordkeeping (at $52,280/yr).

3. Leak Detection and Repair Equipment Descriptions

The Proposed Amendments will require operators to include detailed equipment descriptions for all leaks that do not have an associated equipment ID. Regulatory reporting

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[3] 40 hours for LDAR plans estimate is contained in the spreadsheet "Chapter 5 MultiWell" (US EPA 2022d).

in 2019 included 1,182 leaks that did not include an equipment ID. Staff estimate that it will take 6 minutes (0.1 hr) per piece of equipment to write the equipment description. Thus, this requirement is expected to add $8,131 per year in annual expenses based on the hourly rate of $68.79 (1,182 leaks x 0.1 hr/leak x $68.79/hr).

4. Equipment Reporting for Vapor Collection Status

Under the current Regulation, operators are required to identify which separator and tank systems are emission-controlled using vapor collection systems. The Proposed Amendments add requirements for operators to identify all equipment that is controlled by a vapor collection system, so operators would be newly required to report pneumatic controllers, pneumatic pumps, and compressors that are using vapor collection systems.

Based on 2019 regulatory reporting, there are 3,870 total devices that may be affected by this requirement, including 3,628 pneumatic controllers, 91 pneumatic pumps, 147 non-production reciprocating compressors, and 4 wet seal centrifugal compressors. Staff estimate that noting whether each piece of equipment is connected to a vapor collection system will take 3 minutes (0.05 hr) per piece of equipment per year based on briefly examining the physical components at the site or in pre-existing records. At the hourly labor rate of $68.79, compliance with this requirement is estimated to cost $13,311 per year (0.05 hr/device x 3,870 devices x $68.79/hr).

5. Requirements for Separator and Tank Systems

The Proposed Amendments add new requirements for separator and tank systems with required emission controls, including the design of covers, removal and return to service, compliance demonstration, and recordkeeping. Some of these requirements reference demonstration of the performance of emission control systems.

Staff estimate 4 hours per year of labor time per separator and tank system for administrative tasks, including keeping records of dates when tanks were operated out of compliance, keeping records of dates that tanks were taken out of or returned to service, and keeping records of locations of mobile tanks. Based on 2019 regulatory data, there were 11 separator and tank systems potentially impacted by these added provisions (those that had emission control systems installed pursuant to the regulation or had tested over the minimum emission rate before the control requirements went into effect). At the hourly labor rate of $68.79, compliance with these requirements is estimated to cost $3,027 per year (4 hr/system x 11 systems x $68.79/hr).

6. Requirements, Performance Testing, and Recordkeeping for Vapor Collection Systems and Control Devices

Additional requirements for vapor collection systems and vapor control devices are needed to meet the standards in section 95671 of the regulation, which were added because of the regulation or used in certain places to exempt equipment from flow rate measurements. Proposed requirements include locks or flow indicators on bypass valves, a Professional Engineer's assessment of vapor collection and control system capacity, monthly inspections of vapor control devices and vapor collection systems, performance tests every 60 months, repair of discovered leaks and defects, and additional recordkeeping.

Estimating the costs for these provisions requires first estimating the number of vapor collection systems and control devices potentially subject to the Proposed Amendments. In the absence of better data, staff assume that all vapor collection systems feed into a vapor control device (rather than to sales, onsite use, a boiler, or other options listed in the regulation), and thus the requirements will apply to each set of systems. The remainder of this discussion will just refer to the number of vapor collection systems.

Data is not available on the number of vapor collection systems, but regulatory reporting data does reveal some information about the number of pieces of equipment that are on vapor collection for certain equipment types. For other equipment types that may or may not be controlled by a vapor collection system, staff made assumptions based on their best engineering judgement and counts of those potentially controlled equipment types.

Separator and tank systems must control emissions with a vapor collection system if flash testing shows an annual emission rate greater than 10 metric tons of methane per year (MT CH_4/yr) (if not already controlled by a vapor collection system subject to an air district rule or otherwise exempt). Regulatory reporting data for 2019 show that there were 11 separator and tank systems that either had vapor recovery installed or had tested above the 10 MT CH_4/yr limit prior to the emission control requirements going into effect. Thus, staff assume 11 vapor collection systems were added or may have been added in the intervening time for control of separator and tank systems.

Reciprocating compressors in the non-production sector[4] and wet-seal centrifugal compressors must either maintain emission rates from rod packings and seals below certain limits (i.e., by repairing or replacing the components) or use vapor collection systems to control emissions. Regulatory reporting data for 2019 show that there were 6 non-production sector reciprocating compressors on vapor collection and no wet seal centrifugal compressors on vapor collection. Of the compressors not on vapor collection, only one tested above the flow rate standard in 2019 and that compressor was repaired (it was not put on vapor collection). Therefore, staff therefore assume that 6 compressors have vapor collection systems subject to the additional vapor collection system and control device requirements.

Pneumatic pumps are not allowed to vent gas to the atmosphere. That means such pumps that existed prior to the current regulation either had to be controlled with a vapor collection system or switched out for a compressed air or electricity-based pump. Reporting data from 2019 showed 91 pneumatic pumps at 43 facilities. It is unknown whether these pumps use inherently non-emitting designs or technologies or had vapor collection systems added. For this analysis, staff assume that one vapor collection system may have been added per facility with all pneumatic pumps at each facility being routed to that vapor collection system. Thus, staff assume 43 vapor collection systems for pneumatic pumps.

Continuous-bleed pneumatic controllers are not allowed to vent to the atmosphere, except for certain low-bleed controllers installed prior to 2016. Regulatory reporting data show the number of low-bleed pneumatic controllers in 2019 (60), but do not reveal whether those controllers meet the flow rate and installation year requirements or if they are controlled with a vapor collection system. However, the vast majority of those controllers had reported

[4] In this context, non-production means natural gas gathering and boosting stations, natural gas processing plants, natural gas transmission compressor stations, and natural gas underground storage facilities.

emission flow rates, so staff assume that no pneumatic controllers were controlled with vapor collection systems[5].

Based on the figures and methodology listed above, the number of potentially impacted systems for all of the calculations in this section are estimated at 60.

The Proposed Amendments require vapor collection system and control device bypass valves to either be locked (e.g., with a car-seal or lockout-tagout style lock) or to have a mechanism to alarm when there is flow through the bypass. In this analysis, staff assume that locks will be used to secure the bypass valves when not in operation. Staff obtained costs for aluminum lockout-tagout padlocks with 3-inch clearance shackles from three vendor websites and found an average cost of $20.23 per lock (Grainger 2022, Total Lockout 2022, Brady 2022). Therefore $1,214 will be incurred in the first year only for the purchase of locks ($20.23/lock x 60 locks). Staff further assume that recordkeeping for when the key is checked out (or when a bypass alarm sounds) will require 30 minutes per year per system, as the bypass is not expected to be needed often and this recordkeeping is simply maintaining a log. Thus, there is an annual ongoing recordkeeping cost of $2,064/yr (60 systems x 0.5 hr/system-yr x $68.79/hr).

Under the Proposed Amendments, each vapor collection system will require an initial (first-year only cost) Professional Engineer's assessment of the vapor collection system capacity relative to the amount of vapors directed to it to ensure it is sized properly. Staff estimated the cost associated with this assessment by assuming such an assessment is part of the initial engineering normally involved in installing a new vapor collection system. Staff obtained an estimate of the combined freight and engineering costs for installing a new vapor collection or control device from a regulatory analysis performed by the Colorado Department of Public Health and Environment (CDPHE 2014). CDPHE estimated this combined cost at $2,028[6] (2021$). Staff further assume that half of this cost is related to engineering calculations to properly size the system while the other half is for freight and other engineering. Therefore, a cost of $1,014 per system for the vapor collection sizing calculation is used in this analysis. With 60 systems, the sizing certification is estimated to cost $60,847 in the first year only ($1,014/system x 60 systems).

The Proposed Amendments require performance tests every 60 months to ensure proper collection/destruction efficiency for vapor collection systems and vapor control devices. This is treated as a first year only cost in this analysis because the analysis period is five years and thus only one performance test is required within the analysis period. Staff obtained a cost estimate for performing similar tests in a different sector (vapor recovery certification tests on terminal tanks that deliver gasoline into cargo tanks) based on the costs charged by CARB's Monitoring and Laboratory Division (MLD) for performing such tests. In Northern California, these tests typically range in cost from $3,200 to $8,700 with an average of $6,800 including travel, preparing test instruments, conducting the test, and preparing test reports[7]. The

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[5] Additionally, based on reporting data and follow-up communication with air districts, there are no longer any continuous high-bleed pneumatic controllers.

[6] Adjusted for inflation using a scale up-factor of 1.231 based on the change in the California Consumer Price Index for "All Urban Consumers" from 2013 to 2021. Data from DIR 2022.

[7] Estimated costs were higher for Southern California due to increased travel cost, but staff assume that companies based in relatively close proximity could provide this testing, more similar to the costs for CARB to perform certification in Northern California.

average value, $6,800 per test, is used in this cost analysis. With 60 systems, the performance testing is estimated to cost a total of $408,000 (treated as a first year only cost) ($6,800/system x 60 systems).

Monthly audio-visual-olfactory (AVO) (i.e., listen, look, and smell) inspections of vapor collection systems and vapor control devices are required under the Proposed Amendments, and costs were estimated based on the time required to perform similar AVO inspections at well sites, as estimated by the US EPA. Staff assumed that the complexity of a vapor collection system (and associated vapor control device, if present) in terms of the time required to perform an AVO inspection is between that of a single well site and that of a multi-well site. Thus, staff assume that each monthly AVO inspection takes 0.55 hours per system (the average time for a single well site and multi-well site, not including recordkeeping or travel[8]), as described in Attachment 4 of the US EPA 2022 TSD (US EPA 2022e). Further, staff assumed that recordkeeping would take 30 minutes (0.5 hours) per inspection, in line with US EPA's assumption for a multi-well site (to include recordkeeping for the monthly inspections and the additional minor recordkeeping items in Appendix E). Therefore, the costs for performing the monthly AVO inspections are estimated at $27,241/yr (60 systems x 0.55 hr/inspection x 12 inspections/yr x $68.79/hr) and the additional costs for recordkeeping are estimated at $24,764/yr (60 systems x 0.5 hr/inspection x 12 inspections/yr x $68.79/hr).

If leaks or other defects are found during AVO inspections, they must be repaired under the Proposed Amendments. US EPA assumes $112 per year[9] for a single well site or multi-well site for repair costs and resurveys resulting from AVO inspections, and staff apply that same estimate to vapor collection systems and vapor control devices. Thus, the cost for repairs of leaks or defects are estimated at $6,718/yr (60 systems x $112/yr).

Based on these calculations, the first-year costs (including one-time costs and one year of annual costs) for Appendices E and F requirements are estimated at $530,847. The annual ongoing costs of Appendices E and F requirements are estimated at $60,787/yr. Of those costs, recordkeeping costs include those for recordkeeping of AVO inspections and for checkout of bypass valve lock keys, at a total cost of $26,828/yr.

7. Natural Gas Underground Storage Facility Monitoring Plan Updates and Recordkeeping

The Proposed Amendments add a few clarifications and new requirements for natural gas underground storage facility monitoring plans, such as a requirement to keep records of when monitoring systems are inactivated and the reason why. Additionally, the Proposed Amendments add a requirement to attempt to repair leaks between 1,000-9,999 ppm in a reduced timeframe. Owners or operators will be required to update their plans to reflect these changes.

These changes are expected to have relatively limited impacts on the plans. Staff estimated the labor time necessary for making these changes by reviewing a sample of the currently

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[8] Staff assume that each facility with a vapor collection system is already visited at least monthly so no additional travel expenses will be incurred.

[9] Adjusted for inflation using a scale up-factor of 1.060 based on the change in the California Consumer Price Index for "All Urban Consumers" from 2019 to 2021. Data from DIR 2022.

approved plans and identifying the areas where updates would be necessary as well as the extent of the updates needed. Based on that review, staff estimate that making the updates would take approximately 10 hours of work on average per plan, and this was increased by 50% to account for additional time required for review and submission of the plans, leading to an estimated total labor time requirement of 15 hours per facility. At the hourly labor rate of $68.79, updating the monitoring plans is estimated to cost $12,382 total for the 12 facilities in the state, as a one-time expense (15 hr/facility x 12 facilities x $68.79).

The Proposed Amendments require owners or operators of underground natural gas storage facilities to keep records of when monitoring systems are taken offline and the reasons why. One utility that owns natural gas underground storage facilities indicated in written comments that there are a variety of reasons why these monitoring systems may be taken offline, such as during power outages and when performing routine maintenance on wellheads (SoCalGas 2023). Taking those comments into consideration along with the fact that the recordkeeping required is fairly simple (tracking when the monitors go offline and are returned online as well as the reason), staff estimate that this requirement will take 5 hours per natural gas underground storage facility per year. At the hourly labor rate of $68.79, this provision is estimated to cost $4,127 per year total for the 12 facilities in the state (5 hr/facility x 12 facilities x $68.79).

8. LDAR Recordkeeping and Reporting

Under the current Regulation, owners or operators are required to conduct daily, weekly, or annual audio-visual inspections of certain types of components for indications of a leak. The Proposed Amendments add that these inspections must be documented with a record of the dates that all audio-visual inspections were conducted at each facility. Staff estimates the labor for this documentation to be 3 minutes (0.05 hr) per day per facility to document whether an inspection occurred, based on retrieving a logbook or opening an electronic file, adding the current date, and putting away the logbook or saving/closing the electronic file. Staff estimate that 380 facilities would be subject to this provision based on regulatory reporting data from 2019. At the hourly labor rate of $68.79, this provision is estimated to cost $477,059 per year (0.05 hr/facility per day x 365 days/yr x 380 facilities x $68.79).

Under the Proposed Amendments, owners or operators are required to report the well production status (whether it is actively producing or not) for all leaks found on wellheads. Staff estimate the labor time per leak for determining and recording the production status of the well for each wellhead leak to be 6 minutes (0.1 hr) based on the incremental time to look up records of production status and record that information. Regulatory reporting for the LDAR provisions of the regulation show 7,208 total leaks were discovered in 2019 with a leak threshold of 10,000 ppm. Staff could not determine from the reported data which of these leaks occurred at wellheads. Additionally, the threshold concentration for a leak was lowered from 10,000 ppm to 1,000 ppm starting in 2020. Staff assume that the reduced number of leaks if only wellhead leaks were accounted for and the increased number of leaks from lowering the leak concentration threshold roughly balance one another, and thus the 2019 reported leak count is a reasonable proxy for this estimate. At the hourly labor rate of $68.79, this provision is estimated to cost $49,584 per year (0.1 hr/leak x 7,208 leaks x $68.79).

9. Investigation and Repair of Remotely Detected Emission Sources

The Proposed Amendments require owners or operators to investigate methane emission plumes reported to them by CARB based on remote monitoring data. Depending on the nature and size of the emission source, the owner or operator could be required to repair it. These follow-up activities resemble traditional LDAR activities but are directed based on knowledge of a likely emission plume location rather than on a regular schedule.

Staff use the assumption that 1% of infrastructure elements (e.g., wells, compressor stations, tanks, etc.) may need to be surveyed each year using this approach. This is higher than the ~0.1% rate of infrastructure elements found leaking in the California oil and natural gas sector using a remote sensing technology in a study performed from 2016-2018 (Duren et al. 2019)[10], to account for the potential that multiple infrastructure elements may need to be surveyed in response to some emission detections and in case more frequent measurements lead to a higher rate of emission plume detections. Staff also assume that the fraction of statewide components that need to be inspected in response to emission plume detections will be proportional to the fraction of statewide infrastructure elements that need to be inspected.

Total statewide component counts are derived from CARB's 2007 Oil and Gas Industry Survey (CARB 2013) and the 15-day Change Attachment 2 for the current regulation (CARB 2017d). This results in the component counts in Table B1, with the total component count estimated at 7,982,198. All of these components will be subject to the remote emission detection investigation and repair provisions in the Proposed Amendments. At an assumed annual inspection rate of 1% of components subject to the provision, this results in an estimated 79,822 components being inspected and subject to possible repair (depending on whether an emission source is found that the Proposed Amendments require to be repaired).

Table B1 Estimated Component Counts by LDAR Rule Subjection

Periodic LDAR Rules Components are Subject To	Number of Components	Source or Calculation Method
CARB's Oil and Gas Methane Regulation section 95669	1,585,700	15-Day Change Attachment 2, Table 1
Exempt (heavy oil < 20 API gravity)	2,692,740	2007 Oil and Gas Industry Survey, Table 8-1
Local Air District Rules	3,703,758	[Total Components] – [CARB's Oil and Gas Methane Regulation] – [Exempt]

[10] Calculated based on number leaks and infrastructure elements surveyed in IPC source category 1B2 in Table 1 (259/270,356).

Total Components	*7,982,198*	*[Total components in 2007 Oil and Gas Industry Survey, Table 8-1] + [Difference between "total" and "LDAR components from survey" in 15-Day Change Attachment 2, Table 1]*

Cost calculation methods to perform follow-up LDAR on those components are estimated in the same way as in the 15-Day Change Attachment 2 from the current regulation, with some modifications (CARB 2017d). Specifically, the following adjustments were made:

- Costs for labor and for recordkeeping and reporting were adjusted for inflation based on the change in the California Consumer Price Index from 2015 (dollar year used in the current Regulation's ISOR) to 2021 (latest available annual figure at the time of the calculation)[11]. This results in a scale-up factor of 1.191.
- Only one inspection is needed per year per component rather than four (because the estimated 1% rate of component inspections is per year, whereas quarterly LDAR occurs 4 times per year on each subject component).
- Staff assume that responding to a remotely detected emission plume is more costly per component surveyed than typical LDAR because it must be done on-demand rather than on a planned and optimized route. Therefore, staff assume that this follow-up response survey costs twice as much a traditional LDAR survey per component.
- Staff assume there are no per-facility set-up costs for these types of surveys because they are performed on-demand by redirecting existing resources.

The equations below are used to calculate annual costs listed in Table B2.

$$Inspection\ cost = Components\ surveyed * \frac{Hourly\ cost \times 2080 \frac{hr}{yr}}{70{,}720\ components\ per\ person\text{-}year} * Cost\ multiplier$$

$$Recordkeeping\ and\ reporting\ cost = Components\ survey * \frac{Cost\ per\ person - year}{70{,}720\ components\ per\ person - year} * Cost\ multiplier$$

where,

Components surveyed = 79,822

Hourly cost = $71.46 per hour for inspections (from 15-Day Change Attachment 2, adjusted for inflation) (CARB 2017d)

Cost multiplier = 2 (assumed that these types of surveys are twice as costly as planned LDAR surveys per component)

Cost per person-year = $17,866 per person-year for recordkeeping and reporting (from 15-Day Change Attachment 2, adjusted for inflation) (CARB 2017d)

[11] Based on annual figures from "All Urban Consumers" column. Data from DIR 2022.

D. Share of Costs by Industry

Staff used the same sets of reporting data used in the overall cost analysis for the number of businesses, facilities, pieces of equipment, and leaks impacted by each provision and separated those counts by whether they belong to the Oil and Gas Extraction sector (NAICS code 2111) or the Pipeline Transport of Natural Gas sector (NAICS code 4862, includes natural gas storage).

Table B2 shows the relevant activity counts and resulting costs broken out by sector. The costs are calculated based on those activity counts and the cost calculation methodology previously described.

Table B2 Activity Data for Cost Calculations Separated by Sector[12]

Item	Oil and Gas Extraction Sector (NAICS 2111)	Pipeline Transport of Natural Gas Sector (NAICS 4862)
Continuous low-bleed pneumatic controllers	39	21
Pneumatic pumps	71	20
Facilities with pneumatic pumps	42	1
Non-production sector reciprocating compressors*	10	137
Facilities performing LDAR	345	35
Operators performing LDAR	86	8
LDAR leaks found	5244	1964
LDAR leaks without an equipment ID	94	1088
All pneumatic controllers	2782	846
Fraction of remotely detected emission plumes in sector based on Duren et al. 2019	93.5%	6.5%

[12] Note the following additional assumptions based on reporting data or staff's engineering judgement based on familiarity with these types of equipment: All wet seal centrifugal compressors are in sector 4862, all underground storage facility costs are in sector 4862, all reciprocating compressors controlled pursuant to the regulation are in sector 2111, and all separator and tank systems are in sector 2111.

First-Year (2024) Costs	***$2,057,009***	***$192,693***
Annual Ongoing Costs Starting the Second Year (2025-2028)	***$988,871***	***$107,602***
Five-Year Total Cost	***$6,012,492***	***$623,099***
Fraction of Five-Year Total Cost	***91%***	***9%***

*"Non-production sector" here is defined based on the subsector categories called out in the regulation for compressor standards. These sectors do not align perfectly with the sectors included in each NAICS code designation so some "non-production sector" reciprocating compressors are included under NAICS code 2111.

III. Cost Savings

There are likely to be direct cost savings resulting from preventing the release of natural gas. CARB staff have determined that the uncertainty associated with quantifying emission reductions from the remote emission detection provision preclude performing a quantitative assessment due to limited available data. Because staff could not quantify emission reductions, these cost savings also cannot be quantified. Once this provision is in effect and the remote sensing technologies have begun collecting data, staff expect to be able to use the remote sensing data paired with owner or operator reporting to assess emission reductions.

Additional qualitative discussions of the overall benefits of the Proposed Amendments are in the ISOR in sections IV and VIII.

IV. Methodology to Determine Costs and Benefits of Alternatives to the Proposed Amendments

A. Alternative 1: Adopting Less Stringent Amendments Alternative

Alternative 1 is to remove the remote emission detection inspection and repair provision. Thus, this alternative would only include changes to address US EPA's SIP decision and to improve clarity based on implementation experience. Costs for Alternative 1 are the same as for the Proposed Amendments, without the cost of the measure to inspect and emission sources detected in remote sensing data. Thus, Alternative 1 would reduce the costs associated with the proposed amendments by $375,886 per year, for a remaining total ongoing cost of $720,586 annually or a 5-year total cost of $4,756,159. Alternative 1 would forgo all potential cost savings and emission reductions (not quantitatively estimated in this document) associated with the repair of remotely detected emission sources.

Although emission reductions could not be quantified, CARB staff expect that the remote emission inspection and repair provision would be more cost effective than traditional LDAR activities. The cost of quarterly LDAR for the components covered by CARB's LDAR provisions was estimated at a net cost of $13.8 million per year in the current Regulation's rulemaking analysis (CARB 2017f), where detections exceeding the leak threshold were found at 0.31% of components in 2019 (CARB 2022d). By comparison, the incremental cost of the remote emission inspection and repair provision is estimated at less than 3% of the total pre-existing annual LDAR costs, with an expected higher rate of leak detections per component surveyed due to targeting resources at known emission locations. Further, the costs are directly tied to the efficacy of the detection efforts. That is, costs are only incurred to the extent that leaks are detected.

B. Alternative 2: Adopting More Stringent Amendments Alternative

1. Alternative 2 Description

Alternative 2 is to target additional emission reductions. The added provisions under this alternative include the following:

1. *Prohibit venting pneumatic controllers.* Currently, continuous-bleed pneumatic controllers are prohibited from venting gas to the atmosphere, except for low-bleed pneumatic controllers installed prior to January 1, 2016. Intermittent-bleed pneumatic controllers are also currently allowed to vent to the atmosphere when actuating. This measure would require the remaining low-bleed controllers and all intermittent bleed controllers to either be replaced with no-bleed controllers or have their vapors collected.
2. *Remove heavy oil LDAR exemption.* Currently, the regulation's LDAR provisions do not apply to components used exclusively for oil with an API gravity of less than 20. This measure would expand the coverage of the regulation's LDAR provisions to include components used for oil with an API gravity of less than 20.

2. Summary of Alternative 2 Costs and Benefits

As a whole, Alternative 2 would add approximately $27.4 million to $28.3 million per year in costs (not considering cost savings) over the Proposed Amendments. The additional cost range is reduced to $26.7 million to $27.6 million if considering cost savings. Emission reductions from the additional measures in this alternative are approximately 156,495 metric tons of carbon dioxide equivalent per year (MT CO_2e/yr, using a CH_4 global warming potential of 25) (Table B3).

Table B3 Annual Costs and Cost Savings for Each Incremental Measure in Alternative 2

Measure	Annual Cost	Annual Cost Savings	Annual Net Cost	Emissions Reductions (MT CO_2e/yr)
Prohibit pneumatic controller venting	$1,412,780-$2,281,965	$725,589	$687,191-$1,556,376	149,000

Remove heavy oil LDAR exemption	$26,023,588	$36,501	$25,987,087	7,495
Alternative 2, Total	***$27,436,368-$28,305,553***	***$762,090***	***$26,674,278-$27,543,463***	***156,495***

Alternative 2 would cost approximately $143,817,429 over 5 years, including all provisions in the Proposed Amendments (and using the lower estimate of the incremental Alternative 2 provisions). Alternative 2 would have annual cost savings of approximately $3,810,450 over 5 years including all provisions in the Proposed Amendments.

The remainder of the section includes relevant equations, staff assumptions, and estimated costs for Alternative 2.

3. Capital Recovery Factor and Equipment Lifetime

One-time capital costs in this provision and others under Alternative 2 are amortized into annual costs to reflect that businesses generally do not pay the total cost up front and to allow annual cost to be compared to annual emission reductions. One-time costs are amortized using the Capital Recovery Factor (CRF), the same method used to amortize costs in the original regulation's ISOR Appendix B Economic Analysis (CARB 2016b).

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

where,

CRF = Capital Recovery Factor

i = discount rate; 0.05 in the main analysis (assumed to be 5%, the same assumed in the original regulation's economic analysis (CARB 2016b)), or 0.03 and 0.07 in the sensitivity analysis (to account for uncertainty)

n=project horizon or useful life of equipment

The five percent discount rate was chosen because it is the average of what the United States Office of Management and Budget recommends (OMB 2003; three and seven percent) and what US EPA has used historically for regulatory analyses.

The useful life of equipment was derived from cost estimates from the US EPA 2021 TSD (US EPA 2021) for controllers and combustion devices, and from the original 15-day change errata for LDAR set-up costs (CARB 2017f). Table B4 summarizes the equipment lifetimes and CRFs based on the equation above for each type of capital equipment analyzed under Alternative 2 using the five percent discount rate.

Table B4 Lifetime and CRFs for Capital Equipment and LDAR Set-Up Costs Assessed in Alternative 2

Equipment	Equipment Life	Capital Recovery Factor at 5% Discount Rate (Main Analysis)
Electronic or solar controllers	15 years	0.096
Compressed air controllers	15 years	0.096
LDAR setup	5 years	0.231

Sensitivity Analysis for Capital Recovery Factor Discount Rate

The discount rate used for calculation of the CRFs is an uncertain assumption. In this section, the overall cost estimates are presented for the cases of 3% and 7% discount rates as a sensitivity analysis on the importance of the discount rate assumption. All calculations were performed in the same manner as the main analysis, except the CRFs in Table B5 were used instead of those in Table B4.

Table B5 Lifetime and CRFs for Capital Equipment and LDAR Set-Up Costs Assessed in the Alternative 2 Sensitivity Analysis on Discount Rate

Equipment	Equipment Life	Capital Recovery Factor at 3% Discount Rate (Lower Sensitivity Estimate)	Capital Recovery Factor at 7% Discount Rate (Higher Sensitivity Estimate)
Electronic or solar controllers	15 years	0.084	0.110
Compressed air controllers	15 years	0.084	0.110
LDAR setup	5 years	0.218	0.244

Table B6 shows the annual costs without savings and the annual cost with savings (net cost) using 3% and 7% discount rates. The alternative discount rates in this sensitivity analysis only change the total annual cost and net cost by up to approximately +/- 1.5%. Therefore, the choice of discount rate has only a minimal effect on the estimated costs and cost effectiveness of Alternative 2.

Table B6 Annual Costs and Cost Savings for Each Measure in Alternative 2 using 3% and 7% Discount Rates for Amortization

Measure	Annual Cost with 3% Discount Rate	Annual Net Cost with 3% Discount Rate	Annual Cost with 7% Discount Rate	Annual Net Cost with 7% Discount Rate
Prohibit pneumatic controller venting	$1,236,206-$1,996,718	$510,617-$1,271,129	$1,618,785-$2,614,768	$893,196-$1,889,179
Remove heavy oil LDAR exemption	$25,986,274	$25,949,773	$26,060,902	$26,024,401

4. Cost and Savings Estimates: Prohibit Venting Pneumatic Controllers

Alternative 2 would prohibit all pneumatic controllers that vent natural gas to the atmosphere. For purposes of this cost analysis, staff assume that this would be accomplished by replacing emitting controllers (low-bleed and intermittent-bleed controllers) with types that are inherently non-emitting. For small and medium facilities, staff assume that these would include either grid-electric or solar-powered controllers. For large facilities, staff assume either grid-electric or compressed air controllers (powered by grid-electricity) would be feasible. Compressed air controllers require a compressed air system that may only make sense for a large facility with many controllers.

Costs by Facility Size

Table B7 shows cost estimates from the US EPA 2022 TSD (US EPA 2022c) for converting three different "model plants" of small, medium, and large size onto non-emitting controller technologies. The table below is based on tables 3-3, 3-13, and 3-16 in the US EPA TSD and all costs are adjusted to 2021$ (from 2019$) using the same methodology described previously.

Table B7 Costs to Convert Production, Gathering and Boosting, Transmission, and Storage Sites to Non-emitting Controllers

Model Plant	Number of Controllers*	Control Option	Unamortized Cost ($)	Amortized Annual Cost ($/yr)**
Small	4 controllers	Grid-electric powered controllers	$21,821	$2,095
Small	4 controllers	Solar electric controllers	$24,004	$2,304
Medium	8 controllers	Grid-electric powered controllers	$36,368	$3,491
Medium	8 controllers	Solar electric controllers	$40,733	$3,910
Large	20 controllers	Grid-electric powered controllers	$80,010	$7,681
Large	20 controllers	Compressed air controllers (grid-powered)	$135,069	$12,967

*Sourced from Table 3-3 of the EPA cost analysis
**Based on capital cost and CRF with a discount rate of 5%

Note: the EPA cost analysis contains separate cost data for natural gas processing plants; however, in California there are no pneumatic controllers that vent natural gas at natural gas processing plants.

Staff used regulatory data from 2019 to categorize each reporting facility into small, medium, large, or extra-large based on the number of emitting controllers at each facility (emitting controllers are those which release natural gas to the atmosphere as part of their normal operation). Small facilities were those with 4 or fewer emitting controllers, medium facilities were those 5-8 emitting controllers, large facilities were those with 9-20 emitting controllers, and extra-large facilities were those with more than 20 emitting controllers. For small, medium, and large facilities, the costs in Table B7 were assigned to those facilities. For extra-large facilities, the cost of converting a large facility was scaled up linearly based on the number of emitting controllers (by the ratio of the count of emitting controllers at the facility to 20).

Table B8 lists the number of facilities which fell into each category along with the total costs of the lower and higher option for all of those facilities using a 5% discount rate for amortization.

Table B8 Number of Facilities and Annual Costs by Facility Size

Facility Size	Number of Facilities	Unamortized Cost ($/yr) – Less Expensive Option	Unamortized Cost ($/yr) – More Expensive Option	Amortized Annual Cost ($/yr) – Less Expensive Option	Amortized Annual Cost ($/yr) – More Expensive Option
Small	46	$981,938	$1,080,166	$94,275	$103,680
Medium	24	$872,843	$977,593	$83,784	$93,840
Large	18	$1,440,183	$2,431,248	$138,258	$233,406
Extra-large	36	$11,421,449	$19,281,146	$1,096,463	$1,851,039

Based on this analysis, the estimated cost to convert all of the existing facilities with emitting pneumatic controllers to non-emitting controllers would be between a lower estimate of $1,412,780 and a higher estimate of $2,281,965 annually. Up-front unamortized costs would be $14,716,413 to $23,770,152.

Equation: Conversion of Natural Gas Flow Rate to Methane Emission Rate

Total methane emission reductions from this measure are estimated based mostly on 2019 reporting data. Emission rates of natural gas from low-bleed pneumatic controllers are reported under the regulation. Staff added up the total reported flow rates from all low-bleed pneumatic controllers in 2019 (182.6 standard cubic feet per hour or scf/hr of natural gas). Staff then converted the total reported flow rate from scf/hr of natural gas to metric tons of methane per year (MT CH_4/yr) using the equation below, which yields a total emission rate of 24 MT CH_4/yr for low-bleed controllers.

$$Mass\ of\ CH_4 = \frac{Volume\ of\ NG * Molar\ Mass\ of\ CH_4 * Mole\ Fraction\ of\ CH_4\ in\ NG * 8760\frac{hr}{yr}}{Molar\ Volume * 1000\frac{kg}{MT}}$$

where,

Mass of CH_4 is in MT/yr

Volume of NG (natural gas) = 182.6 scf/hr

Molar volume = 836.6 scf/kg-mol (at 60°F and 1 atm; API 2021)

Mole fraction of CH_4 in NG = 0.788 scf CH_4/scf NG (field gas; API 2021)

Molar mass of CH_4 = 16.04 kg/kg-mol

For intermittent-bleed pneumatic controllers, staff used 2019 reported data on the total number of uncontrolled intermittent-bleed controllers (3,322) and an emission factor from the US EPA's Greenhouse Gas Reporting Program (13.5 scf/hr/controller) (US EPA 2023). Multiplying the controller count by the emission factor results in a total natural gas emission rate of 44,847 scf/hr. The same approach was used to convert the total flow rate in scf/hr of natural gas to MT/yr of methane as was used for low-bleed controllers, resulting in an emission rate of 5,935 MT CH_4/yr.

Based on the calculations above, the total emissions from low-bleed and intermittent-bleed pneumatic controllers are estimated at 394,459 thousand cubic feet per year (MCF/yr) of natural gas[13] or 5,960 MT CH_4/yr (or 149,000 MT CO_2e/yr using 100-yr global warming potential of 25). Thus, replacing all of these controllers with non-emitting options would save that amount of field-quality natural gas and reduce that amount of methane emissions.

Equation: Cost Savings from the Prevention of Natural Gas Loss

To estimate the cost savings by preventing the loss of natural gas that could otherwise be used or sold, staff converted from field gas volume flow rate to pipeline quality gas volume flow rate based on the ratio of the methane composition in each. Staff assume that natural gas is valued at $3.21 per MCF, based on the 5-year average price forecast of Henry Hub natural gas starting in 2024 from EIA's Annual Energy Outlook (EIA 2022a). Staff acknowledge that forecasts for fuel and energy prices can fluctuate due to unexpected shocks in the economy. If the realized fuel prices differ from what is forecasted, there will be proportional changes in the cost savings.

However, it is unlikely that all natural gas that is prevented from being released to the atmosphere will be put toward productive use. CalGEM data from 2021 show that approximately 31% of the natural gas produced from production wells in California is reinjected (CalGEM 2023b, CalGEM 2023c). Thus, the quantity of gas prevented from release is multiplied by a beneficial use factor of 0.69 when estimating cost savings. Using the equation below, staff calculated the value of natural gas savings at $725,589 per year.

$$Value\ of\ NG = Volume\ of\ field\ NG * \frac{0.788 \frac{scf\ CH_4}{scf\ field\ NG}}{0.949 \frac{scf\ CH_4}{scf\ pipeline\ NG}} * NG\ price * Beneficial\ use\ factor$$

[13] Converted from scf/hr as follows: 45,029.6 scf/hr*8760 hr/yr*0.001 MCF/scf

where,

Value of NG is in \$/yr

Volume of field NG = 394,459 MCF/yr

NG price = \$3.21/MCF (EIA 2022a)

Beneficial use factor = 0.69 (because 31% of gas is assumed to be reinjected)

5. Cost and Savings Estimates: Removal of the Heavy Oil LDAR Exemption

Alternative 2 would remove the LDAR exemption for heavy oil components (handling exclusively oil with an API gravity of less than 20). The cost of removing this exemption was calculated using the same methods originally used to calculate LDAR costs in the current regulation's ISOR, but with costs updated based on inflation.

The cost of an LDAR program is broken down into three elements: inspection cost, set-up cost, and recordkeeping and reporting cost. The set-up cost is amortized over 5 years. A 5-year amortization period was selected because operators previously indicated that LDAR companies are expected to change every 5 years, as reported in the 15-day change errata for the current regulation (CARB 2017f). The following equations are used to calculate costs for each.

$$Inspection\ Cost = \frac{Number\ of\ components * Hourly\ cost * 2080\frac{hr}{yr} * 4\frac{inspections}{component}}{70{,}720\frac{components}{person - year}}$$

$$Setup\ costs = Cost\ per\ facility * \frac{799\ facilities\ from\ Survey}{1{,}339{,}185\ components\ from\ Survey} * Number\ of\ component * Amoritization\ factor$$

$$Recordkeeping\ and\ reporting\ cost = \frac{Cost\ per\ person - year}{70{,}720\frac{components}{person - year}} * \frac{4\ inspections}{component - year} * Number\ of\ components$$

where,

Number of heavy oil components = 2,692,740

Hourly cost = \$71.46 (scaling up an estimate of \$60 from the original Regulation's ISOR Appendix B by the inflation factor of 1.191)

Amortization factor = 0.231 (Table B4)

Cost per person-year = \$17,866

The number of components in heavy oil service is estimated to be 2,692,740, as reported in Table 8-1 of CARB's 2007 Oil and Gas Survey (CARB 2013). The hourly cost for inspection is estimated to be $71.46, based on scaling up an estimate of $60 from the current Regulation's ISOR Appendix B by the inflation factor of 1.191 (as described previously, to adjust from 2015$ to 2021$). The set-up cost per facility is estimated to be $1,787, based on scaling up an estimate of $1,500 from the current Regulation's ISOR 15-day change Attachment 2 for inflation (CARB 2017d). The amortization factor for set-up costs is 0.231 from Table B4. The cost per person-year for recordkeeping is estimated to be $17,866, based on scaling up an estimate of $15,000 from the current regulation's ISOR 15-day change Attachment 2 for inflation. The one person-year is estimated to be able to cover recordkeeping and reporting requirements for 70,720 components for that cost, based on information in the current regulation's ISOR.

Based on the equations and data above, the total cost of removing the heavy oil LDAR exemption for inspection, setup, and recordkeeping and reporting is estimated at $26,874,047 annually (Table B9).

Table B9 Annual Cost Estimates by Activity for Heavy Oil LDAR

Activity	Annual Cost
Inspection	$22,639,454
Set-up	$663,045*
Recordkeeping and reporting	$2,721,088

*Amortized annual cost at 5% discount rate. Unamortized cost is $2,870,325.

Emissions Estimates: Emissions by Heavy Oil Component Type and Total Reductions

Total emissions from heavy oil components are estimated in Table B10 using the counts of each type of component in heavy oil service from the 2007 Oil and Gas Industry Survey (CARB 2013; Table 8-1) and total hydrocarbon (THC) emission factors for heavy oil components from a CAPCOA report (CAPCOA 1999).

Table B10 Heavy Oil Component Counts, Emissions Factors, and Estimated Total Emissions

Component Type	Number of Components in Heavy Crude Service	THC Emission Factor (kg/hr/source)	THC Emissions (kg/yr)*
Valves	321,321	1.40E-05	39,407
Connectors	1,932,617	8.00E-06	135,438
Flanges	370,274	2.30E-05	74,603
Open-ended lines (low-emitters)	9,416	1.50E-05	1,237
Open-ended lines (high-emitters)	192	7.11E-02	119,684
Others	54,978	5.70E-05	27,452

* Product of the number of components and the emission factor adjusted from kg/hr to kg/yr (by multiplying by 8,760 hr/yr)

Notes: Analysis assumes 2% of open-ended lines in heavy oil service are high-emitters and 98% are low-emitters, based on rounding the estimated fraction in the original regulation's 15-day change Attachment 2 (CARB 2017d; Table A-1). All other component types were estimated to be low-emitters based on the absence of a high-emitter emissions factor. Pump seals excluded because there is no heavy oil emissions factor available.

The total THC emissions from heavy oil components are estimated at 397,820 kg/hr based on Table B10. Staff converted the total THC emissions to estimated methane emissions based on a generic mass speciation profile of THC emissions for heavy crude operations (API 2021; Table C-1). This speciation profile gives a mass fraction of methane in THC emissions from heavy crude operations of 94.2%.

Thus, 397,820 kg THC/hr is estimated to be equivalent to 374,746 kg CH_4/hr (or 374.7 MT CH_4/yr). Based on a previous estimate by CARB, staff estimate that 80% of these emissions could be abated using quarterly LDAR at a 1,000 ppm leak threshold (CARB 2018). This results in an estimated emissions abatement of 299.8 MT CH_4/yr or 7,495 MT CO_2e/yr from removing the heavy oil LDAR exemption.

Cost Savings Equation: Volume of Natural Gas Savings

To estimate the cost savings gained by preventing the loss of natural gas, the mass of methane emissions abated is converted to volume of natural gas leakage abated using the equation below.

$$Volume\ of\ Natural\ Gas\ Savings = \frac{Mass\ of\ CH_4\ Abated * Molar\ Volume}{Molar\ Mass\ of\ CH_4 * Mole\ Fraction\ of\ CH_4\ in\ NG * 1000\frac{scf}{MCF}}$$

where,

Volume of Natural Gas Savings is in MCF/yr

Mass of CH_4 abated = 299.8 MT CH_4/yr

Molar volume = 836.6 scf/kg-mol (API 2021; at 60°F and 1 atm)

Molar mass of CH_4 = 16.04 kg/kg-mol

Mole fraction of CH_4 in NG = 0.949 scf CH_4/scf NG (pipeline gas, CARB 2016b)

This results in estimated natural gas savings of 11,627 MCF/yr. However, staff assume that only 69% of the saved natural gas would be sold or put to other beneficial use (with the remaining amount reinjected as described previously). At $3.21/MCF, this represents savings of $36,501 per year.

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