MINE SAFETY AND HEALTH ADMINISTRATION (MSHA) RESPIRABLE CRYSTALLINE SILICA RULE

FINAL REGULATORY IMPACT ANALYSIS

Docket No. MSHA–2023-0001

March 2024

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ABBREVIATIONS

AIS	Abbreviated injury scale
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BEA	Bureau of Economic Analysis
BLS	Bureau of Labor Statistics
CAGR	Compound Annual Growth Rate
CWP	Coal Workers' Pneumoconiosis
DOT	Department of Transportation
ESRD	End-stage renal disease
FTE	Full-time equivalent
FRA	Final Risk Assessment
FRIA	Final Regulatory Impact Analysis
GDP	Gross domestic product
ILO	The International Labour Organization
ISO	International Organization for Standardization
MNM	Metal and non-metal
MSHA	Mine Safety and Health Administration
NIOSH	National Institute for Occupational Safety and Health
NMRD	Non-malignant respiratory disease
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
PLHCP	Physician or other licensed healthcare professional
PMF	Progressive Massive Fibrosis
PV	Present value
QRA	Quantitative risk assessment
RCMD	Respirable coal mine dust
SOPs	Standard operating procedures
VSL	Value of a statistical life
WTP	Willingness to pay

EXECUTIVE SUMMARY

MSHA's Final Regulatory Impact Analysis (FRIA) assesses the costs, benefits, economic feasibility, and the economic impacts of the final respirable crystalline silica rule and evaluates regulatory alternatives to the final rule. Under the Federal Mine Safety and Health Act of 1977 (Mine Act), the Secretary of Labor (Secretary) is required to develop and promulgate improved mandatory health and safety standards to prevent hazardous and unhealthy conditions and protect the health and safety of the nation's miners. 30 U.S.C. 811(a). Under Section 101(a) of the Mine Act, these standards must protect lives and prevent injuries in mines and be "improved" over any standards they replace or revise. Moreover, the Secretary must set these standards to assure, based on the best available evidence, that no miner will suffer material impairment of health or functional capacity from exposure to toxic materials or harmful physical agents over their working lives. 30 U.S.C. 811(a)(6)(A). In developing standards that attain the "highest degree of health and safety protection for the miner," the Mine Act requires that the Secretary consider the latest available scientific data in the field, the feasibility of the standards, and experience gained under the Mine Act and other health and safety laws. *Id*. MSHA's final respirable crystalline silica rule will fulfill Congress' direction by avoiding material impairment of health or functional capacity caused by exposure to respirable crystalline silica within the mining industry.

MSHA also acknowledges applicable executive orders pertinent to rulemaking. Executive Order (E.O.) 12866, as amended by E.O. 14094, and E.O. 13563 direct agencies to assess all costs and benefits of available regulatory alternatives and, if regulation is necessary, to select regulatory approaches that maximize net benefits (including potential economic, environmental, public health and safety effects, distributive impacts, and equity).[1]

Under E.O. 12866 (as amended by E.O. 14094), the Office of Management and Budget (OMB)'s Office of Information and Regulatory Affairs (OIRA) determines whether a regulatory action is significant and, therefore, subject to the requirements of the E.O. and review by OMB. 58 FR 51735, 51741 (1993). As amended by E.O. 14094, section 3(f) of E.O. 12866 defines a "significant regulatory action" as a regulatory action that is likely to result in a rule that may: (1) have an annual effect on the economy of $200 million or more; or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or state, local, territorial, or tribal governments or communities; (2) create a serious inconsistency or otherwise interfere with an action taken or planned by another agency; (3) materially alter the budgetary impact of entitlements, grants, user fees or

[1] Executive Order 12866 of September 30, 1993: Regulatory Planning and Review. 58 Fed. Reg. 51735. October 4, 1993. Accessed at https://www.archives.gov/files/federal-register/executive-orders/pdf/12866.pdf on January 5, 2023.
Executive Order 14094 of April 6, 2023: Modernizing Regulatory Review. 88 Fed. Reg. 21879. April 11, 2023. Accessed at https://www.federalregister.gov/documents/2023/04/11/2023-07760/modernizing-regulatory-review on April 19, 2023.
Executive Order 13563 of January 18, 2011: Improving Regulation and Regulatory Review. January 18, 2011. Accessed at https://www.regulations.gov/document/EPA-HQ-OA-2018-0259-0005 on November 13, 2023.

loan programs or the rights and obligations of recipients thereof; or (4) raise legal or policy issues for which centralized review would meaningfully further the President's priorities or the principles set forth in the E.O. OMB has determined that this rule is significant under section 3(f)(1) of E.O. 12866. Pursuant to the Congressional Review Act (5 U.S.C. 801 et seq.), OIRA has determined that this rule meets the criteria set forth in 5 U.S.C. 804(2).

E.O. 13563 directs agencies to propose or adopt a regulation only upon a reasoned determination that its benefits justify its costs; the regulation is tailored to impose the least burden on society, consistent with achieving the regulatory objectives; and in choosing among alternative regulatory approaches, the agency has selected those approaches that maximize net benefits. 75 FR 3821 (2011). E.O. 13563 recognizes that some benefits are difficult to quantify and provides that, where appropriate and permitted by law, agencies may consider and discuss qualitative values that are difficult or impossible to quantify, including equity, human dignity, fairness, and distributive impacts.

To comply with E.O.s 12866 and 13563, MSHA has prepared a Final Regulatory Impact Analysis (FRIA) for the final rule, presented in this document. The purpose of this FRIA is to:

- Profile the mining industry impacted by the final rule;
- Estimate the monetized benefits attributable to the new permissible exposure limit (PEL) resulting from reductions in
    - fatal cases of:
        - lung cancer,
        - non-malignant respiratory disease,
        - end-stage renal disease,
        - silicosis,
    - and non-fatal cases of silicosis;
- Identify additional non-quantified benefits expected from the final rule;
- Estimate the costs that affected mines will incur to achieve compliance with the final rule;
- Assess the economic feasibility of the final rule for the mining industry;
- Evaluate the principal regulatory alternatives to the final rule that MSHA has considered; and
- Respond to public comments on the Preliminary Regulatory Impact Analysis (PRIA).

This FRIA contains supporting data and explanation for the summary materials presented in the final rule. The supporting data and explanations of the summary materials discussed here have been placed in the rulemaking docket at www.regulations.gov, docket number MSHA-2023-0001.

This FRIA relies on the results of MSHA's Final Risk Analysis (FRA) and MSHA's Technological Feasibility Analysis, which reflect revisions made in response to comments received by the public under the proposed rule. It assesses the costs and benefits in the metal and nonmetal (MNM) and coal industries of reducing miners' exposures to respirable crystalline silica to a maximum of 50 μg/m^3 for a full-shift exposure, calculated as an 8-hour time weighted average (TWA), and of complying with the standard's other requirements.

The final rule establishes a new PEL of 50 μg/m^3 for a full-shift exposure, calculated as an 8-hour TWA, and an action level of 25 μg/m^3. The standard requires that mine operators utilize controls to maintain miner exposure levels at or below the PEL. These controls may include the installation of new engineering controls, the repair and maintenance of existing engineering controls, or the introduction of supplementary administrative controls. Temporary respiratory protection is also required for exposures above the PEL.

The final rule further establishes exposure monitoring requirements (including first-time and second-time sampling, above-action-level sampling, corrective actions sampling, post-evaluation sampling, and periodic evaluations defined in the rule) for all mines and medical surveillance requirements for MNM miners.[2] These requirements of the final rule have been established to protect miners from respirable crystalline silica-related morbidity and mortality. In addition, the final rule revises existing respiratory protection standards. MSHA is incorporating by reference American Society for Testing and Materials (ASTM) F3387-19, "Standard Practice for Respiratory Protection." ASTM F3387-19 replaces the 1969 American National Standards Institute (ANSI) "Practices for Respiratory Protection" in order to provide updated protection from all respirable hazards.

The final rule has several changes from the proposed rule published by MSHA. Changes include updates to the compliance dates; removal of the use of objective data (defined in the NPRM)[3] and historical sample data to establish compliance with the PEL; updates to immediate reporting of above-PEL sample results and the frequency of periodic evaluations; updates to the respirator use provision; and updates to medical surveillance commencement and reporting of chest X-ray classification results.

The FRIA was revised in response to these rule changes and to comments on the preliminary regulatory impact analysis (PRIA). Additionally, the FRIA methodology was revised so that all compliance costs and benefits are now annualized over 60 years. Lastly, in this FRIA, compliance costs and benefits are updated to reflect 2022 dollars using the GDP implicit price deflator.

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[2] In the final rule, periodic evaluations are defined as evaluations at least every 6 months or whenever there is a change in: production; processes; installation or maintenance of engineering controls; installation or maintenance of equipment; administrative controls; or geological conditions.

[3] In the NPRM, "objective data" was defined as "information such as air monitoring data from industry-wide surveys or calculations based on the composition of a substance, demonstrating miner exposure to respirable crystalline silica associated with a particular product or material or a specific process, task, or activity. The data must reflect mining conditions closely resembling or with a higher exposure potential than the processes, types of material, control methods, work practices, and environmental conditions in the operator's current operations."

The final rule covers all mine operators and miners. The mining industry includes the MNM and coal mining sectors. The MNM mining sector employs an estimated 211,203 miners and the coal mining sector employs an estimated 73,576 miners (see FRIA Table 2-4). Thus, the MNM mining sector employs approximately 74 percent of all miners affected by the final rule, compared to 26 percent in the coal mining sector.[4]

MSHA estimates the final rule will have an annualized cost of $90.3 million in 2022 dollars at a discount rate of 3 percent.[5] The breakdown of this total cost value by compliance cost for each provision is as follows: 59.0 percent is attributable to exposure monitoring; 20.9 percent to medical surveillance; 15.1 percent to engineering, improved maintenance and repair, and administrative controls; 3.7 percent to additional respiratory protection (e.g., when miners need temporary respiratory protection from exposure at the new PEL when it would not have been necessary at the existing PEL); and 1.4 percent to incorporation of ASTM F3387-19 respiratory protection practices (see FRIA Table ES - 1). MSHA further estimates that of the annualized cost of $90.3 million, the MNM sector will incur $82.1 million (90.9 percent) and the coal sector will incur $8.2 million (9.1 percent) in annualized compliance costs (see FRIA Table ES - 2). The difference in cost between the MNM and coal sectors is primarily driven by the much larger number of MNM mines, as well as differences in mine size and the extent to which current exposures are already below 50 µg/m^3. In addition, MNM mine operators will incur costs to meet the medical surveillance requirements which contributes to the difference in total costs between the MNM and coal sectors.

FRIA Table ES - 1. Summary of Estimated Annualized Compliance Costs by Provision (in millions of 2022 dollars)

Provision	0 Percent Discount Rate		3 Percent Discount Rate		7 Percent Discount Rate	
	Annualized Cost	Percent	Annualized Cost	Percent	Annualized Cost	Percent
Exposure Controls [§60.11]	$13.79	15.5%	$13.66	15.1%	$13.40	14.5%
Exposure Monitoring [§60.12 and §60.13]	$51.60	58.1%	$53.24	59.0%	$55.64	60.2%
Respiratory Protection [§60.14]	$3.38	3.8%	$3.32	3.7%	$3.22	3.5%
Medical Surveillance [§60.15]	$18.82	21.2%	$18.84	20.9%	$18.82	20.4%
Subtotal, Part 60 Costs	*$87.59*	*98.7%*	*$89.05*	*98.6%*	*$91.07*	*98.6%*
ASTM 2019 Parts 56, 57, and 72	$1.18	1.3%	$1.23	1.4%	$1.32	1.4%
Total, All Mines	***$88.77***	***100.0%***	***$90.28***	***100.0%***	***$92.39***	***100.0%***

Note: Due to the uncertainty on how many currently employed miners will participate in voluntary medical surveillance programs, MSHA considered two rates (25 percent and 75 percent) when estimating medical

[4] The analyses performed by MSHA rely largely on miner full-time equivalents (FTEs) as opposed to the total number of miners employed. FTEs are calculated as the total number of hours worked in the given sector divided by 2,000 hours (i.e., the number of hours defined as full-time). When comparing proportions of miner FTEs, the MNM mining sector contributes 72% compared to 28% from the coal mining sector.

[5] Using a 7 percent discount rate, the annualized cost of the rule is estimated at $92.4 million in 2022 dollars.

surveillance costs. The values presented in this table are the average costs between the assumed participation rates of 25 percent and 75 percent.

FRIA Table ES - 2. Summary of Estimated Annualized Compliance Costs by Sector (in millions of 2022 dollars)

Sector	Number of Mines [a]	0 Percent Discount Rate		3 Percent Discount Rate		7 Percent Discount Rate	
		Annualized Cost	Percent	Annualized Cost	Percent	Annualized Cost	Percent
Total, All Mines	***12,631***	***$88.77***	***100.0%***	***$90.28***	***100.0%***	***$92.39***	***100.0%***
Metal/ Nonmetal	11,525	$80.75	91.0%	$82.06	90.9%	$83.84	90.7%
Coal	1,106	$8.02	9.0%	$8.22	9.1%	$8.55	9.3%

Note: [a] The estimated number of current and future mines are based on 2019 data (MSHA, 2022d) and are assumed to remain constant through the 60 years following the start of implementation.

MSHA annualizes all costs using 3 percent and 7 percent real discount rates as recommended by OMB. Real discount rates are distinct from nominal discount rates because they apply to values that have already been adjusted for inflation. Throughout the remainder of this document and unless otherwise specified, discount rates refer to real discount rates. Moreover, monetized benefits are presented using a 3 percent discount rate unless otherwise specified.

All costs and benefits are annualized over a 60-year analysis period. MSHA annualizes benefits of the final rule over a 60-year period to reflect the time needed for benefits to reach the long-run values projected in MSHA's FRA.[6,7] For analytic consistency, costs are also estimated and annualized over a 60-year period. This means that costs for durable equipment are estimated based on their expected service life. For example, the expected service life of a building ventilation system is 30 years; to estimate 60 years of capital costs MSHA assumes that a mine operator would purchase the system in year 1 and again in year 31. Therefore, MSHA's complete analysis of this rule is based on a timeframe of 60 years (which is enough time to analyze 45 years of working life and 15 years of retirement for new miners who only experience new-PEL exposures). For the purposes of the analysis, MSHA holds employment constant over this period.

In estimating the costs of complying with the new PEL (50 $\mu g/m^3$) for MNM and coal mines, MSHA assumed that all mines were compliant with the existing standards of 100 $\mu g/m^3$ for MNM mines (for a full shift, calculated as an 8-hour TWA) and 85.7 $\mu g/m^3$ for coal mines (for a full shift, calculated as an 8-hour TWA).

[6] In the FRIA, the term "long run" refers to the future period of time when all surviving working and retired miners will have only been exposed under the new PEL at any time in their working lives.
[7] Technically, MNM benefits would not reach their long-run average values until 61 years following the compliance date for the coal sector since the compliance deadline for MNM is 1 year after the compliance deadline for coal.

In the FRA, MSHA analyzed the avoided cases attributable to the new PEL by comparing a population of miners exposed only under the new PEL to one exposed only under the existing standards throughout their working and retired lives. These benefits included reductions to excess cases of fatal silicosis, fatal non-malignant respiratory diseases (NMRD), fatal end-stage renal disease, fatal lung cancer, and non-fatal silicosis. These five health outcomes were chosen based on their well-established exposure-response relationships with occupational respirable crystalline silica exposure.[8] In the FRIA, MSHA estimates that, during the 60 years following the start of implementation (i.e., the analysis timeframe for the cost analysis), annual benefits would gradually increase because miners would have a combination of exposures under both the existing standards and the new PEL. Thus, MSHA estimates the excess morbidity and mortality avoided during the same analysis timeframe and monetizes these benefits so that benefits are directly comparable to the costs of the final rule. As a result, the number of cases avoided presented in the FRIA during the 60-year analysis period following the start of implementation is fewer than the number of lifetime cases avoided estimated in the FRA, since miners with exposure under the current limits are gradually replaced by miners with exposure under the new PEL during the 60 years following the start of implementation of the rule.

In the Preliminary Risk Analysis (PRA), MSHA underestimated the number of miners who would benefit from the proposed rule. Based on the 2019 Quarterly Employment Production Industry Profile (MSHA 2019a) and the 2019 Quarterly Contractor Employment Production Report (MSHA, 2019b), the number of working miner full-time equivalents (FTEs) was assumed to be 184,615 for MNM and 72,768 for coal. In the PRA, MSHA assumed excess cases of disease would be reduced only among the working miners. However, once the current mining workforce is replaced with new entrants to the mining industry so that the entire mining workforce has worked only under the new PEL for their entire working life, the future mining workforce will experience fewer excess deaths and illnesses from excess exposure to respirable crystalline silica. The PRA's methodology did not include the number of future retired miners who will experience lower exposures for their working lives under the final rule and will continue to benefit during retirement, and therefore, the PRA underestimated the benefits attributable to the final rule. Consequently, the PRIA also underestimated the benefits attributable to the final rule. While the PRIA did consider reductions in excess risk during years of retirement for future retired miners, the PRIA did not account for the fact that future retired miners are among the population that will benefit after the start of implementation.

The FRA and the FRIA were updated to account for benefits among both working miners and future retired miners. It is important to note, however, that the FRIA only monetizes benefits to *future* retired miners – i.e., retired individuals who were employed as miners at least one year after the start of implementation. The FRIA methodology does not attribute any health benefits to individuals who retired *before* the start of implementation of the final rule. The FRIA is updated to reflect the number of future retired miners, which increases gradually after the start of implementation. For example, in the first year after the start of

[8] The Health Effects document and the FRA discuss the evidence for these relationships in depth, as well as the exposure-response models used for analysis in the FRA.

implementation, there will be no retired miners who benefit from the rule. In the second year after the start of implementation, there will be one cohort of retired miners who benefit from the rule (i.e., those in their final year of mining when implementation began). In this way, the FRIA monetizes benefits to future retired miners while accounting for the fact that future retired miners who benefit from the rule increase in size gradually during the 60-year analysis period.

Using peer-reviewed exposure-response models published in science journals, MSHA estimates that:

- For a future population of working and retired miners only exposed under the new PEL, the final respirable crystalline silica rule will result in a total of 1,067 lifetime avoided deaths (982 in MNM mines and 85 in coal mines) and 3,746 lifetime avoided morbidity cases (3,421 in MNM mines and 325 in coal mines). These avoided cases will be achieved once all miners, working and retired, have been exposed exclusively under the new PEL (see FRIA Table ES - 3).

- Over the first 60 years immediately following the start of implementation, fewer cases will be avoided than are shown in FRIA Table ES - 3 because the annual number of cases avoided will increase gradually to the long-run values that ultimately will be achieved once all miners have been exposed only under the new PEL. FRIA Table ES - 4 shows that, in the first 60 years following the start of implementation, the final rule will result in a total of 531 avoided deaths (487 in MNM and 44 in Coal) and 1,836 avoided morbidity cases (1,673 in MNM and 162 in Coal); these avoided deaths and illnesses are the benefits that MSHA monetized in this regulatory impact analysis.[9] In general, the actual number of cases that will be avoided in the 60 years following the start of implementation (FRIA Table ES - 4) is approximately half the number of avoided cases once benefits reach their long-run average annual values (FRIA Table ES - 3).

- Under a discount rate of 3 percent, the total benefits of the new respirable crystalline silica rule from these avoided deaths and morbidity cases, including the benefits of avoided morbidity preceding mortality, are $246.9 million per year in 2022 dollars (FRIA Table ES - 5).

[9] FRIA Table ES - 4 shows the excess cases that will be avoided in the first 60 years following compliance with the rule (from 2025 through the end of 2084). Lifetime avoided cases, which are shown in FRIA Table ES - 3, are the "long-run" number of excess cases that will be avoided once all surviving miners (both working and retired) have exposures only under the new PEL. This long-run state will be achieved for the first time 60 years after compliance with the rule.

- Because a higher monetary value is placed on an avoided death as compared to an avoided morbidity case, the majority (62.5 percent; $154.3 million) of these benefits is attributable to avoided mortality due to non-malignant respiratory disease (NMRD) ($75.4 million), silicosis ($40.3 million), end-stage renal disease (ESRD) ($28.4 million), and lung cancer ($10.2 million) (FRIA Table ES - 5).

- Benefits from avoided morbidity due to non-fatal silicosis are $72.8 million per year. Of this, $66.3 million are due to cases avoided in MNM mines and $6.5 million are due to cases avoided in coal mines (see FRIA Table ES - 5).

- Benefits from avoided morbidity that precedes fatal cases of NMRD, silicosis, renal disease, and lung cancer, are $19.8 million. Of this, $18.2 million are due to cases avoided in MNM mines and $1.6 million are due to cases avoided in coal mines (see FRIA Table ES - 5).

FRIA Table ES - 3. Estimated Cases of Avoided Lifetime Mortality and Morbidity Attributable to the New Respirable Crystalline Silica Rule Among a Population Exposed Only to the New PEL

Health Outcome	Total Lifetime Avoided Cases Among a Population Exposed Only to the New PEL [a]		
	MNM	Coal	Total
Avoided Morbidity			
Silicosis	3,421	325	3,746
Avoided Morbidity Total (Net of Silicosis Deaths)	**3,421**	**325**	**3,746**
Avoided Mortality			
NMRD (net of silicosis mortality)	489	47	536
Silicosis	233	15	248
ESRD	185	15	200
Lung Cancer [b]	75	7	82
Avoided Mortality Total	**982**	**85**	**1,067**

Notes: [a] Avoided cases include all miners (including contract miners). Calculations show the difference between excess cases when assuming compliance with the existing limits versus assuming compliance with the new PEL of 50 μg/m^3.
[b] A 15-year lag between exposure and observed health effect was assumed for lung cancer estimates.

FRIA Table ES - 4. Estimated Cases of Avoided Mortality and Morbidity Attributable to the New Respirable Crystalline Silica Rule during the 60 Years Immediately Following the Start of Implementation

Health Outcome	Total Avoided Cases During 60 Years Following Compliance [a]		
	MNM	Coal	Total
Avoided Morbidity			
Silicosis	1,673	162	1,836
Avoided Morbidity Total (Net of Silicosis Deaths)	**1,673**	**162**	**1,836**

Health Outcome	Total Avoided Cases During 60 Years Following Compliance [a]		
	MNM	Coal	Total
Avoided Mortality			
NMRD (net of silicosis mortality)	241	22	263
Silicosis	123	11	134
ESRD	90	8	98
Lung Cancer [b]	33	3	36
Avoided Mortality Total	**487**	**44**	**531**

Notes: Due to rounding, some totals do not exactly equal the sum of the corresponding individual entries.
[a] Avoided cases include all miners (including contract miners). Calculations show the difference between excess cases when assuming compliance with the existing limits versus assuming compliance with the new PEL of 50 μg/m^3. Estimates account for the fact that some miners during the 60-year period will have worked under the existing standards (and thus may have combination of exposures under the existing standards and the new PEL), while other new entrants into the mining workforce would be solely exposed under the new PEL.
[b] A 15-year lag between exposure and observed health effect was assumed for lung cancer estimates.

FRIA Table ES - 5. Estimated Monetized Benefits over 60 Years for the New Respirable Crystalline Silica Rule Annualized at a 3 Percent Discount Rate (in millions of 2022 dollars)

Health Outcome	MNM	Coal	Total
Avoided Morbidity (Not Preceding Mortality)			
Silicosis (Net of Silicosis Mortality)	$66.3	$6.5	$72.8
Avoided Morbidity (Not Preceding Mortality) Total	**$66.3**	**$6.5**	**$72.8**
Avoided Mortality			
NMRD (Net of Silicosis Mortality)	$69.1	$6.3	$75.4
Silicosis	$37.0	$3.3	$40.3
ESRD	$26.1	$2.3	$28.4
Lung Cancer	$9.4	$0.9	$10.2
Avoided Mortality Total	**$141.6**	**$12.7**	**$154.3**
Avoided Morbidity (Preceding Mortality)			
NMRD (Net of Silicosis Mortality)	$8.6	$0.8	$9.4
Silicosis	$5.0	$0.5	$5.5
ESRD	$3.4	$0.3	$3.6
Lung Cancer	$1.1	$0.1	$1.2
Avoided Morbidity (Preceding Mortality) Total	**$18.2**	**$1.6**	**$19.8**
Grand Total	**$226.0**	**$20.9**	**$246.9**

MSHA acknowledges that its benefit estimates are influenced by underlying assumptions and that the long timeframe of this analysis (i.e., 60 years) is a source of uncertainty. The main assumptions underlying these estimates of avoided mortality and morbidity include the following:

- Employment is held constant over the 60 years (i.e., the analysis period of the final rule).[10]
- For analyses under the "Baseline" scenario, any exposures to respirable crystalline silica above the existing standards (i.e., 100 μg/m^3 for MNM miners and 85.7 μg/m^3 for coal miners) were capped at 100 μg/m^3 and 85.7 μg/m^3 for MNM and coal exposures, respectively.
- For analyses under the "New PEL 50" scenario, any exposures to respirable crystalline above the new PEL are capped at the new PEL (i.e., 50 μg/m^3).
- Miners have identical employment and hence identical exposure tenures (i.e., 45 years).

In addition to the above-mentioned quantified health benefits, MSHA expects that there will be additional benefits from requiring approved respirators to be selected, fitted, used, and maintained in accordance with ASTM F3387-19. The ASTM standard reflects developments in respiratory protection since the time in which MSHA issued its existing standards. ASTM F3387-19 also includes respiratory protection program elements such as program administration; standard operating procedures (SOPs); medical evaluation; respirator selection; training; fit testing; and respirator maintenance, inspection, and storage. This provision of the final rule will ensure that, in circumstances where respirator use is required, mine operators will provide miners with respiratory protection in compliance with advances in technology and changes in respiratory protection practices. This provision will play a critical role in safeguarding the health of miners by reducing their exposures to respirable crystalline silica and other airborne contaminants. As demonstrated, reductions in occupational exposure to respirable crystalline silica are expected to reduce adverse health outcomes. However, given the uncertainty about the current state of operator respiratory protection practices, MSHA did not quantify the expected additional benefits that would be realized by requiring approved respirators to be selected, fitted, used, and maintained in accordance with the requirements of ASTM F3387-19.

MSHA believes that reductions in coal miners' exposure to respirable crystalline silica may also lead to lower levels of coal mine dust inhalation. MSHA expects that adverse health outcomes attributable to respirable coal mine dust exposure, such as simple and complex coal workers' pneumoconiosis (CWP), will also be reduced. MSHA has not estimated the reduction in risk associated with CWP among coal miners because the literature does not contain an exposure-response model that quantifies the impact of respirable crystalline silica on CWP mortality risk, and because MSHA is not making any assumptions about whether levels of coal mine dust will be reduced due to the final rule. MSHA anticipates that there will be additional unquantified benefits from the reduction in CWP provided by the final rule. MSHA does, however, include benefits from avoided mortality due to progressive massive fibrosis (PMF) – including mortality due to complicated CWP and complicated silicosis – within the avoided silicosis and NMRD deaths.

[10] MSHA recognizes that it is impossible to predict economic factors accurately over such a long period with a high degree of confidence. Given known information and forecast limitations, MSHA believes this is a reasonable assumption.

Finally, MSHA also expects that the final rule's medical surveillance provisions will reduce mortality and morbidity from respirable crystalline silica exposure among MNM miners. The initial mandatory examination that assesses a new miner's baseline pulmonary status, coupled with periodic examinations, will assist in the early detection of respirable crystalline silica-related illnesses. Early detection of illness often leads to early intervention and treatment, which may slow disease progression and/or improve health outcomes. However, MSHA lacks data to quantify these additional benefits.

The net benefits of the final rule are calculated as the difference between the estimated benefits and costs. FRIA Table ES - 6 shows estimated net benefits using alternative discount rates of 0, 3, and 7 percent. As demonstrated by FRIA Table ES - 6, the choice of discount rate has an effect on annualized costs, benefits, and net benefits. While the net benefits of the new respirable crystalline silica rule vary depending on the choice of discount rate used to annualize costs and benefits, total benefits exceed total costs under all discount rates considered. MSHA's estimate of the net annualized benefits of the final rule, using a discount rate of 3 percent, is $156.6 million, with the majority ($144.0 million; 92 percent) attributable to the MNM sector.

FRIA Table ES - 6. Annualized Costs, Benefits, and Net Benefits of MSHA's Final Respirable Crystalline Silica Rule (in millions of 2022 dollars)

Quantified Benefits and Costs	MNM			Coal			Total		
	0%	3%	7%	0%	3%	7%	0%	3%	7%
Benefits									
Avoided Mortality	$230.4	$141.6	$68.9	$20.5	$12.7	$6.4	$250.9	$154.3	$75.3
Avoided Morbidity Preceding Mortality	$27.1	$18.2	$10.0	$2.4	$1.6	$0.9	$29.5	$19.8	$11.0
Avoided Morbidity Not Preceding Mortality	$93.1	$66.3	$41.5	$9.0	$6.5	$4.2	$102.1	$72.8	$45.7
Total [a], [b]	***$350.7***	***$226.0***	***$120.4***	***$31.9***	***$20.9***	***$11.5***	***$382.6***	***$246.9***	***$131.9***
Costs									
Exposure Controls	$11.9	$11.7	$11.4	$1.9	$1.9	$2.0	$13.8	$13.7	$13.4
Exposure Monitoring	$46.1	$47.6	$49.7	$5.5	$5.6	$5.9	$51.6	$53.2	$55.6
Respiratory Protection	$3.3	$3.3	$3.2	$0.1	$0.1	$0.1	$3.4	$3.3	$3.2
Medical Surveillance	$18.8	$18.8	$18.8	--	--	--	$18.8	$18.8	$18.8
ASTM Update	$0.6	$0.7	$0.7	$0.6	$0.6	$0.6	$1.2	$1.2	$1.3
Total	***$80.7***	***$82.1***	***$83.8***	***$8.0***	***$8.2***	***$8.5***	***$88.8***	***$90.3***	***$92.4***
Net Benefits	***$270.0***	***$143.9***	***$36.6***	***$23.9***	***$12.7***	***$3.0***	***$293.8***	***$156.6***	***$39.5***

Notes: Medical surveillance cost is the average cost under the assumed participation rates of 25 percent and 75 percent.
[a] For the purpose of simplifying the estimation of the total monetized benefits of avoided illness and death, MSHA added the monetized benefits of avoided morbidity preceding mortality to the monetized benefits of avoided mortality at the time of death, and both would be discounted at that point.
[b] Totals may not equal the sum of individual values due to rounding.

MSHA also considered three regulatory alternatives to the final rule. Under Regulatory Alternative 1, the PEL and action level would remain the same as in the final rule, but the frequency of above-action-level sampling and periodic evaluations would be reduced. MSHA estimated that the total Part 60 annualized compliance costs under this alternative would total $65.1 million (3 percent discount rate), which is $24.0 million lower than the estimate for Part 60 compliance costs under the final rule. However, MSHA believes that more frequent exposure monitoring will provide mine operators with higher confidence that they are in compliance with the final rule. Thus, MSHA determined that the benefits of increased exposure monitoring under the final rule justify the additional exposure monitoring costs relative to Regulatory Alternative 1.

Under Regulatory Alternative 2, the PEL would be lowered to 25 $\mu g/m^3$, no action level would be designated, and mine operators would not be required to undertake first-time, second-time, above-action-level, or corrective actions sampling. Mine operators would still be required to perform periodic evaluations and post-evaluation sampling as frequently as necessary to ensure compliance with the PEL. At a 3 percent discount rate, exposure monitoring costs less than it does for the final rule. However, this lower monitoring cost is more than offset by the increased control costs necessitated by the requirement that mines maintain respirable crystalline silica exposure levels below 25 $\mu g/m^3$. At an estimated annualized cost of $520.7 million, this alternative would cost nearly six times more than the final requirements.

Under this alternative, MSHA also calculated an increase in benefits owing to the lowered PEL. MSHA estimated the total annualized monetized benefits under Regulatory Alternative 2 would be $516.3 million, which is about twice the estimated benefits under the final rule. Despite this increase in estimated benefits, the increase in compliance costs results in the net benefits of this alternative being negative. MSHA determines that meeting a PEL of 25 $\mu g/m^3$ is not achievable for all mines and, therefore, Regulatory Alternative 2 is not chosen.

Under Regulatory Alternative 3, MSHA calculated exposure as a full-shift time-weighted average (full-shift TWA), rather than as a full-shift, 8-hour TWA. MSHA's calculation normalizes the exposure level for an extended work shift to an 8-hour shift, whereas Regulatory Alternative 3 does not make any adjustment for an extended work shift. Under this alternative, MSHA used the full-shift TWA to assess compliance and re-analyze costs and benefits of the rule. At a 3 percent discount rate, MSHA estimated that total Part 60 annualized compliance costs would be $86.4 million, which is about $2.7 million less than MSHA estimated when using a full-shift, 8-hour TWA. However, annualized benefits also decrease by $45 million at a 3 percent discount rate when a full-shift TWA is used, and the reduction in benefits is greater than the reduction in compliance costs. Under this regulatory alternative, MSHA estimated net annualized benefits at $114.3 million (3 percent discount rate), which is 27 percent lower than net benefits when using a full-shift, 8-hour TWA.

MSHA received public comments related to the PRIA, including comments regarding the estimation of costs and benefits, and the regulatory alternatives. These comments are summarized and addressed in Section 8 of the FRIA.

1 INTRODUCTION

In this chapter, MSHA describes the risk of occupational exposure to respirable crystalline silica as described in *Effects of Occupational Exposure to Respirable Crystalline Silica on the Health of Miners* (i.e., the Health Effects document) and summarizes the final rule text.

1.1 Determination of Risk from Respirable Crystalline Silica

When establishing the need for a new standard, MSHA must identify a material impairment of health or functional capacity, assess the associated risks with the existing exposure levels of the regulated substance, and discuss how the new standard constitutes an improvement over the existing standard. *See Nat'l Min. Ass'n v. United Steel Workers*, 985 F.3d 1309, 1319 (11th Cir. 2021) (holding that "the Mine Act does not contain the 'significant risk' threshold requirement that petitioners would import from the OSH [Occupational Safety and Health] Act" but requiring that MSHA demonstrate that "the new standard constitutes an improvement over the existing . . . standards").

MSHA relies on the FRA and the Health Effects document to support the risk determinations. MSHA first evaluated available data to determine whether or not miners will suffer a material impairment of their health or functional capacity as a result of being occupationally exposed to respirable crystalline silica. MSHA's review included epidemiologic studies, morbidity and mortality analyses, progression and pathology research, death certificate and autopsy reviews, reports on medical surveillance data, and toxicological literature. Based on the findings of this Health Effects document, MSHA determined that occupational exposure to respirable crystalline silica does present a risk of material impairment of health or functional capacity to affected miners. MSHA's review included four respirable crystalline silica-related diseases which are analyzed in the FRA and monetized in this FRIA. Each of these diseases are briefly summarized below.

The first health outcome that MSHA considers is silicosis. Silicosis is a condition in which respirable crystalline silica particles accumulate in the lungs and cause an inflammatory reaction which leads to lung damage and scarring. Silicosis is not reversible and may continue to progress even after exposures have ceased. In the FRA and in this FRIA, MSHA considers benefits from avoided cases of both non-fatal and fatal silicosis.

MSHA also considers other nonmalignant respiratory diseases (NMRD). This group of diseases includes emphysema and chronic bronchitis. Emphysema is a condition in which the alveolar region of the lung is destroyed, causing airway obstruction and impaired gas exchange. Chronic bronchitis is long-term inflammation of the bronchi which increases the risk of lung infections. In the FRA and in this FRIA, MSHA considers benefits from avoided deaths due to NMRD.

The third health outcome that MSHA considers is lung cancer. Lung cancer is a type of cancer that forms in the lung tissue. The condition is irreversible and is usually fatal. MSHA, as well as other government and public health organizations, recognizes respirable crystalline silica as a known human carcinogen. MSHA further reviewed literature for cancer at other sites but found that the evidence was not strong enough to include in its analyses. Thus, in the FRA and in this FRIA, MSHA only considers benefits from avoided deaths due to lung cancer.

The fourth health outcome that MSHA considers is end stage renal disease (ESRD). Renal disease is characterized by a loss of kidney function and ESRD generally involves the need for a regular course of long-term dialysis or a kidney transplant. MSHA believes that occupational exposure to respirable crystalline silica increases risk of ESRD for both coal and MNM miners. In the FRA and in this FRIA, MSHA considers benefits from avoided deaths due to other ESRD.

After concluding that respirable crystalline silica exposures increase a miner's risk of material impairment of health or functional capacity, MSHA sought to assess whether a final rule would reduce that risk. To do so, MSHA applied available exposure-response models to estimate the respirable crystalline silica-related risk of injury and death from silicosis, lung cancer, nonmalignant respiratory diseases (NMRD), and end-stage renal disease (ESRD) of miners exposed to respirable crystalline silica at the existing standards and at the new PEL. The methodology and results of this analysis are presented in greater detail in the FRA and in Section 3.1 of this FRIA. In the main analysis and all sensitivity analyses, the FRA found that the new PEL will result in fewer lifetime excess deaths and cases of non-fatal silicosis as compared to the existing standards. Thus, to protect miners, the final rule addresses the risk of occupational exposure to respirable crystalline silica.

1.2 Summary of the Respirable Crystalline Silica Final Rule

After carefully weighing the advantages and disadvantages of using a regulatory approach to reduce miners' exposures to respirable crystalline silica under existing standards, MSHA concludes that the final rule represents the best choice available, consistent with its statutory obligations under the Mine Act. Rulemaking is necessary to replace older, existing standards with updated and improved health standards.

MSHA has developed a comprehensive final rule to protect miners from exposure to respirable crystalline silica in mines. Below is a summary of each section in the final rule, which is explained in more detail in the preamble to the final rule.

Scope and Application

The final rule applies to all MNM and coal mines. In a change from the proposed rule, mine operators will be given more time to comply with the requirements of this rule. The compliance dates of this final rule will be 12 months after the publication date for coal mine operators and 24 months after the publication date for MNM mine operators. MSHA has provided more time for mine operators, miners, and the mining community to understand the final rule and prepare for compliance. MSHA believes that the delayed compliance dates provide mine operators time to plan and prepare for compliance with the standards, while also ensuring that the improved protection for miners under the final rule take effect as soon as practically possible.

Permissible Exposure Limit (PEL) and Action Level

Section 60.10 of the final rule establishes a single, uniform PEL of 50 μg/m^3 for respirable crystalline silica for all MNM and coal mines. Under this provision, mine operators will be required to ensure that no miner is exposed to an airborne concentration of respirable crystalline silica in excess of 50 μg/m^3 for a full-shift exposure, calculated as an 8-hour TWA. For coal mines, a separate PEL for respirable crystalline silica is established and replaces the Agency's existing respirable dust standard when quartz is present. The single, uniform PEL replaces the Agency's existing standards in 30 CFR parts 56, 57, 70, 71, and 90.

In the final rule, MSHA establishes an action level of 25 μg/m^3 for a full-shift exposure, calculated as an 8-hour TWA. Exposure monitoring (sampling) is required when miners' exposures are at or above the action level. The action level alerts mine operators to take actions so that miners' exposures remain below the PEL. Under the final rule, mine operators who maintain miner exposures below the action level are not required to perform certain sampling requirements.

Control Methods

Under section 60.11 of the final rule, mine operators are required to implement engineering controls needed to ensure that miners are protected from respirable crystalline silica exposures above the PEL, followed by administrative controls if supplementary protection is necessary for compliance. The final rule does not allow for rotation of miners as an acceptable control method.

Exposure Monitoring

Section 60.12 of the final rule requires that all mine operators commence sampling by the compliance date for their mine's respective sector.

For mines with first-time sampling results below the action level, one additional sample (i.e., second-time sampling) must be taken within 3 months. For mines with first-time or second-time sampling results at or above the action level but at or below the PEL, above-action-level sampling must occur every three months until two consecutive sampling results indicate exposure levels are below the action level. Finally, for mines with the most recent sampling above the PEL, corrective actions must be taken; corrective actions sampling must be performed until results indicate exposure levels are at or below the PEL. All samples showing exposures above the PEL must be reported to the MSHA District Manager or other designated office.

Periodic evaluations must be conducted at least every six months after commencing sampling or whenever there is a change in: production; processes; installation or maintenance of engineering controls; installation or maintenance of equipment; administrative controls; or geological conditions. If the mine operator determines, as a result of the periodic evaluation, that miners may be exposed to respirable crystalline silica at or above the action level, the mine operator must conduct sampling to determine the full-shift, 8-hour TWA exposures of the miners.

Corrective Actions

Under section 60.13 of the final rule, if a sample shows that respirable crystalline silica exposure levels are above the PEL, a mine operator must: 1) make approved respirators available to all affected miners before the start of the next work shift in accordance with § 60.14 (b) and (c); 2) ensure that affected miners wear them properly during the period of overexposure; 3) immediately take corrective actions to lower the concentration of respirable crystalline silica to at or below the PEL; and 4) immediately report all operator samples above the PEL to the MSHA District Manager or designated office. Respirators must be made available by the start of the next work shift. Under the final rule, the operator will start corrective actions sampling and continue until sampling shows that exposures are at or below the PEL.

Respiratory Protection

Under section 60.14 of the final rule, the MNM mine operator must use respiratory protection as a temporary measure when miners are working in concentrations of respirable crystalline silica above the PEL while (1) engineering control measures are developed and implemented; or (2) it is necessary by the nature of work involved (for example, occasional entry to hazardous atmospheres to perform maintenance or investigation). Miners who are unable to wear a respirator are to be temporarily transferred to a separate area or task at the same mine where respirator use is not required.

In addition, the final rule requires mine operators establish a written respiratory protection program which meets requirements in accordance with American Society for Testing and Materials (ASTM) F3387-19, including program administration; written standard operating procedures; medical evaluation; respirator selection; training; fit testing; and maintenance, inspection, and storage.

Medical Surveillance

Section 60.15 of the final rule requires that MNM mine operators provide each miner with periodic medical examinations performed by a physician, other licensed health care professional (PLHCP), or specialist at no cost to the miner. Voluntary periodic examinations must be offered to all miners currently employed during the initial 12-month period starting no later than the compliance date of the final rule and then at least every 5 years after.

In addition, mine operators must provide any miner who begins work in the mining industry for the first time a mandatory medical examination within the miner’s first 60 days of employment and a follow-up examination no later than 3 years after the initial examination. Should the follow-up examination show evidence of pneumoconiosis or decreased lung function, a second follow-up examination must be offered no later than 2 years following the initial follow-up examination.

Results of medical examinations or tests shall be provided from the PLHCP or specialist within 30 days of the examination to the miner and to any designee identified by the miner. The mine operator must ensure that results of chest X-ray classifications are sent to the National Institute for Occupational Safety and Health (NIOSH) within 30 days, once NIOSH establishes a reporting system.

Recordkeeping

Evaluation records, sampling records, and corrective actions records must be retained for at least 2 years. Written determination records and written medical opinion records received from a PLHCP must be retained for the duration of the miner's employment plus an additional 6 months.

Changes Between the Proposed Rule and the Final Rule

MSHA has made several changes to the proposed rule. Each change and the reason for the change are discussed in the preamble Section-by-Section Analysis.

The changes include the following:

- In the proposed rule, the effective date, including the compliance date, for all mines was 120 days (or 4 months) after the publication of the final rule. One exception was sampling -- under the proposed rule, all mines would have started sampling 6 months after the effective date (in other words, 10 months after the publication of the final rule). The final rule, however, includes a longer phase-in implementation period for both coal mines and MNM mines. Under the final rule, the compliance date for Part 60 including sampling is 24 months following the publication date for MNM mines and 12 months following the publication date for coal mines.
- Under the proposed rule, objective data and historical sample data (i.e., mine operator and MSHA sample data from the prior 12 months) could be used to demonstrate compliance with exposure monitoring requirements. Under the final rule, objective data and historical sample data may no longer be used to demonstrate compliance with exposure monitoring requirements.
- The proposed rule included no reporting requirement concerning overexposure sampling results. Under the final rule, any sample result exceeding the PEL must be reported to the MSHA District Manager or other designated office.
- Under the proposed rule, periodic evaluations would be conducted semi-annually. Under the final rule, periodic evaluations must be conducted at least every 6 months or whenever there is a change in: production; processes; installation or maintenance of

engineering controls; installation or maintenance of equipment; administrative controls; or geological conditions.

- Under Section 60.14 (a), MSHA limits temporary use of respirators to MNM mines only. Respiratory protection must be used as a temporary measure when MNM miners are working in concentrations of respirable crystalline silica above the PEL while engineering control measures are being developed and implemented; or it is necessary for the nature of the work involved (for example, occasional entry into hazardous atmospheres to perform maintenance or investigation).
- Under the proposed rule, the first voluntary medical examination to be offered to currently employed MNM miners would have been within 3.5 to 4.5 years following the compliance date and subsequent medical examination every 5 years. Under the final rule, the first voluntary medical examination offered to currently employed MNM miners must be within 12 months of the compliance date and subsequent medical examinations every 5 years. The medical examinations shall be available during a 6-month period that begins no less than 3.5 years and not more than 4.5 years from the end of the last 6-month period.
- The proposed rule included no reporting requirement concerning chest X-ray classification results. Under the final rule, the MNM operators must ensure that PLHCPs or specialists provide the results of chest X-ray classifications to NIOSH, once NIOSH establishes a reporting system.
- Under the proposed rule, mine operators would have been required to retain evaluation, sampling, and corrective actions records for at least 2 years; under the final rule, record retention is increased to 5 years.

Changes Between the PRIA and the FRIA

MSHA has updated its cost and benefit estimates in the preliminary regulatory impact analysis (PRIA) to reflect the above changes to the final rule text and to address public comments on the PRIA.

Cost estimate updates include:

- MSHA revised all cost estimates to account for the changes in compliance dates for both coal and MNM mining.
- MSHA revised its cost estimates on exposure monitoring by increasing its estimates of the number of samples and evaluations necessary to fulfill the rule’s requirements.
- MSHA changed the number of mines that incur additional maintenance and repair and administrative costs each year to reduce the number of miners exposed at or above the action level.
- MSHA updated the number of miners that might require additional respirator use.

- In the PRIA, the period over which costs were annualized varied by the type of cost considered. In the FRIA, MSHA updated the methodology to annualize all costs over a 60-year period (see Section 4.1.1.1).
- In the FRIA, MSHA has inflated all cost figures to 2022 dollars (see Sections 4).

Benefit estimate updates include:

- In the PRA and the PRIA, MSHA underestimated benefits by excluding future retired miners from the total population that will benefit from the final rule. In the FRA and the FRIA, MSHA updated the benefits calculation to correct for this exclusion and to include benefits from both working and future retired miners exposed under the new PEL (see Section 3).
- In the FRIA, MSHA has inflated all benefit figures to 2022 dollars (see Sections 3).
- For an informational purpose, MSHA includes in this FRIA an additional sensitivity analysis which was not included in the PRIA and which assesses the impact of miner tenure on the benefits calculation (see Section 5.2).

2 MINERS AND THE MINING INDUSTRY

The final rule will affect all mine operators and miners. This section provides information on the structure and economic characteristics of the metal and nonmetal (MNM) and coal mining industries, including the number and types of mines by size. The section also presents the respirable crystalline silica exposure profile of all at-risk miners in the MNM and coal sectors. These data come from the U.S. Department of the Interior (DOI), U.S. Geological Survey (USGS); U.S. Department of Labor (DOL), Mine Safety and Health Administration (MSHA), Educational Policy and Development and Program Evaluation and Information Resources; DOL, Bureau of Labor Statistics (BLS), Occupational Employment and Wage Statistics (OEWS); U.S. Census Bureau, Statistics of U.S. Businesses (SUSB); and the Energy Information Administration (EIA).

The mining industry can be divided into two major sectors: (1) MNM mines and (2) coal mines, with further distinction made regarding type of operation (i.e., underground mines or surface mines) and commodity (i.e., metal, nonmetal, stone, crushed limestone, sand and gravel, and coal).

MSHA tracks mine characteristics and maintains a database containing the number of mines by mine type and size, number of employees, and employee hours worked.[11] MSHA also collects data on the number of independent contractor firms[12], the number of contract miners they employ, and their employed contract miners' hours worked. Contract miners may work at any mine.[13]

MSHA categorizes mines by size based on employment. For purposes of this industry profile and this analysis, MSHA has categorized mines into the following four size groups:[14] mines that employ: (1) 1 to 20 miners; (2) 21 to 100 miners; (3) 101 to 500 miners; and (4) 501 or more miners. FRIA Table 2-1 presents the number of mines by commodity type and size, their employment excluding contract miners, and their estimated revenues.[15] All mine and employment data are current as of 2019. The table shows that, while the MNM sector has more

[11] All mines are required to apply for an MSHA mine identification number, using MSHA form 7000-51. An MSHA ID is required for each mine site and must be issued before any operations may begin.

[12] Similar to mines all independent contractors may apply for MSHA contractor identification numbers, using form MSHA form 7000-52.

[13] A mine is an establishment of a parent company (also called a controller) owning or controlling one or more mines. MSHA identifies a controller for each mine. 30 U.S.C. 819(d) (each operator shall file the name and address of the "person who controls or operates the mine"). The MSHA dataset shows that some controllers own and operate a single mine and other controllers own several or more mines. (In 2021, there were close to 5,900 mining controllers.) For recent statistics on controllers in the mining industry see the Final Regulatory Flexibility Analysis of the preamble of the final rule.

[14] Miner employment is based on the information submitted quarterly through the MSHA Form 7000-2, excluding Subunit 99 – Office (professional and clerical employees at the mine or plant working in an office); https://www.msha.gov/sites/default/files/Support_Resources/Forms/7000-2_0.pdf.

[15] All miners (including contract miners) will be affected by the final rule. MSHA does not have data on the breakdown of contract miners by individual mine and therefore, does not include contract miners in FRIA Table 2-1. Contract miners are included in the estimates of benefits and costs related to the final rule.

than 10 times the number of mines than the coal sector, it only has approximately 3 times more miners than the coal sector.

In general, economic profiles were developed using 2019 data because this was the most recent year available that was not impacted by temporary changes resulting from the COVID-19 pandemic. To estimate the number of miners, MSHA used the 2019 Quarterly Employment Production Industry Profile (MSHA 2019a) and the 2019 Quarterly Contractor Employment Production Report (MSHA 2019b). MSHA estimated the number of and type of mines using 2019 data from the Mine Data Retrieval System, including the Mines database (MSHA, 2022d), and the 2019 employment data (MSHA, 2019a; MSHA, 2019b). To estimate the exposure profile of miners in the current state and future state (subject to the modeling assumptions of the Baseline and “New PEL 50” scenarios), MSHA used compliance data from 2005 through 2019 to estimate the current levels of exposure to respirable crystalline silica among MNM miners (MSHA 2022b). For the coal sector, MSHA used data from 2016 through 2021 (MSHA 2022a). For the coal sector, MSHA only used exposure data since 2016, by which time all provisions of the Respirable Coal Mine Dust (RCMD) Standard had gone into effect. MSHA did not use earlier data so that the benefits in this FRIA are clearly attributable to this rule and not to the Coal Mine Dust Standard. While the period for the coal compliance data overlaps with the COVID-19 pandemic, a 5-year period was selected to increase the sample size.

The size of the mining industry is difficult for economists to forecast given the uncertainties in future demand for various mined commodities, as well as uncertainties about technological change. MSHA assumed the current mining workforce and the current number of mines would not change during the 60 years following implementation of the final rule. If the industry were to contract or expand in the future, the relative ratio of benefits to costs would remain roughly the same because both the benefits and costs of the final rule are in proportion to the size of the industry. For example, if the number of active mines and employment were to expand by 50 percent in the future, both the benefits (based on employment) and costs (based on the number of mines and miners) of the rule should expand by about 50 percent as well. Therefore, while the absolute size of the industry in the future is uncertain, it is not a primary contributor to uncertainty about whether benefits of the final rule will exceed its costs.

FRIA Table 2-1. Profile of MNM and Coal Mines, by Mine Size

		Estimated Revenues [a]		Number of Mines [b]		Miners Excluding Contract Miners [b]		Production Hours (thousands) [b]		Total Employment [b]	
Mine Commodity	**Mine Size by Miner Employment**	**Millions in 2022 dollars**	***Percent***	**Number**	***Percent***	**Number**	***Percent***	**Number**	***Percent***	**Number**	***Percent***
Metal	Emp ≤ 20	$572.6	1.9%	157	*56.1%*	851	*2.3%*	1,433.8	*1.9%*	999	*2.5%*
Metal	20 < Emp ≤ 100	$1,566.1	5.1%	39	*13.9%*	1,947	*5.3%*	3,921.3	*5.1%*	2,251	*5.6%*
Metal	100 < Emp ≤ 500	$12,817.5	42.0%	62	*22.1%*	15,060	*40.7%*	32,094.2	*42.0%*	16,508	*40.7%*
Metal	500 > Emp	$15,561.6	51.0%	22	*7.9%*	19,168	*51.8%*	38,965.3	*51.0%*	20,771	*51.2%*
Metal	***Total***	***$30,517.8***	***100.0%***	***280***	***100.0%***	***37,026***	***100.0%***	***76,414.7***	***100.0%***	***40,529***	***100.0%***
Non-Metal	Emp ≤ 20	$3,651.5	14.4%	645	*71.9%*	3,694	*16.3%*	6,397.5	*14.4%*	4,237	*16.6%*
Non-Metal	20 < Emp ≤ 100	$10,162.4	40.1%	207	*23.1%*	8,921	*39.3%*	17,805.0	*40.1%*	10,065	*39.3%*
Non-Metal	100 < Emp ≤ 500	$9,412.6	37.1%	42	*4.7%*	8,220	*36.2%*	16,491.4	*37.1%*	9,163	*35.8%*
Non-Metal	500 > Emp	$2,124.2	8.4%	3	*0.3%*	1,845	*8.1%*	3,721.6	*8.4%*	2,134	*8.3%*
Non-Metal	***Total***	***$25,350.6***	***100.0%***	***897***	***100.0%***	***22,680***	***100.0%***	***44,415.4***	***100.0%***	***25,599***	***100.0%***
Sand and Gravel	Emp ≤ 20	$7,110.5	69.7%	5,879	*96.7%*	23,887	*75.0%*	39,673.3	*69.7%*	27,262	*75.9%*
Sand and Gravel	20 < Emp ≤ 100	$2,591.5	25.4%	188	*3.1%*	6,703	*21.1%*	14,459.5	*25.4%*	7,320	*20.4%*
Sand and Gravel	100 < Emp ≤ 500	$497.8	4.9%	10	*0.2%*	1,247	*3.9%*	2,777.6	*4.9%*	1,337	*3.7%*
Sand and Gravel	500 > Emp	$0.0	0.0%	0	*0.0%*	0	*0.0%*	0.0	*0.0%*	0	*0.0%*
Sand and Gravel	***Total***	**$10,199.8**	***100.0%***	***6,077***	***100.0%***	***31,837***	***100.0%***	***56,910.5***	***100.0%***	***35,919***	***100.0%***
Stone	Emp ≤ 20	$4,144.7	28.5%	2,002	*83.1%*	11,198	*31.7%*	20,035.5	*28.5%*	12,563	*31.5%*
Stone	20 < Emp ≤ 100	$6,380.2	43.8%	339	*14.1%*	14,779	*41.9%*	30,842.4	*43.8%*	16,824	*42.2%*
Stone	100 < Emp ≤ 500	$3,808.7	26.2%	67	*2.8%*	8,762	*24.8%*	18,411.6	*26.2%*	9,896	*24.8%*
Stone	500 > Emp	$227.3	1.6%	1	*0.0%*	539	*1.5%*	1,098.8	*1.6%*	602	*1.5%*
Stone	***Total***	***$14,560.9***	***100.0%***	***2,409***	***100.0%***	***35,278***	***100.0%***	***70,388.3***	***100.0%***	***39,885***	***100.0%***
Crushed Limestone	Emp ≤ 20	$6,621.2	45.8%	1,555	*83.5%*	11,771	*48.8%*	22,834.9	*45.8%*	13,495	*49.7%*
Crushed Limestone	20 < Emp ≤ 100	$6,569.2	45.5%	293	*15.7%*	10,480	*43.5%*	22,655.5	*45.5%*	11,641	*42.9%*
Crushed Limestone	100 < Emp ≤ 500	$1,250.7	8.7%	14	*0.8%*	1,856	*7.7%*	4,313.4	*8.7%*	2,002	*7.4%*
Crushed Limestone	500 > Emp	$0.0	0.0%	0	*0.0%*	0	*0.0%*	0.0	*0.0%*	0	*0.0%*
Crushed Limestone	***Total***	***$14,441.1***	***100.1%***	***1,862***	***100.0%***	***24,107***	***100.0%***	***49,803.8***	***100.0%***	***27,138***	***100.0%***
MNM Total	**Emp ≤ 20**	**$22,100.4**	**23.2%**	**10,238**	***88.8%***	**51,401**	***34.1%***	**90,375.0**	***30.3%***	**58,556**	***34.6%***
MNM Total	**20 < Emp ≤ 100**	**$27,269.4**	**28.7%**	**1,066**	***9.2%***	**42,830**	***28.4%***	**89,683.7**	***30.1%***	**48,101**	***28.5%***
MNM Total	**100 < Emp ≤ 500**	**$27,787.4**	**29.2%**	**195**	***1.7%***	**35,145**	***23.3%***	**74,088.3**	***24.9%***	**38,906**	***23.0%***
MNM Total	**500 > Emp**	**$17,913.1**	**18.8%**	**26**	***0.2%***	**21,552**	***14.3%***	**43,785.7**	***14.7%***	**23,507**	***13.9%***

Mine Commodity	Mine Size by Miner Employment	Estimated Revenues [a]		Number of Mines [b]		Miners Excluding Contract Miners [b]		Production Hours (thousands) [b]		Total Employment [b]	
		Millions in 2022 dollars	*Percent*	Number	*Percent*	Number	*Percent*	Number	*Percent*	Number	*Percent*
MNM Total	***Total***	***$95,070.2***	***100.0%***	***11,525***	***100.0%***	***150,928***	***100.0%***	***297,932.6***	***100.0%***	***169,070***	***100.0%***
Coal	Emp ≤ 20	$1,143.0	3.9%	707	*63.9%*	4,358	*8.5%*	9,077.4	*7.7%*	4,611	*8.7%*
Coal	20 < Emp ≤ 100	$3,659.4	12.6%	271	*24.5%*	11,814	*22.9%*	27,591.7	*23.5%*	12,145	*22.9%*
Coal	100 < Emp ≤500	$16,353.5	56.2%	116	*10.5%*	26,145	*50.7%*	59,897.7	*51.0%*	26,818	*50.6%*
Coal	500 > Emp	$7,943.3	27.3%	12	*1.1%*	9,256	*17.9%*	20,962.2	*17.8%*	9,392	*17.7%*
Coal	***Total***	***$29,099.2***	***100.0%***	***1,106***	***100.0%***	***51,573***	***100.0%***	***117,529.0***	***100.0%***	***52,966***	***100.0%***

Notes: NA = Not available

[a] Estimated Coal Revenues were calculated using MSHA Production Figures in Short Tons by Rank: 650.3 million tons Bituminous Coal, 53.2 million tons Lignite Coal, 2.6 million tons Anthracite Coal; and EIA price's per short ton by Coal Rank: EIA Annual Coal Report 2019; Table 31 Average Sales Price of Coal by State And Rank, 2019; US Total: $58.93/ton Bituminous Coal, $19.86/ton Lignite Coal, $102.22/ton Anthracite Coal; https://www.eia.gov/coal/annual/archive/0584_2019.pdf. The estimated revenues for MNM commodities are calculated by applying the proportion of revenues represented by each commodity among all MNM commodities in the 2017 SUSB data and applying that proportion to the 2019 production value for all industrial minerals reported by USGS.

Revenues inflated from 2019 dollars to 2022 dollars using the GDP Price Deflator.

[b] The estimated number of current and future mines, miners, and production hours are based on 2019 data (MSHA, 2019a; MSHA, 2019b; MSHA, 2022d) and are assumed to have remained constant through the 60 years following the start of implementation.

2.1 Structure of the Mining Industry

2.1.1 MNM Mining Sector

The MNM mining sector is made up of metal mines (e.g., copper, iron ore, gold, silver, etc.) and nonmetal mines. In a 2012 study, Watts, *et al*. 2012 examined the trends in the MSHA MNM dust data that was collected during 1974–2010. Their study included nearly 147,000 respirable dust samples with a mass of at least 0.1 mg and a minimum of 1 percent quartz and represented roughly half of all respirable dust samples collected by MSHA. The authors analyzed these data by location, commodity, and occupation. The remaining half of samples collected by MSHA during the same period were not included, as they did not meet the MSHA criteria for respirable quartz dust.[16]

For their analysis, Watts, *et al*. 2012 categorized the nonmetal mines into four commodity groups: nonmetal (mineral) materials such as clays, potash, soda ash, salt, talc, and pyrophyllite; stone, including granite, limestone, dolomite, sandstone, slate, and marble; crushed limestone; and sand and gravel, including industrial sands.[17] MSHA uses the same categorization for this respirable crystalline silica rulemaking analysis.

Based on the 2019 data, the MNM mining sector employs an estimated 169,070 individuals, of which 150,928 are miners (excluding contract miners) and 18,142 are office workers (FRIA Table 2-1). In addition, contract miners in the MNM mining industry report an estimated 71.3 million production hours. Further breakdown by mine size and commodity group is provided below. As mentioned above, the number of mines and the number of miners throughout this FRIA are estimated based on 2019 data and are assumed to have remained constant through the 60 years following the start of implementation.

Metal Mining

There are 24 groups of metal commodities mined in the U.S. metal mines. They represent an estimated 2.4 percent (280/11,525) of all MNM mines and employ an estimated 24.5 percent of all MNM miners (excluding contract miners). Of these 280 estimated mines, 157 (about 56 percent) employ 20 or fewer miners and 22 (7.9 percent) employ greater than 500

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[16] MNM exposure data collected by MSHA is analyzed using the P-2 method, which specifies that filters are only analyzed for quartz if they achieve a net mass gain of 0.100 mg or more. If cristobalite is requested, a mass gain of 0.050 mg or more is required for a filter to be analyzed (MSHA, 2022a). If the filter mass does not reach these criteria, the sample is considered unlikely to reflect noncompliance and is therefore not further analyzed. Thus, such samples could not be included in Watts *et al.* (2012).

[17] Watts *et al.* 2012 treated the sand and gravel and crushed limestone commodities separately for three reasons: 1) they qualified as individual "similarly exposed groups" based on the activities miners performed and the authors' judgement about similarities of their expected exposures [pp. 721, 725 of article]; 2) "because of the large number of [silica exposure] samples collected in these two commodities" [pp. 724, 725], explained by 3) the fact that "over half [57.2 percent] of all active mines or mills [fell] into these two categories" [p. 724]. Although Watts et al. was evaluating data collected 1993 through 2010, the same trend continues in MSHA's 2006 through 2019 respirable crystalline silica dataset and in the information analyzed for this industry profile, which shows that 69 percent of MNM mines now fall into these two commodities.

miners. Additionally, the 2019 MSHA data show that there are a total of 13,792 estimated contract miners in the metal mining industry with an estimated total of 18.9 million reported production hours.

Non-Metal (Mineral) Mining

There are 35 non-metal commodities mined in the US, not including stone and sand and gravel. Non-metal mines represent an estimated 7.8 percent (897/11,525) of all MNM mines and employ an estimate of roughly 15 percent of all MNM miners (excluding contract miners). The majority (71.9 percent) of non-metal mines employ fewer than 20 miners and less than 1 percent employ more than 500 employees. Further, according to 2019 MSHA data, there are a total of 11,346 estimated contract miners in the non-metal mining industry with an estimated total of 14.5 million reported production hours.

Sand and Gravel Mining

Sand and gravel mines account for an estimated 52.7 percent (6,077/11,425) of all MNM mines but are estimated to employ only 21.1 percent of all MNM miners (excluding contract miners). Nearly all (96.7 percent) of these mines employ fewer than 20 employees and the number of miners working in said mines comprises 15.8 percent of all MNM miners (excluding contract miners). In addition, the 2019 MSHA data show that there are a total of 7,512 estimated contract miners in the sand and gravel mining industry with an estimated total of 8.9 million reported production hours.

Stone Mining

The stone mining subsector includes eight different stone commodities. Of these eight, seven are further classified as either dimension stone or crushed and broken stone. Stone mines make up an estimated 20.9 percent (2,409/11,525) of all MNM mines and employ an estimated 23.4 percent of all MNM miners (excluding contract miners). The vast majority of these mines (83.1 percent) employ fewer than 20 miners and the number of miners working in such mines comprises 31.7 percent of all stone miners (excluding contract miners). Further, according to 2019 MSHA data, there are a total of 18,559 estimated contract miners in the stone mining industry with an estimated total of 18.8 million reported production hours.

Crushed Limestone Mining

Crushed Limestone mines make up an estimated 16.2 percent (1,862/11,525) of all MNM mines and are estimated to employ about the same percentage (16.0 percent) of all MNM miners (excluding contract miners). Of the 1,862 crushed limestone mines, the vast majority (83.5 percent) employ fewer than 20 miners and there are no crushed limestone mines that employ over 500 miners. Additionally, 2019 MSHA data show that there are a total of 9,065 estimated contract miners in the crushed limestone mining industry with an estimated total of 10.2 million reported production hours.

2.1.2 Coal Mining Sector

As shown in FRIA Table 2-1, an estimated 1,106 coal mines are in production, based on 2019 data. Of these, 707 (63.9 percent) employ fewer than 20 miners, 271 (24.5 percent) employ between 21 to 100 miners, 116 (10.5 percent) employ between 101 and 500 miners, and the remaining 12 mines (1.1 percent) employ more than 500 miners. The overall coal mine employment is estimated to be 52,966, of which 51,573 are miners (excluding contract miners) and the remaining 1,393 are office workers. Additionally, 2019 MSHA data show that there are a total of 22,003 estimated contract miners in the coal mining industry with an estimated total of 28.0 million reported production hours.

2.2 Economic Characteristics of the Mining Industry

2.2.1 MNM Mining Sector

The value of all MNM mining output expressed in 2022 dollars was estimated at $95.1 billion (U.S. Department of the Interior, 2021).[18] Metal mines, which include iron, gold, copper, silver, nickel, lead, zinc, uranium, radium, and vanadium mines, contributed an estimated $30.5 billion. In the USGS Mineral Commodity Summaries, production values for nonmetals, stone, crushed limestone, and sand and gravel are combined into one commodity group titled "industrial minerals." Therefore, MSHA estimated the production value of each individual commodity by taking the proportion of revenues for the commodity in question among all commodities in the 2017 SUSB and applying that proportion to the 2019 production value for all industrial minerals reported by USGS. This approach yields the following estimates: metal production was valued at an estimated $30.5 billion, non-metal production at $25.4 billion, stone mining at $14.6 billion, crushed limestone at $14.4 billion, and sand and gravel at $10.2 billion.

2.2.2 Coal Mining Sector

The following three major commodity groups make up the US coal mining sector: bituminous, anthracite, and lignite. According to MSHA, bituminous operations represent approximately 92.1 percent of total coal production in short tons and employ 91.9 percent of all coal miners (excluding contract miners). Anthracite operations represent 0.4 percent of coal production in short tons and employ 1.9 percent of all coal miners (excluding contract miners). Lignite operations represent roughly 7.5 percent of total coal production in short tons and employ 6.2 percent of coal miners (excluding contract miners).

To estimate coal revenues in 2019, MSHA combined production estimates with unit prices. Mine production data were taken from MSHA quarterly data and the coal unit prices per ton were taken from the 2019 EIA Annual Coal Report. Revenues were then inflated to 2022

[18] 2019 dollars obtained from source and inflated to 2022 dollars using the GDP Price Deflator.

dollars. As shown in FRIA Table 2-1, total coal revenues expressed in 2022 dollars were estimated to be $29.1 billion.

2.3 Respirable Crystalline Silica Exposure Profile of Miners

Using the quarterly employment data submitted by mines and the OEWS reported by the BLS, MSHA estimated the distribution of miners (excluding contract miners) across different occupational categories. FRIA Table 2-2 and FRIA Table 2-3 present the distribution of the estimated 202,501 miners (excluding contract miners) by occupational category across the MNM and coal sectors, respectively.

FRIA Table 2-2 shows that operators of haulage equipment (large and small) and mobile workers (i.e., laborers, electricians, mechanics, supervisors, and jackhammer operators) comprise the largest segment (79 percent) of MNM miners (excluding contract miners). FRIA Table 2-3 shows that, of the estimated 51,573 coal miners (excluding contract miners), about 11 percent have the job title "continuous mining machine operator," about 43 percent have the job title "large-powered haulage operator" (14,114 surface miners and 7,932 underground miners combined), and about 39 percent have the job title "miner" (9,228 surface miners and 10,653 underground miners combined).

FRIA Table 2-2. Estimated Number of Miners (Excluding Contract Miners) in MNM Sector, by Occupational Category

Occupational Category	Number of Miners [e][f]	Percent
Operators of Large Powered Haulage Equipment [a]	51,959	34.4%
Mobile Workers [b]	46,497	30.8%
Operators of Small Powered Haulage Equipment [c]	21,233	14.1%
Stone Cutting Operators	6,345	4.2%
Miners in Other Occupations	5,747	3.8%
Crushing Equipment and Plant Operators	5,570	3.7%
Truck Loading Station Tenders	5,550	3.7%
Kiln, Mill, and Concentrator Workers	2,910	1.9%
Drillers	2,840	1.9%
Packaging Equipment Operators	2,277	1.5%
Conveyor Operators[d]	-	-
MNM Total	**150,928**	**100.0%**

Source: Occupation Employment and Wage Statistics (OEWS) reported by BLS.
Notes: [a] For example, trucks, front end loaders, bulldozers, and scalers.
[b] The category includes laborers, electricians, mechanics, supervisors, and jackhammer operators.
[c] For example, bobcats and forklifts.
[d] BLS does not report occupations – including Conveyer Operators in MNM mines – with fewer than 50 jobs.
[e] The number of current and future miners were based on 2019 data (MSHA, 2019a; MSHA, 2019b) and are assumed to have remained constant through the 60 years following the start of implementation.
[f] Miners excluding contract miners.

FRIA Table 2-3. Estimated Number of Miners (Excluding Contract Miners) in Coal Sector, by Occupational Category

Occupational Category	Number of Miners [a][b]	Percent
Surface Large Powered Haulage Operators	14,114	27.4%
Underground Miners	10,653	20.7%
Surface Miners	9,228	17.9%
Underground Large Powered Haulage Operators	7,932	15.4%
Continuous Mining Machine Operators	5,811	11.3%
Roof Bolter Operators	2,565	5.0%
Longwall Operators	569	1.1%
Surface Drills Operators	413	0.8%
Surface Crusher Operators	289	0.6%
Coal Total	**51,573**	**100.00%**

Source: Occupational Employment and Wage Statistics (OEWS) reported by BLS
Note: [a] The number of current and future miners are based on 2019 data (MSHA, 2019a; MSHA, 2019b) and are assumed to have remained constant through the 60 years following the start of implementation.
[b] Miners excluding contract miners.

MSHA lacked information on occupational categories for the estimated 82,278 contract miners of which 60,275 (73 percent) work in the MNM sector and the remaining 22,003 (27 percent) work in the coal sector. However, based on MSHA's program experience, MSHA assumed that the distribution of contract miners across the different occupational categories mirrors that of the miners (excluding contract miners) in each of the two sectors. For example, MSHA assumed that, because 1.9 percent of MNM miners (excluding contract miners) are drillers, 1.9 percent of contract miners working in MNM mines (about 1,145 contract miners) are also drillers.

Not all miners work full-time (i.e., 2,000 hours per year) and some miners work overtime (i.e., > 2,000 hours per year) during the course of a year. To account for the fact that miners may experience more or less than 2,000 hours of exposure to respirable crystalline silica per year, MSHA calculates the number of miner full-time equivalents (FTEs) by dividing the estimated total number of hours worked across all miners in a given sector by 2,000 hours (i.e., the number of hours defined as full-time) (FRIA Table 2-4). In the MNM sector, there are an estimated 184,615 FTEs of which 148,966 (81 percent) are miner FTEs (excluding contract miners) and the remaining 35,649 (19 percent) are contract miner FTEs. The shares of miner (excluding contract miner) and contract miner FTEs are similar in the coal sector, with miner FTEs accounting for 81 percent (58,764/72,768) and contract miner FTEs accounting for the remaining 19 percent (14,004/72,768) of total FTEs.

FRIA Table 2-4. Estimated Miner and Contract Miner Full-Time Equivalents (FTEs)

Parameter [a]	MNM	Coal	Total
Number of Contract Miners[b]	60,275	22,003	82,278
Number of Contract Miner Hours [b]	71,297,875	28,007,955	99,305,830
Contract Miner FTEs [c]	35,649	14,004	49,653
Number of Miners (Excluding Contract Miners) [d]	150,928	51,573	202,501
Number of Miner Hours (Excluding Contract Miners) [d]	297,932,646	117,528,968	415,461,614
Miner FTEs (Excluding Contract Miners) [e]	148,966	58,764	207,730
Miner and Contract Miner FTEs Combined [f]	184,615	72,768	257,383

Notes: [a] The estimated number of current and future miners, miner hours, and miner FTEs are based on 2019 data and are assumed to have remained constant through the 60 years following the start of implementation (MSHA, 2019a; MSHA, 2019b).
[b] (Mine Safety and Health Administration, 2022a); (Mine Safety and Health Administration, 2022b)
[c] The figure is calculated by dividing the total number of contract miner hours by 2,000.
[d] From FRIA Table 2-1 above.
[e] Similar to the contract miner FTEs, the figure is calculated by dividing the total number of miner hours by 2,000.
[f] The figure is the sum of the calculated miner and contract miner FTEs.

As presented in FRIA Table 2-5 and FRIA Table 2-6, MSHA distributed the respirable dust samples in its MNM and coal exposure datasets by occupational category and exposure interval, based on MSHA's data on respirable crystalline silica samples. The exposure intervals in the MNM sector are grouped into six ranges: Less than 25 μg/m^3; ≥ 25 μg/m^3 and ≤ 50 μg/m^3; > 50 μg/m^3 and ≤ 100 μg/m^3; > 100 μg/m^3 and ≤ 250 μg/m^3; > 250 μg/m^3 and ≤ 500 μg/m^3; and greater than 500 μg/m^3. In the coal sector, the exposure range of > 50 μg/m^3 and ≤ 100 μg/m^3 is further divided into > 50 μg/m^3 and ≤ 85.7 μg/m^3 and > 85.7 μg/m^3 and ≤ 100 μg/m^3 to account for the conversion from MRE measurement to ISO.[19]

Because exposure data associated with individual miners are not available, MSHA derived the imputed exposure profile of miners and miner FTEs stratified by occupational category and exposure interval. First, MSHA assumed the proportion of miners in a given occupational category who are exposed to a given exposure interval is equal to the proportion of samples from that occupational category which fall within that interval. These proportions were then applied to the estimated number of miner FTEs in the given occupational category to estimate the number of FTEs in that occupational category that are exposed in that interval. Finally, MSHA aggregated all occupational categories to estimate the total number of miner and miner FTEs that fall within any given exposure interval. FRIA Table 2-8 presents the imputed

[19] As discussed in the FRA, the existing PEL for coal is 100 μg/m^3 MRE, measured as a TWA. When this figure is converted to International Organization for Standardization (ISO) from MRE it becomes 85.7 μg/m^3 ISO, measured as a TWA. The current standard for MNM as well as the new PEL for both coal and MNM is measured not as a TWA, but as an 8-hour TWA. There is no single conversion factor that can be applied when adjusting from a full-shift TWA to an 8-hour TWA. This means it is not possible to express the current coal standard as a single ISO 8-hour TWA figure. Given this, MSHA has chosen, when referring to coal's existing PEL, to express it as the approximate value of 85.7 μg/m^3 ISO, as measured as an 8-hour TWA. ISO concentration values (measured as 8-hour TWA) were used as the exposure metric when calculating risk in both the baseline scenario (i.e., full compliance with the current standard) and the "New PEL 50" scenario. As such, exposures were deemed "noncompliant" if they exceeded 85.7 μg/m^3 measured as an ISO 8-hour TWA.

exposure profiles of miners and miner FTEs at risk from respirable crystalline silica exposure at all levels in 2019 in the MNM and coal sectors, respectively.

In the MNM sector, an estimated 13,242 miners (6 percent), including contract miners, have respirable crystalline silica exposures above the existing PEL of 100 $\mu g/m^3$, an estimated 37,966 (18 percent) have exposures above the new PEL of 50 $\mu g/m^3$, and an estimated 77,736 (37 percent) have exposures at or above the action level of 25 $\mu g/m^3$. On an FTE basis, an estimated 11,579 miner FTEs (6 percent), including contract miner FTEs, have respirable crystalline silica exposures above the existing PEL of 100 $\mu g/m^3$, an estimated 33,146 (18 percent) have exposures above the new PEL of 50 $\mu g/m^3$, and an estimated 67,947 (37 percent) have exposures at or above the action level of 25 $\mu g/m^3$ (FRIA Table 2-7).

In the coal sector, an estimated 1,406 miners (2 percent), including contract miners, have respirable crystalline silica exposures above the existing PEL of 85.7 $\mu g/m^3$, an estimated 4,080 (6 percent) have exposures above the new PEL of 50 $\mu g/m^3$, and an estimated 13,971 (19 percent) have exposures at or above the action level of 25 $\mu g/m^3$. On an FTE basis, the figures are similar with an estimated 1,391 miner FTEs (2 percent), including contract miner FTEs, having respirable crystalline silica exposures above the existing PEL of 85.7 $\mu g/m^3$, an estimated 4,035 (6 percent) having exposures above the new PEL of 50 $\mu g/m^3$, and an estimated 13,818 (19 percent) having exposures at or above the action level of 25 $\mu g/m^3$ (FRIA Table 2-8).

FRIA Table 2-5. Percentage Distribution of Respirable Crystalline Silica Exposures in the MNM Industry from 2005 to 2019, by Occupational Category and Exposure Interval

Occupational Category	Number of Samples [a]	Percentage of Samples in ISO Concentration Ranges, µg/m³						Total
		< 25 µg/m³	≥ 25 to ≤ 50 µg/m³	> 50 to ≤ 100 µg/m³	> 100 to ≤ 250 µg/m³	> 250 to ≤ 500 µg/m³	> 500 µg/m³	
Operators of Large Powered Haulage Equipment [b]	17,016	75.8%	15.4%	6.6%	2.0%	0.2%	0.0%	**100.0%**
Mobile Workers [c]	15,216	59.8%	20.4%	12.6%	5.8%	1.1%	0.4%	**100.0%**
Crushing Equipment and Plant Operators	11,565	57.1%	22.5%	13.4%	5.8%	1.0%	0.2%	**100.0%**
Packing Equipment Operators	2,980	55.2%	19.2%	16.3%	7.4%	1.3%	0.6%	**100.0%**
Miners in Other Occupations	2,874	72.7%	15.1%	8.0%	3.0%	0.9%	0.3%	**100.0%**
Stone Cutting Operators	2,446	31.1%	22.1%	27.4%	13.9%	4.0%	1.4%	**100.0%**
Drillers	2,092	66.9%	17.8%	10.2%	3.8%	0.9%	0.4%	**100.0%**
Kiln, Mill, and Concentrator Workers	1,802	57.3%	21.1%	14.6%	4.6%	1.6%	0.7%	**100.0%**
Operators of Small Powered Haulage Equipment [d]	1,110	57.4%	20.7%	15.0%	5.4%	1.0%	0.5%	**100.0%**
Truck Loading Station Tenders	453	65.6%	13.9%	13.5%	6.4%	0.4%	0.2%	**100.0%**
Conveyor Operators	215	54.9%	24.2%	9.8%	8.8%	1.9%	0.5%	**100.0%**
MNM Total	**57,769**	**63.3%**	**19.0%**	**11.6%**	**4.8%**	**1.0%**	**0.3%**	**100.0%**

Source: MSHA MSIS respirable crystalline silica data for the MNM industry, January 1, 2005, through December 31, 2019 (version 20220812). Also see FRA Table 5 for a breakdown by MNM commodity.

Notes: [a] Personal samples collected using ISO-compliant sampling methods and calculated as an 8-hour equivalent TWA. Samples were collected using an air flow rate of 1.7 L/min and reported as full-shift, 8-hour TWAs.

[b] For example, trucks, front end loaders, bulldozers, and scalers.

[c] The category includes laborers, electricians, mechanics, supervisors, and jackhammer operators.

[d] For example, bobcats and forklifts.

FRIA Table 2-6. Percentage Distribution of Respirable Crystalline Silica Exposures as ISO full-shift, 8-hour TWA in the Coal Industry from 2016 to 2021, by Occupational Category and Exposure Interval

Occupational Category	Number of Samples [a]	Percentage of Samples in ISO Concentration Ranges, full-shift, 8-hour TWA, μg/m³							Total
		< 25 μg/m³	≥ 25 to ≤ 50 μg/m³	> 50 to ≤ 85.7 μg/m³	> 85.7 to ≤ 100 μg/m³	> 100 to ≤ 250 μg/m³	> 250 to ≤ 500 μg/m³	> 500 μg/m³	
Underground Large Powered Haulage Operators	21,777	82.4%	14.3%	2.6%	0.2%	0.4%	0.0%	0.0%	**100.0%**
Roof Bolter Operators	14,306	61.3%	29.3%	7.6%	0.7%	1.0%	0.0%	0.0%	**100.0%**
Continuous Mining Machine Operators	9,910	68.1%	23.9%	5.8%	0.7%	1.5%	0.1%	0.0%	**100.0%**
Surface Large Powered Haulage Operators	5,313	80.3%	11.8%	4.1%	0.8%	2.5%	0.3%	0.1%	**100.0%**
Underground Miners	3,926	86.5%	10.1%	2.4%	0.3%	0.6%	0.1%	0.0%	**100.0%**
Longwall Operators	3,176	55.6%	27.0%	11.2%	2.0%	3.9%	0.3%	0.0%	**100.0%**
Surface Miners	2,326	90.4%	7.1%	1.9%	0.1%	0.5%	0.0%	0.0%	**100.0%**
Surface Drills Operators	1,762	57.8%	24.0%	10.2%	1.7%	5.1%	1.0%	0.2%	**100.0%**
Surface Crusher Operators	631	93.2%	4.4%	2.1%	0.2%	0.2%	0.0%	0.0%	**100.0%**
Coal Total	**63,127**	**73.8%**	**19.3%**	**5.0%**	**0.6%**	**1.2%**	**0.1%**	**0.0%**	**100.0%**

Source: MSHA MSIS respirable crystalline silica data for the coal industry, August 1, 2016, through July 31, 2021 (version 20220617). Also see FRA Table 9.
Notes: [a] Personal samples presented in terms of ISO concentrations, normalized to full-shift, 8-hour TWAs. The samples were originally collected for the entire duration of each miner's work shift, using an air flow rate of 2 L/min.

FRIA Table 2-7. Imputed Respirable Crystalline Silica Exposure Profile of Miners and Miner FTEs in the MNM Industry in 2019, by Occupational Category and Exposure Interval

Occupational Category	Number of Miners [a][b]	Miners in ISO Concentration Ranges, µg/m³					
		< 25 µg/m³	≥ 25 to ≤ 50 µg/m³	> 50 to ≤ 100 µg/m³	> 100 to ≤ 250 µg/m³	> 250 to ≤ 500 µg/m³	> 500 µg/m³
Operators of Large Powered Haulage Equipment [c]	72,600	52,465	12,347	5,733	1,863	177	15
Mobile Workers [d]	65,032	38,052	13,391	8,474	3,948	882	285
Operators of Small Powered Haulage Equipment [e]	29,816	17,786	5,922	4,093	1,543	269	204
Stone Cutting Operators	8,934	3,413	1,761	2,127	1,101	376	156
Miners in Other Occupations	8,005	5,185	1,315	904	429	95	78
Crushing Equipment and Plant Operators	7,819	4,314	1,754	1,121	515	93	21
Truck Loading Station Tenders	7,783	5,298	1,149	857	448	21	10
Kiln, Mill, and Concentrator Workers	4,065	2,480	801	540	165	55	24
Drillers	3,942	2,498	803	443	152	31	15
Packing Equipment Operators	3,206	1,976	527	431	208	41	22
Conveyor Operators	-	-	-	-	-	-	-
MNM Total	***211,203***	**133,467**	**39,770**	**24,724**	**10,372**	**2,039**	**831**
Occupational Category	**Number of Miner FTEs [a][b]**	**Miner FTEs in ISO Concentration Ranges, µg/m³**					
		< 25 µg/m³	**≥ 25 to ≤ 50 µg/m³**	**> 50 to ≤ 100 µg/m³**	**> 100 to ≤ 250 µg/m³**	**> 250 to ≤ 500 µg/m³**	**> 500 µg/m³**
Operators of Large Powered Haulage Equipment [c]	63,809	45,967	10,925	5,091	1,656	156	13
Mobile Workers [d]	56,953	33,266	11,747	7,436	3,467	784	252
Operators of Small Powered Haulage Equipment [e]	25,727	15,462	5,062	3,479	1,319	226	179
Stone Cutting Operators	7,630	2,929	1,501	1,807	938	322	133
Miners in Other Occupations	7,119	4,577	1,174	818	392	87	72
Crushing Equipment and Plant Operators	6,755	3,720	1,510	973	451	82	19
Truck Loading Station Tenders	6,750	4,606	1,004	726	388	17	9
Kiln, Mill, and Concentrator Workers	3,578	2,188	706	473	143	47	21
Drillers	3,556	2,255	725	400	136	27	13

Packing Equipment Operators	2,738	1,697	447	365	175	34	19
Conveyor Operators	-	-	-	-	-	-	-
MNM Total	**184,615**	**116,668**	**34,801**	**21,567**	**9,066**	**1,784**	**729**

Notes: [a] The figure includes all miner (including contract miner) FTEs in the MNM sector.
[b] The estimated number of current and future miners and miner FTEs are based on 2019 data (MSHA, 2019a; MSHA, 2019b) and are assumed to have remained constant through the 60 years following the start of implementation.
[c] For example, trucks, front end loaders, bulldozers, and scalers.
[d] The category includes laborers, electricians, mechanics, supervisors, and jackhammer operators.
[e] For example, bobcats and forklifts.

FRIA Table 2-8. Imputed Respirable Crystalline Silica Exposure Profile of Miners and Miner FTEs in the Coal Industry in 2019, by Occupational Category and Exposure Interval

Occupational Category	**Number of Miners [a] [b]**	**Number of Miners in ISO Concentration Ranges, full-shift, 8-hour TWA, μg/m³**						
		< 25 μg/m³	**≥ 25 to ≤ 50 μg/m³**	**> 50 to ≤ 85.7 μg/m³**	**> 85.7 to ≤ 100 μg/m³**	**> 100 to ≤ 250 μg/m³**	**> 250 to ≤ 500 μg/m³**	**> 500 μg/m³**
Surface Large Powered Haulage Operators	20,135	16,175	2,376	830	171	500	68	15
Underground Miners	15,199	13,147	1,541	372	43	85	12	0
Surface Miners	13,164	11,897	928	255	17	62	6	0
Underground Large Powered Haulage Operators	11,316	9,322	1,616	299	27	49	4	0
Continuous Mining Machine Operators	8,290	5,647	1,979	479	56	120	9	0
Roof Bolter Operators	3,659	2,243	1,073	280	27	36	1	0
Longwall Operators	811	451	219	91	16	32	2	0
Surface Drills Operators	589	340	141	60	10	30	6	1
Surface Crusher Operators	412	384	18	8	1	1	0	0
Coal Total	**73,576**	**59,605**	**9,892**	**2,673**	**366**	**916**	**107**	**17**
Occupational Category	**Number of Miner FTEs [a] [b]**	**Number of Miner FTEs in ISO Concentration Ranges, full-shift, 8-hour TWA, μg/m³**						
		< 25 μg/m³	**≥ 25 to ≤ 50 μg/m³**	**> 50 to ≤ 85.7 μg/m³**	**> 85.7 to ≤ 100 μg/m³**	**> 100 to ≤ 250 μg/m³**	**> 250 to ≤ 500 μg/m³**	**> 500 μg/m³**
Surface Large Powered Haulage Operators	19,914	15,997	2,350	821	169	495	67	15
Underground Miners	15,032	13,003	1,524	368	42	84	11	0
Surface Miners	13,020	11,766	918	252	17	62	6	0

Underground Large Powered Haulage Operators	11,192	9,219	1,598	296	26	49	4	0
Continuous Mining Machine Operators	8,199	5,585	1,958	473	55	119	9	0
Roof Bolter Operators	3,619	2,218	1,061	277	27	36	1	0
Longwall Operators	802	446	216	90	16	32	2	0
Surface Drills Operators	582	337	139	59	10	30	6	1
Surface Crusher Operators	407	380	18	8	1	1	0	0
Coal Total	**72,768**	**58,951**	**9,783**	**2,644**	**362**	**906**	**106**	**17**

Notes: [a] The figure includes all miner (including contract miner) FTEs in the coal sector.
[b] The estimated number of miners and miner FTEs are based on 2019 data (MSHA, 2019a; MSHA, 2019b) and are assumed to have remained constant through the 60 years following the start of implementation.

3 BENEFIT ANALYSIS

In Section 3, MSHA estimates the benefits of the final rule. Specifically:

- Section 3.1 overviews the methodology of the FRA, which forecasts the long-run number of respirable crystalline silica-related diseases avoided due to the final rule once all miners (working and retired) have been exposed *only* under the new PEL.

- Section 3.2 presents the actual cases that will be avoided over a regulatory analysis time horizon of 60 years following the start of implementation of the rule, and estimates monetized benefits of the avoided cases during the 60-year analysis period.

    - Section 3.2.1 explains how MSHA adjusts the estimates of Section 3.1 (i.e., the "avoided lifetime cases") to account for the fact that, during the 60 years following the start of implementation of the rule, miners will have a combination of exposures under the existing limits and the new PEL. MSHA refers to these updated estimates as the "avoided cases during the 60 years following the start of implementation of the rule" (or similar terminology).

    - Section 3.2.2 describes MSHA's methodology for monetizing the avoided cases of Section 3.2.1 by assigning a financial value to each avoided death or illness.

    - Section 3.2.3 presents MSHA's methodology for discounting the monetized benefits in order to determine the present value of the expected benefits that will occur in the future.

    - In Sections 3.2.4 through 3.2.6, MSHA discusses the non-quantified benefits of the final rule—benefits resulting from the respiratory protection provisions for MNM and coal mines and from the requirement for medical surveillance at MNM mines.

The major change in estimation of benefits since the PRA and PRIA stems from MSHA's updated estimates of the mining population that will benefit. As stated above, in the PRIA, MSHA underestimated the future number of miners who would benefit from this rule. The current number of working miner full-time equivalents (FTEs) is estimated as 184,615 for MNM and 72,768 for coal.[20] In the PRIA, MSHA assumed excess cases of disease would be reduced only among a future population of these sizes. However, during the 60-year analysis period, working miners whose exposures are reduced by the new PEL will retire and benefit from having spent part of their work tenures under the new PEL (i.e., will have reduced their

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[20] The analysis of this FRIA assumes the mining workforce will not change size during the 60 years following the implementation of the rule to simplify estimation of health benefits. The current and long-term size of the mining workforce was estimated using 2019 data, since the COVID-19 pandemic may have led to temporary changes in the mining workforce that will be reversed in coming years.

cumulative exposures to respirable crystalline silica). These retired miners will be replaced by new miners entering the mining workforce, who will simultaneously benefit from reduced exposures due to the new PEL. Thus, in any given year after the start of implementation, both working and future retired miners whose exposures occurred after the new PEL went into effect will benefit from the rule. The PRIA's methodology did not account for the number of these future retired miners and, therefore, underestimated the number of avoided excess cases attributable to the rule.[21] In the FRIA, MSHA updated the methodology to account for all excess cases that will be avoided among not only working but also future retired miners, who expand the effective exposed population beyond just 184,615 for MNM and 72,768 for coal. These updated estimates are presented in Section 3.1, below.

The FRA and the FRIA were updated to account for benefits among both working miners and future retired miners. It is important to note, however, that the FRIA only monetizes benefits to *future* retired miners who were employed at least one year after the start of implementation. Based on the FRIA methodology, there are no health benefits to individuals who retired *before* the start of implementation of the final rule. The FRIA is updated to reflect the fact that, after the start of implementation, there is a gradual increase in the number of future retired miners who benefit from the rule. For example, in the first year after the start of implementation, there will be no retired miners who benefit from the rule. In the second year after the start of implementation, there will be one cohort of retired miners who benefit from the rule (i.e., those in their final year of mining when implementation began). In this way, the FRIA monetizes benefits to future retired miners while accounting for the fact that the future retired miners who benefit from the rule increase in size gradually during the 60-year analysis period.

The other change in benefits estimation since the PRIA is an inflation adjustment. In the PRIA, all benefits analysis was performed using 2021 dollars and based on the most recent economic parameters available. In this FRIA, the economic parameters have not been changed, but all final monetized results have been inflated to 2022 dollars using the BEA's GDP Price Deflator (U.S. Bureau of Economic Analysis, 2023).

3.1 Estimation of the Lifetime Number of Silica-related Diseases Avoided

In this Section 3.1, MSHA overviews the methodology and results of the FRA. Specifically, MSHA:

- Characterizes the median exposures to respirable crystalline silica that coal and MNM miners experience (FRIA Table 3-1);

[21] More specifically, the PRIA calculated benefits to all 60 cohorts in each year but also applied a scaling factor of 45/60 in order to calculate an average value for a population equal to the number of working miners only. In the FRIA, this scaling factor has been removed.

- Describes the FRA's methodology for calculating the number of lifetime cases that will be avoided once all miners (working and retired) have only been exposed to, at most, the new PEL of 50 $\mu g/m^3$;

- Discusses the specific diseases that the FRA quantifies based on the available exposure-response models;

- Presents the FRA's results, both in terms of the reduction in lifetime excess risk (FRIA Table 3-2) and the avoided lifetime cases (disaggregated in FRIA Table 3-3 and aggregated in FRIA Table 3-4);

- Briefly describes some of the uncertainties considered in the FRA based on the available data, models, and methodology.

MSHA estimates the benefits associated with avoided cases of disease (both morbidity and mortality) attributable to the new PEL of 50 $\mu g/m^3$ for the following health outcomes identified in the FRA[22]:

- Non-fatal cases of silicosis,

- Fatal cases of silicosis,

- Fatal cases of NMRD (other than silicosis[23]),

- Fatal cases of ESRD, and

- Fatal cases of lung cancer.

Avoided lifetime excess cases of respirable crystalline silica related diseases are calculated as the difference between estimated lifetime excess cases under the existing standards of 100 $\mu g/m^3$ for MNM and 85.7 $\mu g/m^3$ for coal[24] to those under the new PEL of 50

[22] CWP is not included in the following list because MSHA does not quantify benefits from CWP in this analysis. A more detailed discussion of the expected impact of the final rule on CWP and MSHA's reasons for not quantifying this relationship may be found in Section 3.2.5.

[23] To avoid counting silicosis deaths twice, MSHA subtracted the number of expected silicosis deaths from the number of expected NMRD deaths.

[24] As discussed in the FRA, the existing standard for coal is 100 $\mu g/m^3$ MRE, measured as a full-shift TWA. To calculate risks consistently for both coal and MNM miners, the FRA converts the MRE full-shift TWA concentrations experienced by coal miners to ISO 8-hour TWA concentrations (see Section 4 of the FRA for a full explanation). Note that exposures at TWA 100 $\mu g/m^3$ MRE and SWA 85.7 $\mu g/m^3$ ISO are only equivalent when the sampling duration is 480 minutes (eight hours). However, for the sake of simplicity, this analysis approximates exposures at the existing coal exposure limit of 100 MRE $\mu g/m^3$ as 85.7 $\mu g/m^3$ ISO for comparison purposes. Thus, ISO concentration values (measured as an 8-hour TWA) were used as the exposure metric when calculating risk under both the "Baseline" scenario (i.e., full compliance with the existing standards) and the "New PEL 50" scenario. To simulate compliance among coal miners, exposures were capped at 85.7 $\mu g/m^3$ measured as an ISO 8-hour TWA, which is approximately equal to the existing coal standard, when calculating risks to coal miners in the baseline scenario.

µg/m^3. MSHA applied the exposure-response relationships developed in the FRA (FRA Table 2) to the imputed exposure profile presented in FRIA Table 3-1 and FRIA Table 3-2 to determine risks associated with various exposure levels for each of the respirable crystalline silica-related diseases.

After distributing the miner population (stratified by occupational category) to exposure groups based on the proportion of total samples occurring in each exposure interval, MSHA further assigned a single value to represent the exposure level in each of the exposure intervals.[25] MSHA assumed full compliance with the existing standards and therefore capped those exposure intervals which exceeded the existing standards at 100 µg/m^3 for MNM miners and at 85.7 µg/m^3 for coal miners. For those exposure intervals containing exposures at or below the existing standards, MSHA assigned the exposure level at the median exposure level calculated from the MSHA inspection samples that fell within the given exposure interval. For example, among MNM exposure samples that were at or below 25 µg/m^3, MSHA calculated a median exposure level of 7.0 µg/m^3 (FRIA Table 3-1). Thus, all MNM miners who are grouped under the exposure interval defined as at or below 25 µg/m^3 are assumed to have a constant exposure level of 7.0 µg/m^3.

Under the "New PEL 50" scenario, MSHA projects that miners in those strata with exposures above 50 µg/m^3 under the existing standards will reduce exposures to 50 µg/m^3 after the start of implementation. For miners with exposures below 50 µg/m^3 under the existing standards, the exposure levels will remain at median levels. FRIA Table 3-1 presents the median exposures for each exposure interval and the assigned exposure level of miners in each exposure interval under the existing standards and under the new PEL.

FRIA Table 3-1. Median Exposures of Miners, by Sector and Exposure Interval

Exposure Interval	From MSHA Exposure Datasets		Under Baseline Scenario		Under New PEL 50 Scenario	
	MNM	Coal	MNM	Coal	MNM	Coal
≤ 25 µg/m^3	7.0	12.3	7.0	12.3	7.0	12.3
> 25 to ≤ 50 µg/m^3	35.0	33.3	35.0	33.3	35.0	33.3
> 50 to ≤ 85.7 µg/m^3	69.0	60.4	69.0	60.4	50.0	50.0
> 85.7 to ≤ 100 µg/m^3		92.4		85.7		50.0
> 100 to ≤ 250 µg/m^3	138.0	126.9	100.0	85.7	50.0	50.0
> 250 to ≤ 500 µg/m^3	322.0	288.3	100.0	85.7	50.0	50.0
> 500 µg/m^3	613.0	666.5	100.0	85.7	50.0	50.0

Note: The "Baseline" scenario caps all exposures at a 100 µg/m^3 (for MNM) or 85.7 µg/m^3 (for coal). The "New PEL 50" scenario caps all exposures at 50 µg/m^3.

[25] In the cost analysis, the two lowest intervals are < 25 µg/m^3 and ≥ 25 to ≤ 50 µg/m^3. The boundary of 25 µg/m^3 was included in the second group for cost purposes since above AL sampling is triggered by exposures at the AL. In the risk analysis and benefits analysis, MSHA used ≤ 25 µg/m^3 and > 25 to ≤ 50 µg/m^3 as the two lowest intervals so that all exposure ranges would be equally sized. However, this does not affect estimates of avoided cases or total benefits because every miner with exposure less than or equal to 50 µg/m^3 is assigned no benefits under the new rule since their exposure is already compliant with the new rule.

In the FRA, to examine the lifetime effect of changing the PEL, MSHA compared the number of lifetime excess respirable crystalline silica-related disease cases that would occur if miners were exposed for their entire working life at or below the new PEL of 50 µg/m^3 to the number of cases that occur at levels of exposure at or below the existing standards (100 µg/m^3 for MNM and 85.7 µg/m^3 for coal) using a life table methodology (see Appendix B of the FRA). Risk estimates for morbidity and mortality due to occupational exposure to respirable crystalline silica are presented in terms of lifetime excess risk per 1,000 exposed miners. Lifetime excess risks and cases are estimated over a 60-year period that includes 45 years of working life (starting at age 21 and retiring at age 65) and 15 years of retirement. This approach is to properly account for adverse health impacts resulting from cumulative exposure to respirable crystalline silica that may manifest during a miner's working years or during a miner's retired years after exposure to respirable crystalline silica has ceased.[26] The annual exposure duration is scaled by a weighted average FTE ratio[27] for all miners including contract miners. FRIA Table 3-2 below presents the estimated lifetime excess risks per 1,000 exposed miners at exposure levels equal to the existing standards, the new PEL, and the differences in lifetime excess risks attributable to the rule for each of the respirable crystalline silica-related diseases.

[26] The assumptions of a 45-year "working life" (constituting 45 years of exposure) is established by precedent as documented in the FRA (73 FR 11292). A 15-year retirement period is used to quantify the full benefits of the rule, which is necessitated in part by the facts that many of these diseases have periods of latency and retired miners continue to experience elevated risk after exiting the workforce. The analysis does not assume every miner lives to the age of 80, but, for the purposes of the analysis, it assumes that no miner lives past the age of 80; the life table methodology accounts for the fact that some miners die in each year from age 21 onward. To the extent that any miners live beyond the assumed maximum age of 80, there would be additional unquantified benefits from the rule. The 15-year retirement period was selected in part because the Miller and MacCalman (2010) study used a 15-year lag between exposure to respirable crystalline silica and its impact on excess lung cancer risk.

[27] FTEs were chosen as the unit of measurement for the benefits analysis because health benefits are a function of hours exposed. Miners who work less than full time experience less than average exposure and are therefore at lower risk, while those who consistently work overtime experience more than average exposure and are at higher risk. Using FTEs adjusts for exposure hours by standardizing miner hours. However, the contract miner FTE ratios likely have some negative bias since any individual who works for multiple contract companies is counted multiple times in the data, inflating the denominator in the FTE ratio calculation. MSHA also notes that the contract miner FTE ratios likely underrepresent the true overall cumulative exposures since contract miners may have other jobs involving exposure to respirable crystalline silica.

FRIA Table 3-2. Incremental Reduction in Lifetime Excess Risk per 1,000 Miners Exposed to Respirable Crystalline Silica Under the Final Rule, by Exposure Interval and Health Outcome

Health Outcome	Exposure Interval	Baseline Scenario		New PEL 50 Scenario		Incremental Reduction in Lifetime Risk Attributable to the Final Rule	
		MNM	Coal	MNM	Coal	MNM	Coal
Morbidity							
Silicosis	≤ 25 μg/m³	10.1	12.8	10.1	12.8	0.0	0.0
	> 25 to ≤ 50 μg/m³	26.3	28.8	26.3	28.8	0.0	0.0
	> 50 to ≤ 85.7 μg/m³	81.3	79.5	43.6	54.2	37.6	25.2
	> 85.7 to ≤ 100 μg/m³		189.9		54.2		135.7
	> 100 to ≤ 250 μg/m³	206.7	189.9	43.6	54.2	163.1	135.7
	> 250 to ≤ 500 μg/m³	206.7	189.9	43.6	54.2	163.1	135.7
	> 500 μg/m³	206.7	189.9	43.6	54.2	163.1	135.7
Mortality							
NMRD	≤ 25 μg/m³	4.0	7.9	4.0	7.9	0.0	0.0
	> 25 to ≤ 50 μg/m³	19.6	21.1	19.6	21.1	0.0	0.0
	> 50 to ≤ 85.7 μg/m³	38.2	37.9	27.9	31.5	10.3	6.4
	> 85.7 to ≤ 100 μg/m³		53.2		31.5		21.7
	> 100 to ≤ 250 μg/m³	54.8	53.2	27.9	31.5	26.9	21.7
	> 250 to ≤ 500 μg/m³	54.8	53.2	27.9	31.5	26.9	21.7
	> 500 μg/m³	54.8	53.2	27.9	31.5	26.9	21.7
Silicosis	≤ 25 μg/m³	2.5	2.5	2.5	2.5	0.0	0.0
	> 25 to ≤ 50 μg/m³	4.8	5.1	4.8	5.1	0.0	0.0
	> 50 to ≤ 85.7 μg/m³	9.4	9.4	5.9	8.1	3.5	1.3
	> 85.7 to ≤ 100 μg/m³		14.1		8.1		5.9
	> 100 to ≤ 250 μg/m³	14.3	14.1	5.9	8.1	8.4	5.9
	> 250 to ≤ 500 μg/m³	14.3	14.1	5.9	8.1	8.4	5.9
	> 500 μg/m³	14.3	14.1	5.9	8.1	8.4	5.9
ESRD	≤ 25 μg/m³	13.0	16.8	13.0	16.8	0.0	0.0
	> 25 to ≤ 50 μg/m³	23.2	23.8	23.2	23.8	0.0	0.0
	> 50 to ≤ 85.7 μg/m³	29.0	28.9	26.1	27.2	2.9	1.7
	> 85.7 to ≤ 100 μg/m³		32.3		27.2		5.1
	> 100 to ≤ 250 μg/m³	32.6	32.3	26.1	27.2	6.5	5.1
	> 250 to ≤ 500 μg/m³	32.6	32.3	26.1	27.2	6.5	5.1
	> 500 μg/m³	32.6	32.3	26.1	27.2	6.5	5.1

<table>
<tr><th rowspan="2">Health Outcome</th><th rowspan="2">Exposure Interval</th><th colspan="2">Baseline Scenario</th><th colspan="2">New PEL 50 Scenario</th><th colspan="2">Incremental Reduction in Lifetime Risk Attributable to the Final Rule</th></tr>
<tr><th>MNM</th><th>Coal</th><th>MNM</th><th>Coal</th><th>MNM</th><th>Coal</th></tr>
<tr><td rowspan="7">Lung Cancer</td><td>≤ 25 µg/m³</td><td>0.4</td><td>0.7</td><td>0.4</td><td>0.7</td><td>0.0</td><td>0.0</td></tr>
<tr><td>> 25 to ≤ 50 µg/m³</td><td>1.8</td><td>2.0</td><td>1.8</td><td>2.0</td><td>0.0</td><td>0.0</td></tr>
<tr><td>> 50 to ≤ 85.7 µg/m³</td><td rowspan="2">3.7</td><td>3.6</td><td rowspan="2">2.6</td><td>3.0</td><td rowspan="2">1.1</td><td>0.7</td></tr>
<tr><td>> 85.7 to ≤ 100 µg/m³</td><td>5.3</td><td>3.0</td><td>2.3</td></tr>
<tr><td>> 100 to ≤ 250 µg/m³</td><td>5.5</td><td>5.3</td><td>2.6</td><td>3.0</td><td>2.8</td><td>2.3</td></tr>
<tr><td>> 250 to ≤ 500 µg/m³</td><td>5.5</td><td>5.3</td><td>2.6</td><td>3.0</td><td>2.8</td><td>2.3</td></tr>
<tr><td>> 500 µg/m³</td><td>5.5</td><td>5.3</td><td>2.6</td><td>3.0</td><td>2.8</td><td>2.3</td></tr>
<tr><td colspan="8">Note: The “Baseline” scenario caps all exposures at a 100 µg/m³ (for MNM) or 85.7 µg/m³ (for coal). The “New PEL 50” scenario caps all exposures at 50 µg/m³.</td></tr>
</table>

For example, FRIA Table 3-2 shows that, under the existing standard of 100 µg/m^3, the lifetime excess risk of silicosis morbidity for MNM miners is 206.7 per 1,000 miners in the 100-250 µg/m^3 exposure interval as compared to the general population. Under the "New PEL 50" scenario, this lifetime excess risk is lowered to 43.6 in 1,000 miners in this same exposure interval. Thus, the estimated reduction in risk attributable to the final rule for MNM miners in this exposure interval is 163.1 per 1,000 miners, which is the difference between 206.7 per 1,000 miners and 43.6 per 1,000 miners. Given an estimated 9,185 MNM miner FTEs in this exposure interval (FRIA Table 2-7), the new PEL will reduce the number of expected lifetime excess silicosis cases in the future by 1,498 (163.1 x (9,185/1000)).

The number of avoided lifetime excess cases over 60 years (i.e., a 45-year working life and 15 years of retirement) for a future population of working and retired miners exposed at the lower PEL during their entire working life is equal to the difference between the number of lifetime excess cases at levels of exposure at or below the existing standard for that population and the number of lifetime excess cases at levels of exposure at or below the new, lower PEL. This approach represents a comparison of miners who have only been exposed at or below the current standards to an otherwise equivalent group of miners who have only been exposed at or below the new PEL of 50 µg/m^3. FRIA Table 3-3 presents the avoided lifetime excess cases for miners attributable to the final rule for each of the respirable crystalline silica-related diseases by exposure interval as a corollary to FRIA Table 3-2. FRIA Table 3-4 presents a summary by health outcome.

FRIA Table 3-3. Estimated Avoided Lifetime Cases Among Miners Exposed to Respirable Crystalline Silica Under the Final Rule, by Exposure Interval and Health Outcome

Health Outcome	Exposure Interval	Baseline Scenario		New PEL 50 Scenario		Avoided Lifetime Cases Attributable to the Final rule	
		MNM	Coal	MNM	Coal	MNM	Coal
Morbidity							
Silicosis (Excluding Silicosis Deaths) [a]	≤ 25 μg/m^3	1,207.1	813.8	1,207.1	813.8	0.0	0.0
	> 25 to ≤ 50 μg/m^3	927.3	309.6	927.3	309.6	0.0	0.0
	> 50 to ≤ 85.7 μg/m^3	2,090.4	247.1	1,096.9	162.7	993.5	84.4
	> 85.7 to ≤ 100 μg/m^3		84.9		22.3		62.7
	> 100 to ≤ 250 μg/m^3	2,356.0	212.5	462.0	55.8	1,894.0	156.7
	> 250 to ≤ 500 μg/m^3	468.3	24.8	91.8	6.5	376.4	18.3
	> 500 μg/m^3	194.8	3.9	38.2	1.0	156.6	2.9
Morbidity Total (Excluding Silicosis Deaths) [a]	**≤ 25 μg/m^3**	**1,207.1**	**813.8**	**1,207.1**	**813.8**	**0.0**	**0.0**
	> 25 to ≤ 50 μg/m^3	**927.3**	**309.6**	**927.3**	**309.6**	**0.0**	**0.0**
	> 50 to ≤ 85.7 μg/m^3	**2,090.4**	**247.1**	**1,096.9**	**162.7**	**993.5**	**84.4**
	> 85.7 to ≤ 100 μg/m^3		**84.9**		**22.3**		**62.7**
	> 100 to ≤ 250 μg/m^3	**2,356.0**	**212.5**	**462.0**	**55.8**	**1,894.0**	**156.7**
	> 250 to ≤ 500 μg/m^3	**468.3**	**24.8**	**91.8**	**6.5**	**376.4**	**18.3**
	> 500 μg/m^3	**194.8**	**3.9**	**38.2**	**1.0**	**156.6**	**2.9**
Mortality							
NMRD (Excluding Silicosis Deaths) [b]	≤ 25 μg/m^3	238.8	426.4	238.8	426.4	0.0	0.0
	> 25 to ≤ 50 μg/m^3	638.6	209.3	638.6	209.3	0.0	0.0
	> 50 to ≤ 85.7 μg/m^3	839.5	100.5	639.9	82.5	199.6	18.0
	> 85.7 to ≤ 100 μg/m^3		18.9		11.3		7.6
	> 100 to ≤ 250 μg/m^3	495.5	47.3	269.5	28.3	226.0	19.0
	> 250 to ≤ 500 μg/m^3	98.5	5.5	53.6	3.3	44.9	2.2
	> 500 μg/m^3	41.0	0.9	22.3	0.5	18.7	0.3
Silicosis	≤ 25 μg/m^3	389.5	193.5	389.5	193.5	0.0	0.0
	> 25 to ≤ 50 μg/m^3	209.2	65.9	209.2	65.9	0.0	0.0
	> 50 to ≤ 85.7 μg/m^3	272.3	33.0	171.5	28.6	100.8	4.4
	> 85.7 to ≤ 100 μg/m^3		6.8		3.9		2.9
	> 100 to ≤ 250 μg/m^3	175.3	17.0	72.2	9.8	103.0	7.2
	> 250 to ≤ 500 μg/m^3	34.8	2.0	14.4	1.1	20.5	0.8
	> 500 μg/m^3	14.5	0.3	6.0	0.2	8.5	0.1
ESRD	≤ 25 μg/m^3	2,049.8	1,322.0	2,049.8	1,322.0	0.0	0.0

Health Outcome	Exposure Interval	Baseline Scenario		New PEL 50 Scenario		Avoided Lifetime Cases Attributable to the Final rule	
		MNM	Coal	MNM	Coal	MNM	Coal
	> 25 to ≤ 50 μg/m³	1,001.2	310.0	1,001.2	310.0	0.0	0.0
	> 50 to ≤ 85.7 μg/m³	842.4	101.8	759.1	95.8	83.4	6.0
	> 85.7 to ≤ 100 μg/m³		15.6		13.1		2.5
	> 100 to ≤ 250 μg/m³	399.1	39.0	319.7	32.8	79.3	6.2
	> 250 to ≤ 500 μg/m³	79.3	4.6	63.5	3.8	15.8	0.7
	> 500 μg/m³	33.0	0.7	26.4	0.6	6.6	0.1
Lung Cancer	≤ 25 μg/m³	56.2	55.9	56.2	55.9	0.0	0.0
	> 25 to ≤ 50 μg/m³	78.3	25.5	78.3	25.5	0.0	0.0
	> 50 to ≤ 85.7 μg/m³	106.9	12.8	76.3	10.5	30.6	2.3
	> 85.7 to ≤ 100 μg/m³		2.6		1.4		1.1
	> 100 to ≤ 250 μg/m³	66.9	6.4	32.1	3.6	34.8	2.8
	> 250 to ≤ 500 μg/m³	13.3	0.7	6.4	0.4	6.9	0.3
	> 500 μg/m³	5.5	0.1	2.7	0.1	2.9	0.1
Mortality Total	**≤ 25 μg/m³**	**2,734.3**	**1,997.8**	**2,734.3**	**1,997.8**	**0.0**	**0.0**
	> 25 to ≤ 50 μg/m³	**1,927.4**	**610.8**	**1,927.4**	**610.8**	**0.0**	**0.0**
	> 50 to ≤ 85.7 μg/m³	**2,061.1**	**248.1**	**1,646.7**	**217.4**	**414.4**	**30.7**
	> 85.7 to ≤ 100 μg/m³		**43.8**		**29.8**		**14.0**
	> 100 to ≤ 250 μg/m³	**1,136.8**	**109.6**	**693.6**	**74.5**	**443.2**	**35.1**
	> 250 to ≤ 500 μg/m³	**225.9**	**12.8**	**137.9**	**8.7**	**88.1**	**4.1**
	> 500 μg/m³	**94.0**	**2.0**	**57.4**	**1.4**	**36.6**	**0.6**
The "Baseline" scenario caps all exposures at a 100 μg/m³ (for MNM) or 85.7 μg/m³ (for coal). The "New PEL 50" scenario caps all exposures at 50 μg/m³.							

Notes: [a] The estimated number of silicosis mortalities is subtracted from the estimated number of silicosis morbidity cases.
[b] NMRD net mortality is the difference between the estimated NMRD and silicosis deaths.

FRIA Table 3-4. Estimated Cases of Lifetime Avoided Morbidity and Mortality Attributable to the Final Rule

Health Outcome	Total Lifetime Avoided Cases Among a Population Only Exposed to the New PEL [a]			Long-Run Average Total Cases Avoided per Year Among Miners Only Exposed to the New PEL [b]		
	MNM	Coal	Total	MNM	Coal	Total
Avoided Morbidity						
Silicosis (Excluding Silicosis Deaths)	3,421	325	3,746	57.0	5.4	62.4
Avoided Mortality						
NMRD (Excluding Silicosis Deaths)	489	47	536	8.2	0.8	8.9
Silicosis	233	15	248	3.9	0.3	4.1
ESRD	185	15	200	3.1	0.3	3.3
Lung Cancer [c]	75	7	82	1.3	0.1	1.4
Avoided Mortality Total	**982**	**85**	**1,067**	**16.4**	**1.4**	**17.8**

Notes: Numbers may not sum to the total due to rounding. The health outcomes are ordered from largest to smallest based on total lifetime avoided cases. Also see FRA Table 17 and FRA Table 18.
[a] Avoided cases apply to all miners, including contract miners. Calculations show the difference between excess cases when assuming compliance with the existing limits versus assuming compliance with the new PEL of 50 $\mu g/m^3$.
[b] The long-run average total cases avoided per year is the number of cases avoided among the surviving at-risk population of working and retired miners in a given year in the future when all working and retired miners have been exposed only under the new PEL.
[c] A 15-year lag between exposure and observed health effect was assumed for lung cancer estimates.

In calculating avoided non-fatal silicosis cases for FRIA Table 3-4 above, MSHA included only moderate-to-severe cases in accordance with the International Labour Organization (ILO) classification system.[28] Moderate-to-severe cases are those registering 2/1+ or more using the ILO method. As discussed in the FRA, based on a study by Buchanan *et al*. (2003) of a cohort of coal miners, MSHA estimates that the new PEL will avoid 3,994 lifetime excess cases of moderate-to-severe silicosis among the total miner population, or about 66.6 cases of moderate-to-severe silicosis avoided annually on a long-run average basis. After subtracting the fatal silicosis cases from these totals, an estimate of 3,746 avoided non-fatal silicosis cases over the 60-year period is obtained, or about 62.4 cases avoided per year on a long-run average basis.

Based on the model of Mannetje *et al*. (2002b) and Toxachemica, Inc. (2004), MSHA estimates that the new PEL will avoid a total of about 248 silicosis lifetime deaths in both the MNM and coal mine sectors or about 4.1 silicosis deaths avoided per year on a long-run average basis.

[28] The ILO Classification of Radiographs of Pneumoconioses is a standardized system to classify the opacities seen on chest radiographs (ILO 1980, 2002, 2011, and 2022). The ILO system grades the size, shape, and profusion of opacities in the lung. Profusion scores for simple pneumoconiosis are graded 1, 2, or 3, with 3 being the most severe, and for complicated pneumoconiosis, A, B, or C, with C being the most severe. Category 0 is a normal film (ILO 2002 and 2011; Wagner et al., 1993; NIOSH 2014b).

Following Park *et al*. (2002), as discussed in the Agency's FRA, MSHA estimates that the new PEL will avoid 536 NMRD lifetime deaths in both the MNM and coal mine sectors, or about 8.9 cases per year on a long-run average basis. Thus, in total, the new PEL is estimated to avoid 784 NMRD lifetime deaths (248 + 536) in both the MNM and coal mine sectors or about 13.1 cases avoided per year on a long-run average basis.

MSHA also finds that miners with significant exposures to respirable crystalline silica are at elevated risk of ESRD. Based on Steenland *et al*. (2002a), MSHA estimates that the new PEL will avoid 200 cases of ESRD over the lifetime of the current miner population, or about 3.3 cases annually on a long-run average basis.

Combining the four major fatal health endpoints analyzed in the FRA (i.e., NMRD, silicosis, ESRD, and lung cancer), MSHA estimates that the new PEL will avoid 1,067 premature deaths over the lifetime among a future population of MNM and coal miners that is equal in size to the current MNM and coal miner population. This is the equivalent of an average of 17.8 cases avoided annually, given a 45-year working life of exposure to the new PEL and following miners 15 years into retirement as summarized in FRIA Table 3-4.

In summary, FRIA Table 3-4 shows the lifetime excess cases that will be avoided among a population of miners that has only been exposed to the new PEL.[29] These estimates are calculated by taking the difference in expected number of excess cases between (a) the "Baseline" scenario, which assumes compliance with the existing standards and assumes miners are only exposed under the existing standards, and (b) the "New PEL 50" scenario, which assumes compliance with the new PEL of 50 μg/m^3 and assumes miners are only exposed under the new PEL. However, the avoided excess cases shown in FRIA Table 3-4 were not monetized in this economic analysis because fewer cases would be avoided immediately after the start of implementation since working miners will have been exposed under the existing limits. During the 60 years following implementation, annual benefits will increase gradually toward the long-run annual values shown in the right half of FRIA Table 3-4. Thus, MSHA also calculated the actual number of excess cases that the rule is expected to prevent during a 60-year analysis time period following the start of implementation of the rule. During this 60-year analysis time period, miners will have a combination of exposures under both the existing standards and the new PEL. The final benefits are based on monetizing these actual expected number of avoided excess deaths and illness during the 60-year analysis period (see Section 3.2 for further discussion).

The Agency notes that these estimates assume that miners are exposed to a constant concentration of respirable crystalline silica for their entire working lives, from the start of age 21 through the end of age 65. In other words, miners were assumed not to enter or exit jobs with respirable crystalline silica exposure mid-career or switch to other exposure groups during their working lives. The sensitivity analysis of Section 5.2 evaluates the benefits of the rule when changing the assumption of a 45-year mining tenure. Section 5.2 considered alternative

[29] The "long run" refers to the period of time when all surviving miners (working and retired) have only been exposed under the new PEL.

assumptions of 35, 25, and 15 years of mining exposure. In all scenarios, benefits from avoided mortality increase while benefits from avoided morbidity due to silicosis decrease, which is consistent with what OSHA found when performing their working tenure sensitivity analysis (OSHA, 2016a). Hence, the final rule was found to have positive net benefits under all modeled tenures. MSHA's risk estimates are based on the application of exposure-response models derived from several individual epidemiological studies, as well as the pooled cohort studies of Steenland *et al*. (2001a) and Mannetje *et al*. (2002b). MSHA recognizes that there is uncertainty around any of the point estimates of risk derived from any single study. In its FRA, MSHA has made efforts to characterize some of the more important sources of uncertainty to the extent that available data permit. This includes characterizing statistical uncertainty by reporting the confidence intervals around each of the risk estimates based on sampling variation, the healthy worker survivor bias, the use of average (rather than median) exposures, the possibility that new controls could lead to some miners' exposures being reduced below 50 $\mu g/m^3$, and the exclusion of samples that were not analyzed. MSHA believes that these efforts reflect many, but not necessarily all, of the uncertainties associated with the approaches taken by researchers in their respective risk analyses.

Another source of uncertainty involves the degree to which MSHA's risk estimates reflect the risk of disease among miners with widely varying exposure patterns. Some miners may be exposed to fairly high concentrations of respirable crystalline silica only intermittently, while others may experience more regular or constant exposure. Risk models employed in the FRA are based on a cumulative exposure metric, which is the product of median respirable crystalline silica concentration and duration of miner exposure for a specific job. Consequently, these models predict the same risk for a given cumulative exposure regardless of the pattern of exposure and thus reflect a miner's long-term median exposure without regard to variances in exposure.

Further, MSHA acknowledges that differences exist in the relative toxicity of respirable crystalline silica present in different work settings. This may be due to factors such as differences in the crystal structure of respirable crystalline silica (i.e., polymorphs), the presence of mineral or metal impurities on particle surfaces, whether the particles have been freshly fractured or are aged, and size distribution of particles. However, none of these factors conclusively eliminate the risk of occupational disease from respirable crystalline silica exposure. Moreover, the estimates from the studies and analyses relied upon in the FRA are representative of a wide range of work settings reflecting differences in respirable crystalline silica polymorphism, surface properties, and impurities. Thus, the Agency believes that the results of its risk assessment are broadly relevant to all occupational exposure situations involving respirable crystalline silica.

Additionally, as discussed in the FRA, the exposure datasets on which the risk analysis is based may contain some upward bias, the magnitude of which cannot be quantified. In some but not all cases, MSHA inspectors sample miners working in specific jobs they believe have the highest exposures. Consequently, the exposure profiles developed from these datasets may distribute a larger proportion of samples into higher exposure intervals, thereby potentially inflating the number of miners assigned to higher exposure intervals. This bias could result in an overestimation of the avoided cases and corresponding benefits. However, MSHA believes the impact of this bias may be counteracted by other potential biases (e.g., the healthy worker survivor bias, also discussed in the FRA) that are likely causing underestimation of the avoided lifetime excess cases and corresponding benefits.

3.2 Estimating the Stream of Benefits Over Time

In this Section 3.2**.**, MSHA estimates the monetized benefits of the final rule. Specifically, MSHA:

- Describes the methodology for estimating the avoided cases in each of the 60 years following the start of implementation of the rule, accounting for the fact that miners will initially have a combination of exposures under the existing standards and the new PEL (Section 3.2.1);

- Presents the total avoided cases over the 60-year analysis period (FRIA Table 3-5) when accounting for the fact that benefits will gradually increase as miners with exposures under the existing rule are replaced by miners with exposures under the new PEL;

- Monetizes the avoided cases over the 60-year analysis period, by placing a monetary value on each avoided death or avoided illness (Section 3.2.2), and presents the total monetized benefits associated with the cases avoided during the 60-year analysis period (FRIA Table 3-6);

- Describes the methodology for discounting the monetized benefits (Section 3.2.3) and presents the annualized benefits over the 60-year analysis period (aggregated in FRIA Table 3-7, and disaggregated by year in FRIA Table 3-8);

- Discusses unquantified benefits resulting from the respiratory protection provisions for MNM and coal mines and from the requirement for medical surveillance at MNM mines.

Occupational risk assessments are generally designed to estimate the risk of an occupation-related illness over the course of an individual worker's lifetime. As discussed previously, the current mining cohort's occupational exposure profile for a particular substance can be matched against the expected profile of a mining cohort which will only experience exposures under the final rule (i.e., 60 years after the start of implementation of the final rule). However, in order to annualize the benefits for the period of time after the respirable crystalline silica rule takes effect (i.e., when working miners will have exposures under both the existing standards and the new PEL), it is necessary to create a timeline of benefits for an entire active workforce over that period.

Prior to implementation of the new PEL, all living miners accruing lifetime cases (both working miners and future retired miners) were assumed to have exposure histories characterized by exclusive exposure under the existing standards. Similarly, 60 years after the start of implementation of the new PEL, all living miners accruing lifetime cases (both working miners and retired miners) will have exposure histories characterized by exclusive exposure under the new PEL.[30] However, during the initial 60-year period, the different miner cohorts possess heterogeneities that change from one year to the next as older cohorts reach the end of their life and are replaced by newer cohorts. Specifically, different miner cohorts will have a different number of years of exposure under the existing standards and under the new PEL. During this initial 60-year period following the start of implementation of the rule, the excess cases avoided per year will gradually increase to the long-run averages discussed in the preceding section and presented in FRIA Table 3-4.

To characterize the magnitude of benefits during the 60 years following the start of implementation of the rule (during which time some miners will be exposed under both the existing standards and the new PEL), MSHA uses the underlying risk models to calculate the yearly reduction in lifetime excess risk of cases of respirable crystalline silica-related disease, beginning from the start of implementation of the rule and extending to 60 years in the future, at which time all working or future retired miners will experience the full benefits of the reduced exposure.[31]

The same changes between the PRIA and the FRIA regarding benefits estimation which were discussed above apply to the calculations throughout Section 3.2. Other than the inclusion of future retired miners detailed above in Section 3, there are no methodological changes in the avoided morbidity and mortality calculations between the PRA and the FRA. Similarly, other than the inclusion of future retired miners and the inflation of values to 2022 costs, there are no methodological changes in the monetized benefits between the PRIA and the FRIA.

3.2.1 Methodology for Estimating Annual Cases Avoided over Initial 60 Years Following the Start of implementation

Below, MSHA describes the methodology for calculating the number of cases in each of the 60 years immediately following the start of implementation of the rule, which is the regulatory time horizon chosen for the analysis. During these years, miner cohorts may experience a mixture of exposures under the existing standards and the new PEL. As this 60-year period progresses, annual excess cases avoided will increase gradually to the long-run average values presented in FRIA Table 3-4 of Section 3.1. Upon reaching the long-run average values in FRIA Table 3-4, annual excess cases avoided will be constant because all miner cohorts will have experienced exposures only under the new PEL. A detailed explanation of this life

[30] Because the start of implementation date for coal is one year before that of MNM, MNM benefits will reach the long-run values one year after coal benefits reach the long-run values.

[31] Benefits are assumed to begin accruing in 2025 for coal miners and 2026 for MNM miners. Thus, coal miners' benefits will achieve the long-run average values 60 years after the start of implementation of the rule in 2025, and MNM miners' benefits will achieve the long-run average values 61 years following the start of implementation of the rule in 2026.

table approach is provided in Appendix B of the FRA. The approach described here refers to the quantities defined in that section, including the survival rate, S_t, the disease-specific death risk, r_t, the disease-specific hazard, h_t, and the all-cause death hazard, d_t.

In MSHA's FRA, lifetime excess risks and excess lifetime cases are estimated for each group with exposure levels of ≤25 μg/m^3, >25 to ≤50 μg/m^3, >50 to ≤85.7 μg/m^3 (coal only), >85.7 to ≤100 μg/m^3 (coal only), >50 to ≤100 μg/m^3 (MNM only), >100 to ≤250 μg/m^3, >250 to ≤500 μg/m^3, and >500 μg/m^3. While all groups experience risk, the reduction in lifetime excess risk is exclusively attributable to those groups who are exposed to concentrations of respirable crystalline silica that exceed the new PEL of 50 μg/m^3. Under the assumption of full compliance with the existing standards, there are two such groups who experience risk reductions due to the new PEL: (1) miners who are currently exposed to concentrations of 100 μg/m^3 for MNM or 85.7 μg/m^3 for coal[32], and (2) miners who are currently exposed to concentrations between 50 μg/m^3 and 100 μg/m^3 for MNM, or between 50 μg/m^3 and 85.7 μg/m^3 for coal. The first group experiences an exposure reduction from 100 μg/m^3 to 50 μg/m^3 in the case of MNM, and from 85.7 μg/m^3 to 50 μg/m^3 in the case of coal. The second group experiences an exposure reduction from 69.0 μg/m^3 to 50 μg/m^3 in the case of MNM, and 60.4 μg/m^3 to 50 μg/m^3 in the case of coal. (As presented in FRIA Table 3-1, 69.0 μg/m^3 is the median exposure value for MNM samples in the exposure interval >50 to ≤100 μg/m^3, and 60.4 μg/m^3 is the median exposure value for coal samples in the exposure interval >50 to ≤85.7 μg/m^3). In each of the 60 analysis years following the start of implementation, annual excess cases avoided are estimated for both affected exposure groups. Total excess cases avoided for the given year is the sum of excess cases avoided in each of these two groups.

Life tables are used to calculate excess risks. After assessing the life table approach used by OSHA to calculate risks in the *Occupational Exposure to Respirable Crystalline Silica -- Review of Health Effects Literature and Preliminary Quantitative Risk Assessment*, MSHA adopted a similar method to that of OSHA. (See, for example, the methodological description in Section II.B *Lung Cancer Risk Estimates* on pp. 269-280; OSHA, 2013b.) A detailed description of the life table methodology is provided in Appendix B of the FRA.

Briefly, each group of miners that enters the workforce at the start of age 21 in a given calendar year represents a distinct generation cohort. By assumption, 60 such cohorts are alive at any given time, each having entered the workforce at the start of age of 21 during a different calendar year. At any single point in time, 45 of these surviving cohorts are still working, and 15 are retired. Each of these cohorts is assumed to have the same initial size $n \approx \frac{1}{45}N$ when they enter the mining workforce at the start of age of 21, where N is the total population of working miners. Due to death, however, each cohort decreases gradually in size as time passes. The life tables compute the survival rate S_t, which is the expected proportion of the original cohort that is alive at each year t. These survival rates are used to estimate the avoided cases only among expected survivors. In a given year, all 60 cohorts could experience fewer excess cases and

[32] Anyone with exposure above the existing exposure standard was assumed to only have exposure equal to the existing standard.

lower excess risks if they encountered lower exposures at any point in their career due to the new PEL having gone into effect while they were still working.

The population of interest, for which risks and benefits are calculated in this section and in the FRA, includes working and retired miners, including contract miners, which span all 60 cohorts.[33] As presented in Appendix B of the FRA, the number of cases occurring during any yearlong period starting at time t among a single cohort of constant initial size n is:

$$c_t = n \times r_t \tag{1}$$

where c_t is the number of cases and r_t is the disease-specific death risk in year t. The risk r_t is equal to the expected proportion of the original cohort $n = \frac{1}{45}N$ who will die in year t from the disease being analyzed. Sixty years after the start of implementation, all 60 cohorts with surviving members have identical life tables characterized by exclusive exposure under the new PEL. Prior to that time, the population will be composed of individuals belonging to 60 different miner cohorts each possessing a different set of exposure histories depending on the number of years they spent under the existing standard vs. under the new PEL. In general, older cohorts will have had fewer years under the new PEL, and newer cohorts will have had more years under the new PEL.

Accordingly, a superscripted i can be used to index the 60 different cohorts. The total cases that occur in a single year across all 60 cohorts (working and retired) are:

$$\sum_{i=1}^{60} c_t^{(i)} = \sum_{i=1}^{60} n \times r_t^{(i)} \tag{2}$$

The total cases that would have occurred in a single year if the existing standards had remained in effect are:

$$\sum_{i=1}^{60} \tilde{c}_t^{(i)} = \sum_{i=1}^{60} n \times \tilde{r}_t^{(i)} \tag{3}$$

where $\tilde{c}_t^{(i)}$ and $\tilde{r}_t^{(i)}$ are the expected cases and disease-specific mortality risks under the existing standards in year t.

During early years following the start of implementation, some miner cohorts will contain surviving members who retired before the new PEL took effect. These retired miners who never experienced new-PEL exposures would receive no benefit from the new PEL because $r_t^{(i)} = \tilde{r}_t^{(i)}$ at all years t in the cohort's life table. That is, for these older miners who were already retired when the new PEL took effect, the new PEL provides no benefit, and their life

[33] As stated previously, in the FRIA calculations, benefits do not accrue to any miners who retire before the start of implementation of the final rule.

table contains 45 years of exposure under the existing standards. In contrast to these miners who receive no benefit from the new PEL, the youngest cohorts will enter the workforce after the new PEL takes effect, giving them reduced cases during each year of their life table. For these younger cohorts, the life table contains 45 years of exposure under the new PEL. Between these two extremes, there are miners who will experience a combination of exposures under both standards. As an intermediate example (for illustrative purposes), a miner who began working 5 years before the new PEL takes effect will possess 5 years of higher exposure (e.g., 100 µg/m^3), followed by 40 years of reduced exposure at 50 µg/m^3, and 15 years of retirement associated with lower cumulative exposure over their working life. This miner would therefore receive benefits from the new PEL during the ages of 26 through 80.

For any miner cohort i, the cases avoided in a selected year t is the difference in expected cases under the existing standards $\tilde{c}_t^{(i)}$ and expected cases under the new PEL $c_t^{(i)}$:

$$\Delta c_t^{(i)} = \tilde{c}_t^{(i)} - c_t^{(i)} \tag{4}$$

Summing $\Delta c_t^{(i)}$ across all 60 surviving miner cohorts (including working and retired miners) in a given year t yields the cases avoided $\Delta c_t k$ in that year t:

$$\Delta c_t = \sum_{i=1}^{60} \Delta c_t^{(i)} \tag{5}$$

Substituting Eq. 4 and Eq. 1 into Eq. 5 yields:

$$= \sum_{i=1}^{60} \left(\tilde{c}_t^{(i)} - c_t^{(i)} \right) \tag{6}$$

$$= \sum_{i=1}^{60} n \times \tilde{r}_t^{(i)} - \sum_{i=1}^{60} n \times r_t^{(i)} \tag{7}$$

$$= n \left(\sum_{i=1}^{60} \tilde{r}_t^{(i)} - \sum_{i=1}^{60} r_t^{(i)} \right) \tag{8}$$

$$= \frac{N}{45} \left(\sum_{i=1}^{60} \tilde{r}_t^{(i)} - \sum_{i=1}^{60} r_t^{(i)} \right) \tag{9}$$

Eq. 9 gives the avoided lifetime cases in year t across all 60 cohorts of working and retired miners. Importantly, *N* in this formula represents the size of a single exposure group (either the group exposed at the current standard, or the group exposed between the current standard and the new PEL). For MNM, *N* = 11,796 for the exposure group over 100 µg/m^3, and *N* = 21,805 for the exposure group >50 to ≤100 µg/m^3. Per cohort of 21-year-olds, this corresponds to 262 MNM miners exposed at 100 μg/m^3 and 485 MNM miners exposed between >50 to ≤100 μg/m^3. For coal, *N* = 1,391 for the exposure group over 85.7 μg/m^3, and *N* = 2,644 for the exposure group >50 to ≤85.7 μg/m^3. Per cohort of 21-year-olds, this corresponds to 31 coal miners exposed at 85.7 μg/m^3 and 59 coal miners exposed between >50 to ≤85.7 μg/m^3. Applying Eq. 9 to both groups (either for MNM or for coal) and summing the cases avoided Δc_t gives the total cases avoided in year t. For example, among MNM miners, the total cases avoided in year t is:

$$(\Delta c_t)_{\text{total}} = (\Delta c_t)_{>100\ \mu\text{g/m}^3} + (\Delta c_t)_{50\text{-}100\ \mu\text{g/m}^3} \quad (10)$$

To calculate the total number of cases avoided during each of the 60 years immediately following the start of implementation of the rule, a separate life table was constructed for each distinct miner cohort containing surviving members during any of the 60 years following the start of implementation of the new rule.

For silicosis morbidity, a life table was not used because the Buchanan *et al.* (2003) model provides an equation for directly calculating the excess risk of silicosis morbidity after a lifetime of cumulative exposure. For each exposure interval, the total cumulative exposure from 45 years of mining was inputted into this equation, and the resulting lifetime excess risk was applied to the number of miners exposed at that interval to acquire the number of cases of silicosis morbidity. This was done for the Baseline scenario (which capped exposures at the existing limits) and the New PEL 50 Scenario (which capped exposures at the new PEL of 50 μg/m^3), and the difference between these gives the avoided cases of silicosis morbidity.

The Buchanan *et al*. (2003) model is different from the other studies MSHA used for modeling. Whereas the other studies quantified the relative risk for miners at all ages based on a broad range of possible cumulative exposures, the Buchanan *et al*. (2003) model used a logistic regression to predict the probability of a miner being diagnosed with 2/1+ silicosis near the end of his life. MSHA decided not to use this model (which was based on 50- to 74-year-olds) to estimate the risk at intervening years (e.g., for 22-year-old miners, 23-year-old miners, all the way up through 80-year-old miners). Instead of using life tables to calculate the benefits in each year following the start of implementation of the rule, MSHA assumed that the annual number of avoided cases of silicosis morbidity would increase linearly from 0 to the long-run value shown in FRIA Table 3-4. This matches OSHA's approach for analyzing the stream of benefits associated with silicosis morbidity in its silica rule (OSHA, 2016b).

FRIA Table 3-5 presents the estimated number of avoided deaths and illnesses during the 60 years following the start of implementation of the new rule. The estimates in FRIA Table 3-4 are roughly double the estimates of FRIA Table 3-5. FRIA Table 3-4 shows the avoided lifetime cases among a miner population that is only exposed to the new PEL, whereas FRIA Table 3-5 shows the cases that would actually be avoided during the 60 years following implementation among miners who may have a combination of exposures under both the existing standard and the new PEL.

FRIA Table 3-5. Estimated Cases of Avoided Mortality and Morbidity Attributable to the New Respirable Crystalline Silica Rule over 60 Years (Regulatory Analysis Time Horizon) Following the Start of Implementation

Health Outcome	Total Avoided Cases During 60 Years Following the Start of Implementation of the Rule [a]		
	MNM	Coal	Total
Avoided Morbidity			
Silicosis	1,673	162	1,836
Avoided Morbidity Total (Net of Silicosis Deaths)	**1,673**	**162**	**1,836**
Avoided Mortality			
NMRD (net of silicosis mortality)	241	22	263
Silicosis	123	11	134
ESRD	90	8	98
Lung Cancer [b]	33	3	36
Avoided Mortality Total	**487**	**44**	**531**

Notes: Numbers may not sum to the total due to rounding. The health outcomes are ordered from largest to smallest based on total avoided cases.
[a] Avoided cases include both production and contract miners. Calculations show the difference between excess cases when assuming compliance with the existing limits versus assuming compliance with the new PEL of 50 μg/m^3. Estimates account for the fact that some miners during the 60-year period will have worked under the existing standards (and thus may have combination of exposures under the existing standards and the new PEL), while other new entrants into the mining workforce would be solely exposed under the new PEL.
[b] A 15-year lag between exposure and observed health effect was assumed for lung cancer estimates.

3.2.2 Monetizing the Benefits of the Final rule

MSHA also provides estimates of the monetary value of the benefits associated with the final rule.

Placing a Monetary Value on Individual Silica-Related Deaths Avoided

To represent the value of each avoided silica-related death, MSHA uses a value of a statistical life (VSL) estimate of $11.8 million for the year 2021 ($12.6 million when inflated to 2022 dollars) based on estimates originally developed by the U.S. Department of Transportation (2022). For each year beyond 2021, MSHA adjusts this VSL value to account for growth in real income. Assuming a constant rate of income growth, g, and a constant income elasticity η, MSHA calculates the VSL in year, t, as:

$$VSL_t = VSL_{2021} \times (1+g)^{(t-2021)} \times \eta \qquad (11)$$

According to the DOT guidelines for regulatory impact analysis (RIA), DOT agencies are recommended to use an income elasticity assumption of 1 ($\eta = 1$) in their analyses (U.S. Department of Transportation, 2022). MSHA estimates the rate of income growth using data on the real gross domestic product per capita, $\overline{GDP}$, from 1971 through 2021 by the U.S. Bureau of Economic Analysis (BEA) as:

$$g = \left(\frac{\overline{GDP}_{2021}}{\overline{GDP}_{1971}}\right)^{\frac{1}{(2021-1971)}} - 1 = \left(\frac{\$58{,}624}{\$24{,}640}\right)^{\frac{1}{50}} - 1 = 1.75\% \quad (12)$$

Thus, for each year beyond 2021, MSHA calculates the VSL for year t as:

$$VSL_t = VSL_{2021} \times (1.0175)^{(t-2021)} \quad (13)$$

Placing a Monetary Value on Individual Silica-Related Diseases Avoided

In addition to the benefits that are based on the implicit value of deaths avoided, workers also place an implicit value on occupational injuries or illnesses avoided, which reflect their willingness to pay to avoid monetary costs (i.e., costs for medical expenses and lost wages) and quality-of-life losses resulting from these occupational illnesses or injuries. Non-fatal cases of silicosis, lung cancer, NMRD, and ESRD can adversely affect miners for years or even decades. Similarly, cases which ultimately prove fatal may adversely impact miners' lives for years prior to death.

Consistent with Buchanan *et al*. (2003), MSHA estimates the total number of moderate-to-severe silicosis cases avoided by the final rule as measured by 2/1+ or more severe x-rays (based on the ILO rating system). However, while radiological evidence of moderate-to-severe silicosis is evidence of significant material impairment of health or functional capacity, placing a precise monetary value on this condition is difficult, in part because the severity of symptoms may vary significantly among affected miners. For that reason, the Agency employs a broad range of valuation, which should encompass the range of severity affected miners may encounter.

Using the willingness-to-pay (WTP) approach and previous estimates of valuations of non-fatal, but permanently disabling injuries, OSHA previously identified the value of silica-related morbidity (both for cases preceding death and for non-fatal cases) in its rulemaking to range from \$64,000 to \$5.2 million in 2012 dollars. MSHA used the reported GDP implicit price deflator index to inflate the midpoint of this range (\$2.63 million) from 2012 dollars to 2021 dollars. The reported GDP implicit price deflator indices for 2012 and 2021 are 100.0 and 118.49, respectively, based on data from the BEA (U.S. Bureau of Economic Analysis, 2022). This results in a GDP implicit price adjustment factor, *s*, of

$$s = \frac{(118.49 - 100.000)}{100.000} = 0.183 \quad (14)$$

Using this adjustment factor, MSHA computes the average value of each avoided silicosis morbidity case, VM_{avg}, in 2021 dollars as:

$$VM_{avg} = \$2.63 \text{ million } \times (1 + s) = \$2.63 \text{ million } \times (1 + 0.183) = \$3.12 \text{ million} \quad (15)$$

After performing the calculations in 2021 dollars, all final results were converted to 2022 dollars. In 2022 dollars, the average value of each avoided silicosis morbidity case is $3.34 million.

This valuation is applied to non-fatal silicosis cases as well as to silica-related deaths to account for the social costs of morbidity before death. To simplify the calculation of the monetized benefits of avoided illness and death, MSHA adds the monetized benefits of avoided morbidity preceding mortality to the monetized benefits of avoided mortality at the time of death, at which point both are discounted. In theory, however, the monetized benefits of avoided morbidity should be recognized (and discounted) at the onset of morbidity, as this is what a worker's WTP is presumed to measure—that is, the risk of *immediate* death or an *immediate* period of illness that a miner is willing to pay to avoid. For this reason, the present value of discounted benefits for avoided morbidity has some tendency toward underestimation in this analysis. A parallel underestimate occurs with regard to avoided morbidity not preceding mortality, since it implicitly assumes that the benefits occur at or before retirement, as per the Buchanan *et al*. (2003) model, but many, if not most, of the 2/1+ or higher silicosis cases will have begun years before (with those classifications included in the Buchanan *et al.* (2003) model, in turn, preceded by a 1/0 classification). As a practical matter, however, the Agency lacks sufficient data to refine the analysis in this way.

Summary of Monetized Benefits

FRIA Table 3-6 presents the estimated annualized (over the first 60 years) undiscounted benefits from each of these components of the valuation, based on yearly benefit streams (see Technical Appendix C for annual benefits during the 60 years following the start of implementation of the rule). As shown, the full monetized benefits, undiscounted, for the New PEL 50 scenario are estimated at $382.6 million annually. The total value of benefits is dominated by avoided mortality ($250.9 million). The analysis illustrates that most of the value of benefits from avoided morbidity is related to non-fatal silicosis cases in the MNM sector ($93.1 million). The value of comparable benefits (i.e., avoided non-fatal silicosis cases) for the coal sector is $9.0 million.

FRIA Table 3-6. Estimated Annualized Undiscounted Monetized Benefits of the Silica Rule for Avoided Morbidity and Mortality (in millions of 2022 dollars)

Health Outcome	MNM	Coal	Total
Avoided Mortality	$230.4	$20.5	$250.9
Avoided Morbidity (Preceding Mortality)	$27.1	$2.4	$29.5
Avoided Morbidity (Not Preceding Mortality)	$93.1	$9.0	$102.1
Total	**$350.7**	**$31.9**	**$382.6**

Adjustment to Monetized Benefits

MSHA's estimates of the monetized benefits of the final rule are based on the imputed value of each avoided death and each avoided respirable crystalline silica-related disease. As previously discussed, the estimated value of an avoided death and an avoided morbidity due to a crystalline respirable silica-related disease are $12.6 million and $3.34 million, respectively, in 2022 dollars. However, two related factors suggest that the value of avoided deaths and respirable crystalline silica-related diseases will tend to increase over time.

Economic theory suggests that the value of reducing life-threatening and health-threatening risks—and correspondingly the willingness of individuals to pay to reduce these risks—will increase as real per capita income increases. With increased income, an individual's health and life becomes more valuable relative to other goods because, unlike other goods, they are without close substitutes and in relatively fixed or limited supply. Expressed differently, as income increases, consumption will increase but the marginal utility of consumption will decrease. In contrast, added years of healthy life are not subject to the same type of diminishing returns—implying that an effective way to increase lifetime utility is by extending one's life and maintaining one's good health.

Second, real per capita income has broadly been increasing throughout U.S. history, including in recent periods. Based on the predicted increase in real per capita income in the United States over time and the expected resulting increase in the value of avoided deaths and diseases, MSHA adjusted its estimates of the future benefits of the final rule to reflect the anticipated increase in these values over time (see FRIA Table 3-8). As discussed in Section 3.2.2 above, for each year beyond 2021, MSHA inflated the VSL value to account for growth in real income using the formula specified in Eq. 13.

3.2.3 Discounting of Monetized Benefits

As previously noted, the estimated stream of benefits arising from the final rule is not constant from year to year, both because of the 60-year delay after the rule takes effect until all active and retired miners obtain reduced respirable crystalline silica exposure over their entire working lives and because of, in the case of lung cancer, a 15-year latency period between reduced exposure and a reduction in the probability of disease. Thus, an appropriate discount rate is needed to allow conversion to an equivalent steady stream of annualized benefits. Benefits of the final rule are annualized over a 60-year period because (a) the types of diseases caused by exposure to respirable crystalline silica dust take significant time to develop before they become apparent, and (b) this is the period of time after which benefits will have reached their long-run values because miners who are already working when the rule promulgates are exposed under both the existing PEL and the new PEL (e.g., a miner who has worked 20 years under the existing PEL will have only received the benefit of working 25 years at the lower exposure limit before retiring compared to the full 45 years at the lower exposure limit for a miner who enters the workforce after the start of implementation).[34]

Alternative Discount Rates for Annualizing Benefits

Following OMB (2003) guidelines, MSHA estimates the annualized benefits of the final rule using discount rates of 3 percent and 7 percent. Consistent with the Agency's own

[34] See Section 4.1.1.1 for more information on annualization.

practices in recent proposed and final rules, MSHA also estimates, for benchmarking purposes, undiscounted benefits—that is, benefits using a zero percent discount rate.

The rate of time preference approach is intended to measure the tradeoff between current consumption and future consumption, or in the context of the final rule, between current benefits and future benefits. The *individual* rate of time preference is influenced by uncertainty about the availability of the benefits at a future date and whether the individual will be alive to experience the delayed benefits. By comparison, the *social* rate of time preference takes a broader view over a longer time horizon—ignoring individual mortality and the riskiness of individual investments (which can be accounted for in a range of discount rates).

The usual method for estimating the social rate of time preference is to calculate the post-tax real rate of return on long-term, risk-free assets, such as U.S. Treasury securities. According to data from the U.S. Department of the Treasury, the daily treasury real long-term rates have ranged from -0.64 to 4.4 percent over the 2000-2021 period (U.S. Department of the Treasury, 2022).

Summary of Annualized Benefits under Alternative Discount Rates

FRIA Table 3-7 presents MSHA's estimates of the sum of the annualized benefits of the final rule, using alternative discount rates, r, of 0, 3, and 7 percent. Results are presented for each of the two mining sectors (MNM and coal), as well as for the two sectors combined. To calculate annualized benefits, MSHA first calculated the present value, PV, of the stream of benefits over the rule horizon of 60 years as:

$$PV = V_{t=0} + \frac{V_{t=1}}{(1+r)} + \frac{V_{t=2}}{(1+r)^2} + \frac{V_{t=3}}{(1+r)^3} + \cdots + \frac{V_{t=60}}{(1+r)^{60}} = \sum_{t=0}^{60} \frac{V_t}{(1+r)^t} \qquad (16)$$

where the value of benefits, V, due to total cases of avoided deaths, FT, and avoided morbidity, MOR, in year t is:

$$V_t = (VSL_t \times FT_t) + (VM_{avg} \times MOR_t) \qquad (17)$$

MSHA then annualizes the stream of benefits over 60 years as:

$$Annualized\ Benefits = \begin{cases} PV\ if\ r = 0 \\ PV \times \dfrac{r \times (1+r)^{60}}{(1+r)^{60} - 1} \text{ if r} > 0 \end{cases} \qquad (18)$$

Given that the stream of benefits extends out 60 years, the value of future benefits is sensitive to the choice of discount rate. From FRIA Table 3-7, the undiscounted total benefits are estimated at $382.6 million annually, which is the same as FRIA Table 3-6. Using a 3 percent discount rate, the annualized benefits are $246.9 million. Using a 7 percent discount rate, the annualized benefits fall to $131.9 million. As demonstrated, going from undiscounted benefits to a 7 percent discount rate has the effect of cutting the annualized benefits of the final rule by over 70 percent.

FRIA Table 3-7. Annualized Benefits over 60 Years for the New PEL 50 Scenario by Discount Rate (in millions of 2022 dollars)

Health Outcome	MNM			Coal			Total		
	0%	3%	7%	0%	3%	7%	0%	3%	7%
Avoided Morbidity (Not Preceding Mortality)									
Silicosis (Excluding Silicosis Deaths)	$93.1	$66.3	$41.5	$9.0	$6.5	$4.2	$102.1	$72.8	$45.7
Avoided Morbidity (Not Preceding Mortality) Total	**$93.1**	**$66.3**	**$41.5**	**$9.0**	**$6.5**	**$4.2**	**$102.1**	**$72.8**	**$45.7**
Avoided Mortality									
NMRD (Excluding Silicosis Deaths)	$115.7	$69.1	$31.3	$10.5	$6.3	$2.8	$126.2	$75.4	$34.2
Silicosis	$55.8	$37.0	$21.0	$4.8	$3.3	$2.0	$60.6	$40.3	$23.0
ESRD	$42.6	$26.1	$12.7	$3.7	$2.3	$1.2	$46.2	$28.4	$13.9
Lung Cancer	$16.39	$9.4	$3.9	$1.47	$0.9	$0.4	$17.9	$10.2	$4.2
Avoided Mortality Total	**$230.4**	**$141.6**	**$68.9**	**$20.5**	**$12.7**	**$6.4**	**$250.9**	**$154.3**	**$75.3**
Avoided Morbidity (Preceding Mortality)									
NMRD (Excluding Silicosis Deaths)	$13.4	$8.6	$4.4	$1.2	$0.8	$0.4	$14.6	$9.4	$4.7
Silicosis	$6.8	$5.0	$3.3	$0.6	$0.5	$0.3	$7.4	$5.5	$3.6
ESRD	$5.0	$3.4	$1.9	$0.4	$0.3	$0.2	$5.4	$3.6	$2.0
Lung Cancer	$1.9	$1.1	$0.5	$0.2	$0.1	$0.0	$2.0	$1.2	$0.6
Avoided Morbidity (Preceding Mortality) Total	**$27.1**	**$18.2**	**$10.0**	**$2.4**	**$1.6**	**$0.9**	**$29.5**	**$19.8**	**$11.0**
Grand Total	**$350.7**	**$226.0**	**$120.4**	**$31.9**	**$20.9**	**$11.5**	**$382.6**	**$246.9**	**$131.9**

Taken as a whole, the Agency's best estimate of the total annualized benefits of the final rule—using a 3 percent discount rate with no adjustment for the increasing value of health benefits over time—is $246.9 million. Of these benefits, $154.3 million (62.5 percent) are attributable to avoided mortality, $72.8 million (29.5 percent) are attributable to avoided silicosis morbidity (not preceding mortality), and the remaining $19.8 million (8.0 percent) are attributable to avoided morbidity preceding mortality. FRIA Table 3-8 shows the annualized, undiscounted benefits as derived over the 60 years after the respirable crystalline silica rule becomes effective including the assumed factors for increasing monetized benefits in response to increases in per capita income over time.

FRIA Table 3-8. Stream of Benefits over 60 Years After the Start of Implementation for the PEL of 50 μg/m^3 Accounting for Income Growth

Year After Start of Rule Implementation	Total Number of Avoided Cases (MNM and Coal Combined)		Value of Avoided Cases by Year (MNM and Coal Combined) (in millions of 2022 dollars)			
	Avoided Mortality	Avoided Silicosis Morbidity	Avoided Mortality	Avoided Morbidity (Preceding Mortality)	Avoided Morbidity	Total
Year 1 [a]	0.0163	0.0798	$0.22	$0.05	$0.27	**$0.54**
Year 2	0.1084	1.1162	$1.49	$0.36	$3.73	**$5.58**
Year 3	0.2277	2.1273	$3.19	$0.76	$7.10	**$11.06**
Year 4	0.3756	3.1118	$5.36	$1.25	$10.39	**$17.00**
Year 5	0.4381	4.1886	$6.36	$1.46	$13.98	**$21.81**
Year 6	0.6014	5.1564	$8.88	$2.01	$17.22	**$28.10**
Year 7	0.7284	6.1807	$10.94	$2.43	$20.64	**$34.01**
Year 8	0.9009	7.2147	$13.77	$3.01	$24.09	**$40.87**
Year 9	1.0907	8.2893	$16.97	$3.64	$27.68	**$48.28**
Year 10	1.2970	9.2651	$20.53	$4.33	$30.93	**$55.79**
Year 11	1.5203	10.2903	$24.48	$5.08	$34.36	**$63.92**
Year 12	1.7693	11.3220	$28.99	$5.91	$37.80	**$72.70**
Year 13	2.0427	12.3957	$34.06	$6.82	$41.39	**$82.27**
Year 14	2.3392	13.3772	$39.69	$7.81	$44.66	**$92.16**
Year 15	2.6575	14.3957	$45.88	$8.87	$48.06	**$102.81**
Year 16	3.0007	15.4359	$52.71	$10.02	$51.54	**$114.26**
Year 17	3.4101	16.4563	$60.95	$11.39	$54.94	**$127.27**
Year 18	3.8194	17.4340	$69.46	$12.75	$58.21	**$140.41**
Year 19	4.2286	18.5117	$78.24	$14.12	$61.80	**$154.16**
Year 20	4.6377	19.5431	$87.31	$15.48	$65.25	**$168.05**
Year 21	5.0468	20.5681	$96.68	$16.85	$68.67	**$182.20**
Year 22	5.4557	21.5540	$106.34	$18.21	$71.96	**$196.52**
Year 23	5.8645	22.6357	$116.31	$19.58	$75.57	**$211.46**
Year 24	6.2731	23.6713	$126.59	$20.94	$79.03	**$226.57**
Year 25	6.6817	24.7213	$137.20	$22.31	$82.54	**$242.04**
Year 26	7.0903	25.7645	$148.13	$23.67	$86.02	**$257.82**
Year 27	7.4981	26.8397	$159.39	$25.03	$89.61	**$274.04**
Year 28	7.9054	27.8289	$170.99	$26.39	$92.91	**$290.30**

Year After Start of Rule Implementation	Total Number of Avoided Cases (MNM and Coal Combined)		Value of Avoided Cases by Year (MNM and Coal Combined) (in millions of 2022 dollars)			
	Avoided Mortality	Avoided Silicosis Morbidity	Avoided Mortality	Avoided Morbidity (Preceding Mortality)	Avoided Morbidity	Total
Year 29	8.3121	28.9018	$182.94	$27.75	$96.49	**$307.18**
Year 30	8.7183	29.9413	$195.23	$29.11	$99.96	**$324.31**
Year 31	9.1238	31.0154	$207.89	$30.46	$103.55	**$341.90**
Year 32	9.5277	32.0087	$220.89	$31.81	$106.87	**$359.57**
Year 33	9.9301	33.0882	$234.25	$33.15	$110.47	**$377.87**
Year 34	10.3308	34.1346	$247.97	$34.49	$113.96	**$396.42**
Year 35	10.7301	35.1548	$262.06	$35.82	$117.37	**$415.25**
Year 36	11.1276	36.2030	$276.52	$37.15	$120.87	**$434.55**
Year 37	11.5209	37.2861	$291.31	$38.46	$124.49	**$454.26**
Year 38	11.9100	38.3370	$306.42	$39.76	$127.99	**$474.17**
Year 39	12.2949	39.3688	$321.86	$41.05	$131.44	**$494.34**
Year 40	12.6759	40.4258	$337.64	$42.32	$134.97	**$514.92**
Year 41	13.0525	41.5130	$353.75	$43.58	$138.60	**$535.93**
Year 42	13.4208	42.5916	$370.10	$44.81	$142.20	**$557.10**
Year 43	13.7808	43.6486	$386.68	$46.01	$145.73	**$578.41**
Year 44	14.1328	44.7299	$403.49	$47.18	$149.34	**$600.02**
Year 45	14.4769	45.8397	$420.55	$48.33	$153.04	**$621.93**
Year 46	14.8128	46.8694	$437.84	$49.45	$156.48	**$643.77**
Year 47	15.1353	47.9006	$455.20	$50.53	$159.92	**$665.66**
Year 48	15.4448	48.9332	$472.64	$51.57	$163.37	**$687.57**
Year 49	15.7416	49.9673	$490.15	$52.56	$166.82	**$709.53**
Year 50	16.0260	51.0028	$507.74	$53.51	$170.28	**$731.52**
Year 51	16.2974	52.0397	$525.37	$54.41	$173.74	**$753.53**
Year 52	16.5477	53.0786	$542.77	$55.25	$177.21	**$775.23**
Year 53	16.7775	54.1193	$559.94	$56.01	$180.69	**$796.64**
Year 54	16.9874	55.1618	$576.87	$56.72	$184.17	**$817.75**
Year 55	17.1781	56.2061	$593.55	$57.35	$187.65	**$838.56**
Year 56	17.3492	57.2522	$609.96	$57.92	$191.15	**$859.03**
Year 57	17.4904	58.3008	$625.68	$58.39	$194.65	**$878.72**
Year 58	17.6030	59.3521	$640.73	$58.77	$198.16	**$897.66**

Year After Start of Rule Implementation	Total Number of Avoided Cases (MNM and Coal Combined)		Value of Avoided Cases by Year (MNM and Coal Combined) (in millions of 2022 dollars)			
	Avoided Mortality	Avoided Silicosis Morbidity	Avoided Mortality	Avoided Morbidity (Preceding Mortality)	Avoided Morbidity	Total
Year 59	17.6885	60.4057	$655.11	$59.06	$201.68	**$915.84**
Year 60	17.7482	61.4617	$668.82	$59.26	$205.20	**$933.28**
Discount Rate = 0%		**NPV**	**$15,053.02**	**$1,772.57**	**$6,128.86**	**$22,954.45**
		Annualized Value	**$250.88**	**$29.54**	**$102.15**	**$382.57**
Discount Rate = 3%		**NPV**	**$4,269.73**	**$548.07**	**$2,015.67**	**$6,833.47**
		Annualized Value	**$154.28**	**$19.80**	**$72.83**	**$246.91**
Discount Rate = 7%		**NPV**	**$1,056.52**	**$154.03**	**$641.31**	**$1,851.86**
		Annualized Value	**$75.26**	**$10.97**	**$45.68**	**$131.91**
[a] Year 1 corresponds to 2025, which is the first year when the coal industry is required to comply.						

As previously mentioned, MSHA has not estimated the monetary value of less severe silicosis cases (i.e., those measured at 1/0 to 1/2 on the ILO scale). The Agency believes the economic benefits of this rule to miners with less severe cases of silicosis could be substantial, insofar as even milder cases of silicosis may be accompanied by a lifetime of medical surveillance and lung damage, and may require a change in career. However, many of these effects can be difficult to isolate and measure in economic terms, particularly in those cases where there is no obvious effect at this less severe stage of disease on physiological function or performance. Thus, MSHA has not included these less severe silicosis cases in the analyses for this final rule and it is possible that this may lead to an underestimate of benefits.

3.2.4 Unquantified Benefits of Medical Surveillance Among MNM Miners

Medical surveillance programs are useful in identifying workers who have or who are developing occupational illnesses (Wilken *et al.*, 2012). Such programs also help assess the magnitude of a given occupational illness or injury and its temporal trend (i.e., whether the problem is increasing or decreasing) (Fine, 1999). At present, there are medical surveillance requirements for coal mines, under which coal mine operators are required to provide a series of medical examinations (e.g., chest x-ray, spirometry, symptom assessment). These medical examinations are mandatory for miners who begin work at a coal mine for the first time. Further, for those miners already working at coal mines, voluntary medical examinations are available every 5 years. The medical surveillance provision of the final rule establishes similar requirements for MNM mines, including an initial series of mandatory medical examinations when a miner first enters the mining industry and periodic voluntary examinations thereafter.[35] MSHA believes that the initial series of mandatory examinations that assess a miner's baseline pulmonary status coupled with periodic voluntary examinations will assist in the early detection of respirable crystalline silica-related illnesses. Early detection of illness often leads to early intervention and treatment, which may slow disease progression and/or improve health outcomes. Thus, MSHA expects that the final rule's medical surveillance provisions will further reduce mortality and morbidity from respirable crystalline silica exposure among MNM miners. However, MSHA is unable to quantify the magnitude of these expected reductions because it is not possible for MSHA to estimate: 1) the reduced rates of mortality and morbidity that would be attributable to the medical surveillance provision of the final rule, and 2) the extent to which miners would be inclined to get medical examinations at their own time and expense, in lieu of the medical surveillance program (i.e., the baseline scenario).

In addition to the direct benefit of earlier detection of respirable crystalline silica-related illness, the final rule's medical surveillance requirement would also have an indirect benefit by promoting greater awareness among MNM miners of the potential hazards of respirable crystalline silica exposure. Increasing awareness may encourage MNM miners to take proper precautions in their work, and mine operators to be more cognizant of MSHA's safety and

[35] The final rule also requires that the first voluntary examination be offered to existing MNM miners within 12 months of the start of implementation.

health standards in general. Again, such benefits would be difficult for MSHA to quantify with any reasonable degree of confidence.

3.2.5 Unquantified Benefits Associated with Avoided Pneumoconiosis Among Coal Miners

MSHA's 2014 Coal Dust rule quantified benefits among coal miners related to reduced cases of coal workers' pneumoconiosis (CWP), NMRD, and progressive massive fibrosis (PMF) due to lower exposure limits for RCMD. In the 2010 quantitative risk analysis (QRA) (Kogut, 2010), MSHA estimated the reduction in excess risks of CWP, NMRD, and PMF due to (a) lowering the exposure limit for RCMD from 2.0 mg/m^3 (and 1.0 mg/m^3 for Part 90 miners and intake airways) to the equivalent of 1.5 mg/m^3 for a full shift that a miner works (and 0.5 mg/m^3 for Part 90 miners and intake airways) and (b) changing the basis for determinations of noncompliance from the average of 5 samples to a single, full-shift sample obtained by MSHA. MSHA also estimated additional reductions in risk based on changes to the sampling strategies and a revised definition of normal product shift. Risk reductions were calculated both through age 73 and through age 85.

Other changes implemented in the 2014 Coal Dust rule were estimated to reduce risk of CWP, NMRD, and PMF. Basing noncompliance on a single, full-shift sample obtained by MSHA applies not only to the concentration of RCMD but also to the concentration of respirable crystalline silica. The 2014 rule also changed the definition of normal production shift. This change allowed MSHA to identify more instances where the respirable crystalline silica concentration exceeded the exposure limit.

In the 2010 Coal Dust QRA, risk was calculated for three ranks of respirable coal mine dust: low, medium, and high. Coal rank is a measure of the coal's moisture and carbon content, with high rank dust having less than 4 percent of moisture in the air-dried coal or more than 84 percent of carbon (dry ash-free coal). The largest reductions in NMRD risk were predicted among miners in occupations exposed to high rank RCMD; MSHA noted that equal changes in exposure levels were expected to produce substantially greater improvement for high rank coal dust miners (17 fewer deaths per 1,000 exposed miners) than for low/medium rank coal dust miners (7 fewer deaths per 1,000 exposed miners).

MSHA believes the final rule will provide additional reductions in CWP, NMRD, and PMF beyond those attributable to the 2014 Coal Dust rule. NIOSH emphasized the important role respirable crystalline silica plays in causing these diseases, stating that, "in concentrating on this particular exposure-response relationship with coal mine dust, we must not forget that [coal] miners today are being exposed to excess silica levels, particularly in thinner seam and small mines, and that this situation could well get worse as the thicker seams are mined out. Hence, since silica is more toxic than mixed coal dust, tomorrow's [coal] miners could well be at greater risk, despite a reduction in the mixed coal mine dust standard" (NIOSH 2010a). While this FRIA quantifies the benefits associated with reduced levels of respirable crystalline silica, this final rule will likely also lead to reductions in RCMD and thus additional unquantified benefits. However, reductions in disease due to reduced RCMD have not been quantified in this FRIA as the RCMD reductions depend largely on the control measures that mine operators implement. The benefits quantified here may underestimate the true benefits of this rule, as MSHA does not account for expected reductions in morbidity and mortality resulting from lower RCMD.

While the 2014 Coal Dust rule regulated high concentrations of RCMD, miners still experience elevated risk from high concentrations of respirable crystalline silica. MSHA sample data show that high concentrations of respirable crystalline silica and high rank RCMD are not always correlated, and miners continue to be exposed to higher concentrations of respirable crystalline silica despite experiencing compliant exposure levels of RCMD. For these miners, the incremental benefits from this final rule over the benefits from the Coal Dust rule may be particularly high. Other miners will also receive benefits from this rule that are not attributable to the Coal Dust rule, including miners in occupations for which respirable crystalline silica concentrations have increased over time.

Regarding CWP, this FRIA monetizes avoided CWP mortality (aggregated with other forms of non-malignant respiratory disease) but not avoided CWP morbidity. Exposure-response relationships are not available for respirable crystalline silica exposure and CWP mortality or CWP morbidity. CWP can be misdiagnosed as silicosis or other forms of non-malignant respiratory disease. Given the challenges in modeling CWP morbidity and mortality, MSHA does not separately estimate benefits to coal miners due to further reductions in CWP expected under this final rule. The final rule does, however, quantify the benefits of avoided deaths and illnesses, among coal miners, from all forms of NMRD (which may include mortality from complicated CWP), as a result of the new PEL. Among coal miners, MSHA estimates 47 lifetime avoided deaths from NMRD (See FRIA Table 3-4).

3.2.6 Unquantified Benefits of Updated Standards for Respiratory Protection

Under the final rule, MSHA incorporates by reference ASTM International Respiratory Protection Standard, F3387-19 in § 60.14(c). MSHA is also revising the Agency's existing respiratory protection standards in 30 CFR § 56.5005 and § 57.5005 (both titled *Control of Exposure to Airborne Contaminants*), and § 72.710 *Selection, Fit, Use, and Maintenance of Approved Respirators to incorporate by reference the ASTM standards.* The ASTM F3387-19 replaces the American National Standards Institute (ANSI) Z88.2-1969, Practices for Respiratory Protection (ANSI Z88.2-1969). Under the final rule, MSHA requires that mine operators establish a written respiratory protection program for all airborne contaminants that meets the following requirements in accordance with the ASTM: program administration; standard operating procedures; medical evaluation; respirator selection; training; fit testing; and maintenance, inspection, and storage.

The primary benefit resulting from MSHA's updated standards for respiratory protection in MNM and coal mines is to reduce miners' inhalation of airborne hazards. The benefit of the ASTM F3387-19 standard is the use of improved respiratory technology and updated respiratory protection practices such as established fit test methods and frequencies, and improved training. Quantitative estimates of these benefits are difficult to estimate because of uncertainties regarding the current state of operator respiratory protection programs.

The sections that follow provide a qualitative discussion of the benefits of the ASTM F3387-19 standard's key improvements compared to the ANSI Z88.2-1969 standard.

Respiratory Protection Program Clarifications

While both the ASTM F3387-19 and ANSI Z88.2-1969 standards provide for written respiratory protection programs, ASTM F3387-19 provides additional clarification on the required content of the respiratory protection programs by specifying that mine operators develop written SOPs for more, defined elements of the program. Such clarification will help mine operators improve their existing respiratory protection practices or develop new respiratory protection programs.

Greskevitch, *et al*. (2007), reporting on a 2001-02 NIOSH and BLS survey of 40,002 establishments (including between 2,250 and 2,500 mining establishments), provided a more detailed description of respiratory protection program (RPP) deficiencies in the mining industry. This survey identified significant program weaknesses among mining establishments that reported respirator use. For instance, the survey found that 80.8 percent of mining establishments that used air-purifying gas/vapor filters did not have written change-out schedules; 61 percent were using an "improper method for setting air pressure to control airflow on airline respirators," or they did not know which methods they used; 54.3 percent were either unaware of or did not have "written procedures to periodically evaluate the effectiveness of respirator use;" 51.3 percent did not have a "written program for deciding how respirators are used;" and 38.8 percent did not have or were not aware of "written procedures or schedules for respirator maintenance." The authors concluded that "[w]ritten procedures and staff training are important for maintaining the quality of respirator programs," and that "[p]roperly written documentation helps assure continuity in decision making for all aspects of a respiratory protection program" (Greskevitch, *et al.*, 2007).

ASTM F3389-19 includes provisions for written SOPs addressing specific program elements, including each of the key program deficiencies identified by Greskevitch, *et al*. (2007). This clear delineation of program elements will benefit operators by removing ambiguity so that operators know what to include in their programs and will ensure consistent and effective RPPs across the mining industry. Such RPPs will provide better miner protection through reduced inhalation exposures by ensuring that miners' work environments are assessed and that miners are provided with the correct type of respiratory protection based on that assessment. For example, NIOSH certifies three levels of respirator particle filters under 42 CFR 84, with the highest efficiency filter (P100, filters at least 99.97 percent of airborne particles and is strongly resistant to oil) more protective for miners than the lowest (N95, filters at least 95 percent of airborne particles and is not resistant to oil) (National Institute for Occupational Safety and Health, 2019). MSHA has observed some mine operators providing miners with this least protective level of respiratory protection. In § 60.14(c), MSHA requires mine operators to provide high efficiency filters to miners exposed to respirable crystalline silica above the new PEL until exposures are below the PEL. A comprehensive written respiratory protection program will help ensure miner work environments are considered in respirator selection, a sufficient supply of high efficiency particulate filters is readily available, and supervisors and miners recognize when to replace particulate filters.

The standard's provision that SOPs be made available to workers further ensures that the program requirements are accessible to the miners who will be wearing the respirators. Removing ambiguity regarding required program content also assists operators with compliance efforts.

Medical Evaluation Clarification

The ASTM F3387-19 standard provides detailed information and clear instruction to RPP administrators on the information (e.g., type of respirator to be used, frequency of use, and duration of use) that they will provide to physicians or other licensed healthcare professionals (PLHCPs) to assist them in determining a miner's medical suitability for respirator use. The standard also identifies management responsibilities to provide the PLHCP with supplemental information before the PLHCP makes a recommendation concerning a miner's ability to use a respirator. While some PLHCPs may request this information as standard practice, clearly defining the information ensures consistency and allows RPP program administrators to collect the information and provide it to PLHCPs in an efficient manner. This ensures that all PLHCPs have the information needed to make informed assessments on miners' health and their ability to perform assigned tasks while wearing the required respirator. More informed medical evaluations benefit both miners and operators by helping to improve miner health and reduce occupational illnesses.

ASTM F3387-19 also allows the use of licensed healthcare professionals to perform the medical evaluations rather than limiting this task to physicians, as specified in the ANSI Z88.2-1969. This flexibility improves operators' ability to obtain qualified healthcare services near their mines, which may be in remote areas.

Defined Fit Test Frequencies

Under existing standards, ANSI Z88.2-1969 requires that respirator users be fit tested on the make and model of the respirator; however, since its publication significant advances in assessing respirator fit, including the development of qualitative and quantitative fit testing protocols, have been made. Due to variability in face size characteristics among individuals, different sizes of respirator facepieces are now available which contrasts with the one-size-fits-all approach of the ANSI Z88.2-1969 standard. The ASTM F3387-19 standard provides for a qualitative fit test or quantitative fit test to determine proper fit of tight-fitting facepiece respirators. Employees will be fit tested with the same make, model, style, and size of the respirator that they will use. To accommodate different facial types, a variety of sizes, models, and styles will be provided to the wearer. Fit testing will be done prior to initial use of the respirator, whenever a different respirator facepiece (i.e., size, style, model, or make) is used, and at least annually thereafter. Additional fit tests will be done whenever an employee reports or the employer, PLHCP, supervisor, or program administrator make visual observations of changes in the employee's physical condition that could affect respirator fit under 29 CFR 1910.134 (OSHA, 2017). A study by NIOSH found that annual fit testing is necessary to ensure that miners receive optimal protection from the respirator and wearers are comfortable with the respirator fit (NIOSH, 2016). ASTM F3387-19 provisions for annual or more frequent fit tests will allow operators to routinely assess the continued quality of user respirator fits, identify situations where poor respirator fits have developed, and make respirator changes as needed to ensure the continued protection of respirator wearers.

Strengthened Training Requirements

Employee training is an important part of a RPP and is essential for correct respirator use. The ANSI Z88.2-1969 standard contains basic minimal training requirements. It requires that respirator users be instructed and trained "in the proper use of respirators and their limitations." The ASTM F3387-19 standard provides comprehensive guidance, including specific competencies for respirator trainers and users and training for respirator wearers, supervisors, and persons issuing respirators. Among these provisions are trainer qualification to ensure consistent training as well as an annual training for users. Annual training ensures users remain familiar and knowledgeable about workplace respiratory hazards and how to properly use, maintain, and store their respirators.

The strengthened training provisions of ASTM F3387-19 will help address training deficiencies in the mining industry thereby resulting in more effective and complete RPP implementation and reduced miner inhalation exposures.

Strengthened Respiratory Protection Program Evaluation Requirements

ASTM F3387-19 includes several provisions that strengthen respiratory protection program evaluation. ASTM F3387-19 provides for an annual written audit of all aspects of the respiratory protection program by the program administrator as well as an additional periodic audit conducted by a knowledgeable person not directly associated with the RPP. In addition, the standard outlines the specific elements of the program to be evaluated.

In discussing weaknesses observed during a 2001-02 NIOSH and BLS survey of mining establishments, Greskevitch, *et al.* (2007) also noted the importance of periodic evaluation of written respiratory protection programs to ensure proper program implementation and respirator use. Evaluation provisions, coupled with the respiratory protection program clarifications discussed above, will ensure the ongoing effectiveness of mines' respiratory protection programs. In addition, strengthened evaluation provisions will help ensure better miner protection through reduced inhalation exposures when miners must wear respirators when it is necessary by the nature of work involved, such as occasional entry into hazardous atmospheres to perform maintenance or investigation, and while engineering controls are being implemented.

4 COSTS OF COMPLIANCE

This final rule establishes a new, lower PEL for exposure to respirable crystalline silica for all MNM and coal mines. To provide miners with a consistent level of protection as workers in other industries, MSHA is lowering its existing standards for exposure to respirable crystalline silica to a new PEL of 50 $\mu g/m^3$ in both MNM and coal mines. The new PEL will be expressed as a full shift exposure, calculated as an 8-hour TWA. The uniform, new PEL for all MNM and coal mines will also eliminate the existing respirable dust standard when quartz is present for coal mines.

Under the final rule, mine operators must: implement exposure control (§ 60.11) conduct exposure monitoring and report all samples over the PEL to MSHA (§ 60.12); take corrective actions, provide miners with respirators when a sampling result indicates the miner's exposure exceeds the PEL, and ensure that miners wear them properly (§ 60.13); provide respiratory protection during temporary activities for MNM miners (§ 60.14 (a), take action to transfer miners unable to wear a respirator at all mines, provide NIOSH approved respirators at all mines, and have a written respiratory protection program at all mines. (§ 60.14 (b & c); make periodic medical examinations available to MNM miners and ensure certain medical records are reported to NIOSH (§ 60.15); and retain records for specified durations at all mines (§ 60.16). In addition, the final rule requires mine operators to develop or revise existing respiratory protection programs and practices in accordance with the ASTM F3387-19 (§§ 56.5005, 57.5005, and 72.710). Based on these requirements, MSHA estimates that mine operators will incur aggregate annualized costs of $90.3 million in 2022 dollars (using a 3 percent discount rate). These annualized compliance costs are expected to comprise about 0.07 percent of annual estimated industry revenues, well below the 1 percent threshold that represents a presumption of no significant economic impacts to the industry. The total annualized costs are further broken down by provision and by sector below:

- Under the FRIA, these costs are attributable to the following provisions of the final rule:
  - Exposure Monitoring ($53.2 million, 59 percent of total)
  - Exposure Controls ($13.7 million, 15 percent of total)
  - Respiratory Protection ($3.3 million, 4 percent of total)
  - Medical Surveillance ($18.8 million, 21 percent of total), and
  - ASTM standards incorporation by reference ($1.2 million, 1 percent of total).

MSHA estimates that 91 percent of compliance costs will be incurred by the MNM sector ($82.1 million) and the remaining 9 percent will be incurred by the coal sector ($8.2 million). The primary reason for the difference in costs incurred by sector is that the MNM sector has more than ten times the mines (11,525 compared to 1,106) and almost three times the miners (150,928 compared to 51,573) as the coal sector (see FRIA Table 2-1). Differences in mine size and the extent to which current exposures are already below 50 µg/m3 also contribute to the differences in estimated compliance costs. In addition, MNM mine operators will incur costs to meet the medical surveillance requirements which further drives the difference in total costs between the MNM and coal sectors.

Estimated compliance costs in the FRIA exceed estimated costs for the proposed rule by approximately $33 million per year (annualized at 3 percent; compare, for example, FRIA Table ES - 1 with the same table in the PRIA). The two reasons for the increase in compliance costs are: inflationary adjustments and changes in exposure monitoring requirements. Adjusting estimated compliance costs from 2021 dollars to 2022 dollars accounts for about 7 percent of the increase. After inflating compliance costs in the PRIA to 2022 dollars, the remaining difference between estimated costs in the PRIA and the FRIA is approximately $28.6 million per year. Nearly two-thirds of this increase in estimated compliance costs ($19.0 million) is attributable to the changed exposure monitoring requirements under the final rule. The remainder is largely attributable to increased estimates for exposure controls ($7.5 million) and respiratory protection ($2.2 million). MSHA expects that mine operator sampling will increase because the final rule does not allow mine operators to use objective data and historical sample data (i.e., operator and MSHA sample data from prior 12 months) to demonstrate compliance with exposure monitoring requirements.

In the remainder of this section, MSHA presents the methods and data used to estimate the expected compliance costs of the final rule. Section 4.1 provides an overview of MSHA's approach to estimating costs. Section 4.2 describes the components of and rationale for the requirements mine operators must meet to comply with the PEL under 30 CFR Part 60, which includes exposure monitoring, exposure controls, additional respiratory protection, and medical surveillance for MNM mines. Section 4.3 analyzes the changes in respiratory protection practices due to incorporating by reference the 2019 ASTM standard and estimates the costs from this action.

4.1 Overview of Cost Estimation

As described in the Technological Feasibility analysis, MSHA identified measures that will allow mines to reduce respirable crystalline silica dust concentrations from the existing PEL of 100 µg/m^3 for MNM and the existing exposure limit of 85.7 µg/m^3 for coal to the new PEL of 50 µg/m^3 in the final rule. Those measures include:

- Conducting exposure monitoring (including first-time sampling, second-time sampling, above-action-level sampling, corrective actions sampling, periodic evaluation, and post-evaluation sampling) to ensure the mine meets the requirements of the final rule and to identify potential control failures so that mine operators can undertake corrective action.
- Developing and implementing engineering controls.
- Performing maintenance and repair of existing dust controls.

- Implementing administrative controls that will reduce miners' exposure to respirable crystalline silica dust.
- Providing respiratory protection to miners who did not need it at the existing PEL but might need it—temporarily—at the new PEL.
- Requiring MNM operators to make specified medical examinations available for all their miners.
- Requiring respiratory protection practices in accordance with the 2019 ASTM standard.

4.1.1 Methodology

For each of the measures described above, MSHA will overview the cost estimation methodology and discuss how those costs differ across the two major mining sectors (MNM and coal).

As detailed above, MSHA determined the expected measures necessary for mines to comply with each provision of the final rule. MSHA then estimates the costs incurred by a typical mine to comply with each provision. These include one-time costs, such as those to purchase and install an engineering control, provide equipment expected to last multiple years (e.g., respirators), or devise and implement an administrative control. They also include recurring costs, such as the operating and maintenance (O&M) costs of using an engineering control or the value of the labor hours and supplies used to perform exposure monitoring. To aggregate costs for each provision, MSHA first multiplies the average cost per mine by the number of mines expected to incur that cost or the average cost per miner by the number of miners expected to be affected by the provision. These costs are summed across all provisions for each of the two major mining sectors to estimate total mining industry costs. Compliance costs were estimated for the PRIA using 2021 as the year of analysis. In this FRIA, compliance costs were updated to reflect 2022 dollars using the GDP implicit price deflator.

4.1.1.1 Cost Annualization

Different provisions of the final rule result in different patterns of compliance costs in affected mines. The cost of complying with each provision depends on the particular combination of one-time versus recurring costs, the timing of those costs, and the frequency of repeated incurrences of one-time costs. In addition, the value of the annual total costs and benefits vary substantially year by year. The most significant variation is that mine operators may begin incurring costs as soon as the final rule is promulgated, while the benefit attributable to the reduction in exposure to respirable crystalline silica dust may not become apparent until decades after its promulgation.

It is not appropriate to compare one dollar in cost incurred today with one dollar in benefits accrued 20 or more years from now because of the time value of money (i.e., the value of one dollar today is worth more than the value of one dollar a year from now). To ensure costs and benefits can be compared, MSHA annualizes costs and benefits. Cost annualization takes a series of costs incurred over time and converts them to a sequence of equal annual costs with the same present value as the original costs. An example of this concept is the conversion of the purchase price of a house into a series of monthly mortgage payments. In this example, the resulting sequence of equal monthly payments of principal and interest over 30 years has the same present value as the initial purchase price of the house.

Annualized costs are therefore expressed as equal values per year over the full analysis period and are convenient metrics for long-term analysis because they are immune to annual variations in cost while still accounting for the time value of money.

MSHA annualizes costs using 3 percent and 7 percent discount rates as specified in OMB guidance. Costs are estimated and annualized over a 60-year period. This means that durable equipment costs, for example, are estimated based on their expected service life. For example, the expected service life of a building ventilation system is 30 years; MSHA assumes that a mine operator would need to purchase the system in Year 1, then replace it in Year 31 to estimate 60 years of capital costs.

Annualization of all types of compliance costs over a 60-year period is a change from the PRIA. In the PRIA, cost components that did not require significant upfront costs, such as respirators, for example, or were primarily composed of recurring labor costs (e.g., sampling) were annualized over shorter time horizons, frequently 10 years. Such costs would be multiplied by a scalar to estimate 60 years of compliance costs; for example, cost components annualized over 10 years would be multiplied by a factor of six to estimate 60 years of costs.

The PRIA approach is not tenable for the final rule because of the one-year difference in the compliance dates for MNM and coal mines. MNM mine operators will incur zero costs in Year 1 of the rule while coal mine operators will be accruing compliance costs. If the same 10-year annualization were used for administrative controls, for example, the first year of zero costs in MNM mines would incorrectly be repeated six times over the 60-year analytic period with a year of zero costs appearing in years 11, 21, 31, 41, and 51. This would significantly underestimate the annualized costs of the rule. Therefore, MSHA chose to annualize all costs over 60 years regardless of cost type.

As discussed in Section 3.2.1, benefits are also annualized over a 60-year analysis period. Annualized costs and benefits can be directly compared to determine the net annualized benefit.

4.1.1.2 Labor Costs

For each expected measure discussed below, MSHA justifies it based on utility and major cost components. In general, the measures specified for the two mining sectors (MNM and coal) do not differ in either justification or cost structure.

Costs for each sector will vary for several reasons. First, the number of mines that will need to develop and implement new engineering controls and administrative controls to reach the new PEL will vary by sector. Second, average hourly wages vary between sectors, even for miners in the same occupation or who perform the same tasks. Third, certain occupations and tasks vary between sectors, so more miners of one occupation in MNM mining, for example, might need greater protection than those miners performing an equivalent task in coal mining.

Many of the measures for which MSHA estimates costs are primarily – but not completely – based on the time miners need to perform specified tasks. These measures include exposure monitoring, exposure controls (including developing and implementing engineering controls, increased maintenance and repair of existing engineering controls, and administrative controls), and temporary respiratory protection measures. In general, MSHA uses fully loaded hourly wage rates to value the time spent on these activities. MSHA's source for unburdened wage rates is the BLS's Occupational Employment and Wage Statistics (OEWS) statistics for the mining industry.[36] Unloaded wage rates are adjusted to account for the employer cost of providing employee benefits (U.S. Bureau of Labor Statistics, 2021b) and overhead (U.S. Department of Labor, 2019). In total, the unloaded rate is multiplied by 1.663 (1.493 benefit multiplier + 0.17 overhead multiplier) to estimate the loaded wage rate.

In general, the labor cost of performing certain activities (e.g., checklist for equipment operators) is estimated using sources such as MSHA's experience and knowledge, the Technological Feasibility and Economic Analyses for OSHA's Silica rule (2013c), NIOSH's Best Practices for Dust Control in Coal Mining (NIOSH, 2021a)(NIOSH, 2021a), and industry and manufacturer representatives through conversations or peer-reviewed and gray publications.[37]

These sources are also used to estimate the value of multipliers which are in turn used to estimate, for example, the cost of parts for equipment repairs relative to the cost of time mine operators spend on labor for maintenance and repairs; or the costs of preparing signage,

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[36] Bureau of Labor Statistics (BLS): Occupational Employment and Wage Statistics (OEWS). National industry-specific and by ownership. May 2021. Downloaded from https://www.bls.gov/oes/tables.htm on April 29, 2022. Three North American Industry Classification System (NAICS) codes are relevant to this analysis: 212100: Coal Mining; 212200: Metal Ore Mining; 212300: Nonmetallic Mineral Mining and Quarrying.
Department of Labor (DOL). 2019. Defining and Delimiting the Exemptions for Executive, Administrative, Professional, Outside Sales and Computer Employees. Final Rule. 84 Federal Register 51230.

[37] Gray literature generally consists of publications such as reports, working papers, white papers and evaluations prepared by subject matter experts in academia, government agencies, and industry that has not been subject to a formal peer-review process.

informational posters, and training materials relative to the labor costs to identify opportunities for administrative controls and to prepare procedures to implement those controls.

These sources are also used to estimate variation in hours and costs over time. For example, it is likely that the opportunities to identify effective administrative controls will decrease over time because, as opportunities are identified, there will be fewer new opportunities to find in following years and those remaining opportunities are likely to have less effect on miners' exposure to respirable crystalline silica dust. Thus, it is likely that the labor hours that mine operators assign to administrative controls will decrease over time.

In addition to the references listed above, market research (ERG, 2023) on current prices is used to estimate the costs for engineering controls and other equipment (e.g., respirators). To the extent that prices may not be current, MSHA updates prices to 2022 dollars using the Bureau of Economic Analysis's GDP implicit price deflator.[38]

4.2 Types of Costs to Meet the New Permissible Exposure Limit under 30 CFR Part 60

4.2.1 Compliance Costs for Exposure Monitoring Requirements

Under § 60.10, the final rule lowers the existing PEL for respirable crystalline silica for MNM and coal mines. The final rule also establishes requirements for exposure monitoring that must be met for mine operators to comply with the rule. In this section, MSHA presents its analysis and estimate of costs attributable to exposure monitoring under the final rule.

Mines Affected by Exposure Monitoring Requirements

MSHA first presents a tabulation of mines affected by exposure monitoring requirements in FRIA Table 4-1. This table further characterizes active mines reported in FRIA Table 2-4 by the number of quarters in which they were active in 2019 (i.e., whether a mine reported at least 520 miner working hours in any quarter of 2019). All active mines are required to conduct exposure monitoring; however, MSHA believes the costs for exposure monitoring will vary with mine size and quarters in operation.

As shown in FRIA Table 4-1, a total of 12,631 mines across all commodities were active for at least one quarter in 2019; over 70 percent of those mines (8,849/12,631) were active for the entire year in 2019, and 86 percent of those mines ((8,849 + 2,110)/12,631) were active for two quarters or more. Roughly equal percentages of MNM mines (87 percent) and coal mines (85 percent) were active for three or four quarters in 2019. The primary difference between mines that were active at least 6 months a year and those that were active less than 6 months a year is mine size. A total of 1,672 mines across all commodities were active for only one or two quarters in 2019; of these, only 7 mines employed more than 20 miners (0.4 percent). The

[38] Gross Domestic Product: Implicit Price Deflator, Index 2017=100, Annual, Seasonally Adjusted. Downloaded from https://fred.stlouisfed.org/series/GDPDEF#0 on October 26, 2023.

remaining 1,665 mines employed 20 or fewer miners. Both mine size and quarters of activity affect the number of samples taken, and thus the cost of compliance of exposure monitoring.

FRIA Table 4-1. Mines and Miners, Activity by Quarter, by Sector, 2019

Sector and Mine Size	Total		Active 4 Quarters		Active 3 Quarters	
	Mines	Miners Including Contractor Miners	Mines	Miners Including Contractor Miners	Mines	Miners Including Contractor Miners
All Mines						
Miners ≤ 20	10,945	75,737	7,203	64,330	2,077	7,505
20 < Miners ≤ 100	1,337	78,170	1,298	76,208	33	1,592
100 < Miners ≤ 500	311	87,768	310	87,599	0	0
500 < Miners	38	43,104	38	43,104	0	0
Total	***12,631***	***284,779***	***8,849***	***271,240***	***2,110***	***9,097***
MNM						
Miners ≤ 20	10,238	69,520	6,764	59,495	1,978	6,817
20 < Miners ≤ 100	1,066	61,316	1,047	60,359	15	726
100 < Miners ≤ 500	195	50,469	194	50,299	0	0
500 < Miners	26	29,899	26	29,899	0	0
Total	***11,525***	***211,203***	***8,031***	***200,052***	***1,993***	***7,544***
Coal						
Miners ≤ 20	707	6,217	439	4,835	99	688
20 < Miners ≤ 100	271	16,854	251	15,849	18	866
100 < Miners ≤ 500	116	37,299	116	37,299	0	0
500 < Miners	12	13,205	12	13,205	0	0
Total	***1,106***	***73,576***	***818***	***71,188***	***117***	***1,554***
	Active 2 Quarters		**Active 1 Quarter**			
All Mines						
Miners ≤ 20	1,087	2,776	578	1,127		
20 < Miners ≤ 100	2	140	4	230		
100 < Miners ≤ 500	0	0	1	170		
500 < Miners	0	0	0	0		
Total	***1,089***	***2,916***	***583***	***1,526***		
MNM						
Miners ≤ 20	1,004	2,344	492	864		
20 < Miners ≤ 100	0	0	4	230		
100 < Miners ≤ 500	0	0	1	170		
500 < Miners	0	0	0	0		
Total	***1,004***	***2,344***	***497***	***1,264***		
Coal						
Miners ≤ 20	83	432	86	263		
20 < Miners ≤ 100	2	140	0	0		
100 < Miners ≤ 500	0	0	0	0		
500 < Miners	0	0	0	0		
Total	***85***	***572***	***86***	***263***		

Estimated Cost by Monitoring Requirement

There are five types of exposure monitoring required under the final rule:

- First-time sampling and second-time sampling based on a representative fraction of miners (§ 60.12(a)(1)). First-time sampling occurs at the start of the rule's respective compliance date for coal mines and MNM mines. Second-time sampling occurs within 3 months of first-time sampling. Unlike the proposed rule, mine operators will not be allowed to use historical sample data or objective data for first-time and second-time sampling; all mines will have conduct samplings.

- Above-action-level sampling of a representative fraction of miners. If the most recent sampling results are at or above the action level (§ 60.12(a)(2)), above-action-level sampling starts 3 months after the most recent sampling and continues until two consecutive samples demonstrate that miners' exposures are below the action level.

- Corrective actions must be performed for samples over the PEL. The mine operator must take corrective actions to reduce exposure and conduct corrective actions sampling until sample results are at or below the PEL (§ 60.12(b)). All corrective actions sample results exceeding the PEL must be immediately reported to the MSHA District Manager or other office designated by the District Manager.

- Periodic evaluations must be performed at least every 6 months, or whenever there is a change in production, processes, engineering or administrative controls, or geological conditions that may reasonably be expected to result in new or increased respirable crystalline silica exposures to ensure that any change will not have increased miners' exposures (§ 60.12(c)).

- If the periodic evaluations conducted under § 60.12(c) determine that miners may be exposed to respirable crystalline silica at or above the action level, post-evaluation sampling must be conducted to assess the exposure for each miner who is or may be reasonably expected to be at or above the action level (§ 60.12 (d)).

MSHA sets the specified monitoring (sampling and evaluation) frequencies because the Agency has determined that it is necessary for mine operators to establish a baseline for any miner who is reasonably expected to be exposed to respirable crystalline silica. In addition, more frequent sampling above-action-level will allow mine operators to gather verifiable evidence of exposure trends earlier than would semi-annual or annual sampling. This will help mine operators quickly identify areas where sampling can be discontinued, but most important, identify areas where additional measures are needed to keep miner exposures from approaching or exceeding the PEL. Information and data provided by the monitoring requirements will better protect miner health than would less frequent monitoring. The sampling frequency in the final rule responds to some comments and is consistent with MSHA's statutory responsibility under the Mine Act to provide miners with the highest level of health protection. *See* 30 U.S.C. 811(a)(6)(A).

For quantitative monitoring, MSHA estimates total sampling costs as a function of several factors: the unit cost of sampling, made up of labor costs (miners' and samplers' time and hourly wage), laboratory costs for analyzing the samples, and clerical costs for recording the results; the number of samples that constitute the required representative fraction, each time the operator conducts sampling; and the frequency with which operators are assumed to carry out different types of monitoring. For qualitative monitoring, MSHA estimates periodic evaluation costs as a function of labor costs and the frequency of evaluation.

Collecting and preparing an exposure sample is expected to require a similar process and, therefore, similar costs regardless of the type of sampling (i.e., first-time sampling, second-time sampling, above-action-level sampling, corrective actions sampling, and post-evaluation sampling). The differences are that additional reporting time is required for samples above the PEL and the frequency with which each type of sampling is performed. Below, MSHA describes the assumptions used to estimate sampling costs. In addition, MSHA details the assumptions used to estimate the costs for periodic evaluations.

Monitoring Cost Components

To estimate the costs of exposure monitoring, MSHA looked at the following cost components:

To calculate costs per sample, MSHA broke down sampling costs into:

- Labor costs:
    - Sampling: time taken to prepare for and take the samples.
    - Lost work: time lost from work to equip miner with sampling device.
    - Recordkeeping: time to record and report sample results.
    - Time to prepare a periodic evaluation.
- Laboratory analysis fees.

To estimate the total cost of exposure monitoring, MSHA calculated the number of samples expected to be taken by evaluating the following factors:

- Representativeness, that is, where several miners perform the same tasks on the same shift and in the same work area, the fraction of those miners sampled to obtain a representative sample, which MSHA estimated based on mine employment and occupation profiles.

- Type of exposure monitoring (i.e., above-action-level sampling, corrective actions sampling, post-evaluation sampling).
- Exposure level (i.e., below the action level, between the action level and PEL, or above the PEL).
- Number of periodic evaluations.

To calculate total sampling costs, MSHA estimated the number of samples taken based on the type of sampling. For example, above-action-level sampling is performed quarterly. The frequency with which post-evaluation sampling is conducted is determined by the number of periodic evaluations, which are conducted on average 2.4 times per year. Exposure level also affects sampling cost because two consecutive samples below the action level could lead to a cessation of above-action-level sampling. Conversely, sample results exceeding the PEL would lead to corrective actions sampling. Thus, when the percentage of samples above the PEL or action level decreases, the number of samples decreases.

FRIA Table 4-2 summarizes the major cost components of each type of monitoring, and how the costs of each of the types of monitoring measures are estimated. In addition, the table summarizes the definitions of each component used in the calculations. MSHA's estimates for individual cost components are based on market research (ERG, 2023), exposure and operator data, and Agency experience. Each of these components is discussed in detail below.

FRIA Table 4-2. Exposure Monitoring Estimation

Exposure Monitoring Requirement [a]	Determination of Cost per Sample or Evaluation [a], [b]	Number of Samples or Evaluations [a]	Condition for Exposure Monitoring Requirement and Frequency [a]
First-time and second-time sampling	Sampling labor cost + lost work time + recording time + laboratory fees	Representative sample of all miners who may reasonably be expected to be exposed to respirable crystalline silica, by mine size	All mines Twice
Above-action-level sampling	Sampling labor cost + lost work time + recording time + laboratory fees	Miners that meet condition for periodic sampling × percent of miners needed for representative sample, by mine size	Miners at or above the action level (≥25 μg/m^3) but at or below the PEL (≤ 50 μg/m^3) Number of quarters mine is in operation. Three months after sampling results at or above the action level and continues until two consecutive samples demonstrate that miners' exposures are below the action level
Corrective actions sampling	Sampling labor cost + lost work time +	Sample results above the PEL (> 50 μg/m^3) × 1.25	Samples taken because first-time or second-time samples, above-action-level samples, or post-

	recording time + laboratory fees		evaluation samples showed results above the PEL; multiple samples might be necessary to demonstrate post-corrective action exposure level is below the PEL
Post-evaluation sampling	Sampling labor cost + lost work time + recording time + laboratory fees	2.5 percent of all miners × percent of miners needed for representative sample, by mine size	If evaluation shows exposure level may exceed the action level, sampling performed to determine if exposure level is at or above the action level
Periodic evaluation	Hours per evaluation × in-house loaded industrial hygienist wage	Number of mines × frequency of evaluation x 1.2	All mines Every 6 months, or when there is a change in production, processes, engineering or administrative controls, or geological conditions that may reasonably be expected to result in new or increased respirable crystalline silica exposures.

Notes: [a] Throughout this table, miners refer to both miners (excluding contract miners) and contract miners. [b] Lost work time, recording time, and laboratory cost fees as presented in FRIA Table 4-3 are constant within each commodity type (coal, metal, nonmetal) across all mine sizes. Sampling labor costs are constant within each commodity but vary by mine size because there is a fixed component (e.g., the cost of an IH) that is spread over more samples as mine size increases.

Labor Costs

The most important component of sampling cost is the time required to conduct the activities. For sampling, this includes the time needed to prepare for sampling, take the samples, and perform recordkeeping tasks on the results. Sampling takes time, which is valued at the hourly wage of the person wearing the sampling equipment and the person conducting the sampling. To err on the side of overestimation, MSHA assumed that in MNM mines, sample preparation and collection is performed by an industrial hygienist (IH). The IH may be an in-house specialist or an external consultant.[39] As a national average, the IH consultant is assumed to charge $1,606 per day, including travel and report preparation costs. The time for the in-house IH is valued at their loaded average hourly wage. MSHA assumed that half of MNM mine operators hire a contract IH, while the other half use an on-staff IH for sampling. For coal mines, miners certified to perform sampling under 30 CFR § 70.202, 71.202, and 90.202 can conduct the sampling required under the final rule. MSHA assumed coal mine operators will use certified miners for sample preparation and collection; therefore, the average labor cost for coal mine sampling is less than 40 percent of that for MNM mine sampling.

[39] Some MNM mines may train their miners or other in-house employees to conduct sampling. In such scenarios, an IH would not be used and the labor cost of sampling would be based on the loaded hourly wage for the participating employee.

In addition to the labor time of the person conducting sample preparation and collection, there are other activities associated with sampling which cost labor time. Time miners spend being equipped with a sampling device is time they do not spend working. MSHA assumes time lost to work is one half hour of labor time valued at the average loaded hourly wage of mine "Extraction Workers" (Standard Occupational Code 47-5000).

Recordkeeping takes 15 minutes per sample which is valued at the average loaded hourly wage of mine "Occupational Health and Safety Specialists" (Standard Occupational Code 19-5011). MSHA assumed an additional 2 minutes per sample would be needed for the mine operator to report sample results above the new PEL to the District Manager. Because only a fraction of sample results will be reported to the District Manager, the effective time allotted is substantially larger; for example, if 50 percent of sample results are reported to MSHA, then this 2-minute estimate effectively allots 4 minutes per sample that is actually reported.

Periodic evaluations are also prepared by "Occupational Health and Safety Specialists." MSHA assumes the preparation of an evaluation takes 2 hours, which is valued at the average loaded hourly wage of the Occupational Health and Safety Specialist.

MSHA also assumed the personnel conducting sampling can collect 2, 3, and 4 samples per day at small, medium, and large mines, respectively. This determines the number of days needed to complete sampling at a mine, and therefore directly affects the labor costs of sampling.

The labor cost of exposure monitoring is summarized in FRIA Table 4-3.

FRIA Table 4-3. Sampling and Evaluation Labor Cost – Average Unit Costs

Sampling cost		
Sampling labor cost Metal Mine Nonmetal Mine Coal Mine	$1,102* per day of sampling $1,066* per day of sampling $400 per day of sampling * Average of cost of independent IH contractor ($1,606 per day) and in-house IH	Preparing and setting up sampling equipment; collecting samples; sending samples to laboratory; recording results
Lost work time due to sampling Metal Mine Nonmetal Mine Coal Mine	$25 per miner sampled $20 per miner sampled $25 per miner sampled	30 minutes of "Extraction Worker" valued at loaded hourly wage
Recordkeeping time due to sampling Metal Mine Nonmetal Mine Coal Mine	$21 per sample $19 per sample $23 per sample	17 minutes of IH valued at loaded hourly wage
Laboratory fees for sample analysis Laboratory fee	$150 per sample	Processing samples and reporting results
Other costs and parameters		

Periodic evaluation labor cost (including report preparation) Metal Mine Nonmetal Mine Coal Mine	 $149 per evaluation $131 per evaluation $162 per evaluation	2 hours of IH valued at loaded hourly wage

Laboratory Analysis Costs of Sampling

MSHA estimates that laboratory analysis will cost the mine operator $150 per sample. This includes the cost of packing and shipping the sample to the lab, the laboratory analysis, and reporting sample results to the operator. Costs for laboratory analysis are included in FRIA Table 4-3.

Number of Samples – Representative Sampling

Mine operators are required to conduct representative sampling. Because this determines the minimum number of samples required each time sampling is carried out, it is a major determinant of sampling costs. Where several miners perform the same tasks on the same shift and in the same work area, the mine operator may sample a representative fraction (i.e., at least two) of these miners to meet the sampling requirements. The final rule requires that mine operators sample a representative group of miners who are expected to have the highest exposure to respirable crystalline silica.

MSHA estimated the number of miners considered a representative sample based on the size of the mine. In small mines that employ 20 or fewer miners (including contract miners), MSHA assumes that a sample comprising at least 50 percent of miners will be necessary to collect a representative sample. In medium-sized mines with 20 to 100 miners, the assumption is that a minimum 25 percent of miners will need to be sampled for the sample to be representative. In large mines with 100 or more miners, the Agency assumes that a minimum 15 percent of miners will need to be sampled for the sample to be representative.

Frequency of Exposure Monitoring – Number of Samples and Evaluations

Another component of sampling cost is the frequency with which it must be performed. Sampling frequency depends on sample results as specified by MSHA's exposure monitoring requirements.

First-time and Second-time Sampling: This type of sampling is performed by all mine operators. First-time sampling occurs by the relevant compliance date for existing mines. Second-time sampling occurs within 3 months following first-time sampling. The second-time sampling must be taken after the operator receives the results of the first-time sampling but no sooner than 7 days after the prior sampling was conducted. First-time and second-time sampling must be representative based on miners reasonably expected to be exposed to respirable crystalline silica. The number of samples taken at a mine will depend on the size of the mine. After the first-time and second-time sampling are completed, each operator will determine the next action based on sample results. If the results of both the first-time and second-time samplings are below the action level, no further sampling is required unless there are changes identified by periodic evaluations that may reasonably be expected to result in new or increased respirable crystalline silica exposures (periodic evaluations are further discussed below).

Subsequent to Year 1 for Coal and Year 2 for MNM, only new mines will be performing first-time and second-time sampling. MSHA projects that about 2 percent of mines in any given year will be new entrants to the mining industry, although the total number of mines in each year remains roughly constant.

Above-action-level Sampling: This is required because the most recent sample is at or above the action level; and it must be representative. Above-action-level sampling will not be required of all mines, but only for those mines showing exposure levels at or above the action level. This sampling continues as long as the most recent sample results demonstrate exposure at a mine is at or above the action level but below the new PEL.

MSHA believes that above-action-level sampling will decline over time as mine operators come into compliance but not entirely disappear. Although reducing exposures below the action level is costly for mine operators, repeated sampling is also costly. Mine operators have both a financial incentive and a human resource incentive to reduce exposures not just below the new PEL but below the action level. From a human resource standpoint, reducing exposures below the action level will ensure that mine operators have a healthier miner population, thus reducing employee time-off and turnover. Reducing exposures below the action level will also ensure that mine operators can discontinue sampling if exposures consistently remain below the action level.

Corrective Actions Sampling: Corrective actions sampling is required whenever a sample result exceeds the new PEL. The estimated above-action-level sampling includes all samples at or above the action level, which includes a subset of samples that exceeds the PEL. A sample result above the PEL requires the mine operator to take corrective actions and conduct corrective actions sampling to determine if the actions reduced exposures at or below the PEL.

MSHA also uses the number of samples exceeding the PEL to estimate the number of corrective actions taken. After each corrective action, the mine operator must sample to determine it the corrective action reduced exposures below the PEL. Not all corrective actions may be effective in reducing exposures below the PEL. Therefore, MSHA increased the number of estimated corrective action samples from the PRIA exceeding 50 $\mu g/m^3$ by 25 percent to account for situations requiring more than one corrective action to be taken before miners' exposures no longer exceed the PEL.

Periodic Evaluation: MSHA used different assumptions to estimate costs for periodic evaluation requirements. MSHA assumes that mines operating 3 or 4 quarters per year conduct two periodic evaluations per year, and mines operating 1 or 2 quarters per year conduct one periodic evaluation per year.

Periodic evaluations will be critical for portable mines that move frequently and encounter different conditions that expose miners to respirable crystalline silica. These evaluations and any related samplings will allow operators to verify that adequate engineering controls are in place and are maintained properly to protect miners as they move to different worksites. Once the operator has determined that engineering controls are adequate, subsequent evaluations will be necessary to ensure those engineering controls remain in place, regardless of mining location. MSHA increased the number of periodic evaluations by 20 percent (i.e., annual periodic evaluations are equal to 2.4 times the number of mines) because some mines, including but not limited to portable mines, will need to perform evaluations more than twice per year due to changes in production, process, installation or maintenance of engineering controls, installation or maintenance of equipment, administrative controls, or geological conditions as specified by the final rule.

Post-Evaluation Sampling: As discussed above, periodic evaluations may require an operator to conduct sampling to determine if any change may reasonably be expected to result in new or increased exposure levels. MSHA used the same assumptions for time and labor as with other sampling. MSHA further assumed that post-evaluation sampling will be conducted among 2.5 percent of miners. This percentage is relatively small because the periodic evaluations assess the type of change (e.g., installation of new equipment) or where changes might have occurred (e.g., start of mining a new seam). Thus, post-evaluation sampling is highly targeted. MSHA did not directly link the estimated number of post-evaluation samples taken to the number of evaluations performed because any given evaluation might result in a range from zero to multiple samples. Instead, it maintained the methodology linking samples taken to the number of miners used for other types of sampling.

Storage of Exposure Monitoring Records: Under the final rule, MSHA requires mines to keep records of exposure monitoring results for 5 years, an increase over the 2 years of record storage in the proposed rule. MSHA did not estimate costs for this component of exposure monitoring because it estimates that on average a report consists of 20 pages plus three images. Assuming the mine performs quarterly above-action level sampling, the mine operator might expect to store an average of 92 pages of sampling reports per year. If we double this to account for semi-annual periodic evaluations and the results of corrective actions sampling, if any, the mine might require storage for 184 pages of reports per year, or 920 pages over 5 years. A larger mine requiring, for example, 100 samples per mine might need 9,200 pages of storage over 5 years.

MSHA expects that most mine operators will choose to store these reports on their computer system. The labor cost of recordkeeping has already been incorporated in the cost of sampling. As for costs of storing records, one gigabyte of computer memory can store over 64,000 pages of Word files or 15,000 image files (LexisNexis Discovery Services, 2024). Thus, a small mine might require from 2 percent to 6 percent of 1 gigabyte to store monitoring reports for 5 years;[40] a larger mine might require up to 60 percent of 1 gigabyte of computer memory for storage. In 2023, *ComputerWeekly* (Adshead, 2023) estimated the cost of 1 gigabyte of memory was $0.05 on a traditional hard drive and $0.08 on a flash drive. If we double these values to account for storage on the backup system, computer storage costs are less than $1.00 per mine over 5 years. [41] Therefore, MSHA believes that additional record storage costs under the final rule are *de minimis* and did not estimate them for the cost of this rulemaking.

Trends in Sample Results and Sampling Costs

MSHA expects the percentage of samples that exceed the action level or exceed the new PEL will decline over several years following promulgation, even when no additional engineering control costs are incurred, and additional maintenance and repair compliance costs remain constant. First, mine operators will gain experience; they will identify improved methods of maintaining equipment (e.g., what controls are most important; what controls need more frequent attention) and administrative controls that will effectively reduce exposures without increasing maintenance and repair costs. In addition to the mines MSHA designated as "affected" (i.e., requiring the implementation of additional controls to meet the new PEL), MSHA now assumes additional mines will incur increased maintenance and repair costs and administrative costs to reduce exposure levels to below the action level so they may discontinue above-action-level sampling.

Second, some engineering controls are likely to reduce exposures not just below the new PEL, but below the action level. For example, adding an enclosed cab with air conditioning and filtered air to mobile equipment or control rooms will likely enable the operator to reduce the exposures below the new PEL and the action level.

Third, improving the control of respirable crystalline silica dust in part of the mine is likely to reduce exposure elsewhere in the mine. For example, reducing exposure levels at truck loading and unloading stations might also reduce exposure levels at any part of the mine downwind from those stations. The combination of these effects is observable in the coal industry. Although the existing PEL is set at 100 μg/m^3, less than 20 percent of samples at coal mines exceed the final rule's action level (FRIA Table 4-4). MSHA expects similar effects are likely to occur at MNM mines under this final rule.

FRIA Table 4-4. Estimated Percentage of Sample Results Taken by Type and Year

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Years–7 – 60
Percent of samples ≥ 25 μg/m^3							
All Mines [a]	*19.0%*	*29.3%*	*26.5%*	*23.6%*	*20.7%*	*17.9%*	*15.0%*

[40] In general, Adobe Acrobat pdf files range widely in size because files containing a lot of high-resolution graphics and images are significantly larger than an equivalent number of text pages. Therefore, it was not possible to obtain size estimates of a "typical" 20-page report with 3 images in pdf format. MSHA therefore used typical storage space for image files as a proxy for the size of such a report to generate the upper estimate of storage size.

[41] It is possible that some mines will choose to print reports and store them in a filing cabinet. MSHA expects that few mine operators will choose this option, but that most mines that do will be small mines. MSHA estimates that paper storage of reports might cost about $44 per year over 5 years.

Metal/Nonmetal [b]	NA	33.2%	29.5%	25.9%	22.3%	18.6%	15.0%
Coal	19.0%	18.3%	17.7%	17.0%	16.3%	15.7%	15.0%
Percent of samples > 50 μg/m^3							
All Mines	***5.5%***	***13.5%***	***12.2%***	***11.0%***	***9.7%***	***8.5%***	***7.2%***
Metal/Nonmetal	NA	16.3%	14.7%	13.0%	11.3%	9.7%	8.0%
Coal	5.5%	5.4%	5.3%	5.3%	5.2%	5.1%	5.0%

Notes: [a] Estimated as a weighted average of results for Metal/Nonmetal mines and Coal mines.
[b] Estimated as a weighted average of results for the five commodity types comprising Metal/Nonmetal mines.

MSHA estimated the percentage of samples exceeding the action level in the first year of compliance based on its historical exposure profile developed using the Agency's compliance sampling data. Because there are no data indicating the yearly rate at which mine operators will reduce miner exposures to levels below the action level, MSHA assumed the percentage of samples exceeding the action level would decline linearly until reaching 15 percent in Year 7 and subsequent years (FRIA Table 4-4).

In addition, not all mines operate year-round. Except for first-time and second-time sampling, MSHA adjusted all types of sampling for mines that operate fewer than four quarters per year. Each mine is assumed to take sampling with a frequency equal to the number of quarters the mine is open. For example, mines which are open only two quarters per year are assumed to conduct sampling twice during a calendar year. Portable mines are not exempt from the final rule. All mine operators, including portable mines, must conduct exposure monitoring in accordance with § 60.12.

FRIA Table 4-4 shows the percentage of samples in MSHA's database that exceed 50 μg/m^3 in Year 1. MSHA assumes this percentage will linearly decline to 8 percent by Year 7 in MNM mines and 5 percent in Coal mines.

Estimated Number of Samples and Evaluations Taken and Exposure Monitoring Costs by Type

FRIA Table 4-5 below presents the estimated number of samples by sampling type and by commodity sector in the first 7 years of the analysis because MSHA expects a long-run average to be reached in Year 7. MSHA projects that in the first 2 years (following the coal and MNM compliance dates), 259,059 samples will be taken compared to 92,663 per year in Years 7 through 60. This is a result of: (a) declines in first-time and second time sampling after the first year of compliance and (b) declines in above-action-level and corrective actions sampling as mine operators become more experienced in developing and implementing new controls.

Of the 259,059 samples expected to be taken in the first 2 years following the individual coal and MNM compliance dates, MSHA projects that approximately 76 percent (197,985/259,059) will be in the MNM sector. In Years 7 through 60, about 81 percent (75,324/92,663) will be in the MNM sector, due to the greater number of MNM mines in the industry.

As shown in FRIA Table 4-5, corrective actions sampling is expected to peak in Year 3 with 46,912 samples. By Year 7, this value is expected to decrease to 27,743 samples per year. Comparatively, post-evaluation sampling is expected to remain relatively constant at 16,953 samples per year from Year 2 onwards.

FRIA Table 4-5. Estimated Number Samples and Evaluations Taken by Type and Year

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Years–7 - 60
All Mines							
Sample Totals, All Mines							
All Types	***41,599***	***217,460***	***146,009***	***131,783***	***117,558***	***103,332***	***92,663***
First-time and second-time sampling [a]							
Mines	1,106	11,547	253	253	253	253	253
Miners	73,576	212,675	5,696	5,696	5,696	5,696	5,696
Samples	29,796	124,884	3,082	3,082	3,082	3,082	3,082
Above-action-level sampling [b]							
Mines [c]	-	-	-	-	-	-	-
Miners	13,727	92,941	146,671	130,341	114,011	97,681	85,434
Samples [d]	5,423	48,275	79,062	69,948	60,834	51,720	44,885
Corrective actions sampling [e]							
Mines [c]	-	-	-	-	-	-	-
Miners	4,031	40,664	67,967	60,816	53,665	46,513	41,246
Samples [d]	1,991	27,348	46,912	41,800	36,689	31,577	27,743
Periodic Evaluations							
Mines	1,106	12,631	12,631	12,631	12,631	12,631	12,631
Evaluations	2,449	28,308	28,308	28,308	28,308	28,308	28,308
Post-evaluation sampling [f]							
Mines [c]	-	-	-	-	-	-	-
Miners	3,679	14,239	14,239	14,239	14,239	14,239	14,239
Samples [d]	4,390	16,953	16,953	16,953	16,953	16,953	16,953
Metal/Nonmetal							
Sample Subtotals, MNM Mines							
All Types	-	*197,985*	*126,983*	*113,207*	*99,432*	*85,656*	*75,324*
First-time and second-time sampling [a]							
Mines	-	11,525	231	231	231	231	231
Miners	-	211,203	4,224	4,224	4,224	4,224	4,224
Samples	-	124,288	2,486	2,486	2,486	2,486	2,486
Above-action-level sampling [b]							
Mines [c]	-	-	-	-	-	-	-
Miners	-	66,222	120,930	105,578	90,227	74,875	63,361
Samples [d]	-	37,719	68,892	60,165	51,437	42,710	36,165
Corrective actions sampling [e]							
Mines [c]	-	-	-	-	-	-	-
Miners	-	32,698	60,129	53,106	46,083	39,060	33,792

Samples [d]	-	23,414	43,041	37,993	32,944	27,896	24,110
Periodic Evaluations							
Mines	-	11,525	11,525	11,525	11,525	11,525	11,525
Evaluations	-	25,859	25,859	25,859	25,859	25,859	25,859
Post-evaluation sampling [f]							
Mines [c]	-	-	-	-	-	-	-
Miners	-	10,560	10,560	10,560	10,560	10,560	10,560
Samples [d]	-	12,564	12,564	12,564	12,564	12,564	12,564
Coal							
Sample Subtotals, Coal Mines							
All Types	*41,599*	*19,475*	*19,025*	*18,576*	*18,126*	*17,676*	*17,339*
First-time and second-time sampling [a]							
Mines	1,106	22	22	22	22	22	22
Miners	73,576	1,472	1,472	1,472	1,472	1,472	1,472
Samples	29,796	596	596	596	596	596	596
Above-action-level sampling [b]							
Mines [c]	-	-	-	-	-	-	-
Miners	13,727	26,719	25,741	24,763	23,785	22,806	22,073
Samples [d]	5,423	10,556	10,170	9,783	9,397	9,010	8,720
Corrective actions sampling [e]							
Mines [c]	-	-	-	-	-	-	-
Miners	4,031	7,966	7,838	7,710	7,582	7,454	7,454
Samples [d]	1,991	3,934	3,871	3,807	3,744	3,681	3,633
Periodic Evaluations							
Mines	1,106	1,106	1,106	1,106	1,106	1,106	1,106
Evaluations	2,449	2,449	2,449	2,449	2,449	2,449	2,449
Post-evaluation sampling [f]							
Mines [c]	-	-	-	-	-	-	-
Miners	3,679	3,679	3,679	3,679	3,679	3,679	3,679
Sample [d]	4,390	4,390	4,390	4,390	4,390	4,390	4,390

Notes: [a] For years 2 – 60 for Coal mines, and years 3 – 60 for MNM mines, MSHA assumes that 2 percent of mines will be new and therefore undertake first-time and second-time sampling, but with no net growth, the total number of mines will remain constant.

[b] This includes above-action-level sampling and results that exceed the new PEL thus requiring corrective actions. Above-action-level sampling is expected to decline linearly from current exposure levels from year 1 to the start of year 7, after which time the frequency of sampling at or above the action level will be constant, as shown in FRIA Table 4-2. Sample results exceeding the new PEL are also expected to decline linearly from current exposure levels in year 1 to the start of year 7, after which time the frequency of sampling will be constant.

[c] The calculations for above-action-level, corrective actions, and post-evaluation sampling are based on the number of miners while the calculations for first-time and second-time sampling are based on the number of mines. Because MSHA requires representative sampling (see discussion below FRIA Table 4-3), it expects that in general the number of samples taken will be less than the number of miners.

[d] Half a year of above-action-level sampling and corrective actions sampling occurs in year 1 for Coal mines and year 2 for Metal/Nonmetal mines.

[e] When the most recent sample results exceed the PEL, corrective actions sampling is performed to ensure that the post-corrective actions exposure level is below the PEL.
[f] If a periodic evaluation shows that the exposure level may be exceed the PEL, post-evaluation sampling is performed to assess if the exposure level is, in fact, at or above the action level.

MSHA projects that the number of above-action-level samples will increase from 5,423 in Year 1 to 48,275 in Year 2 and to 79,062 in Year 3 as more mines start their above-action-level sampling. MSHA projects the percentage of samples that exceed the action level will decline starting from Year 4 due to the implementation of engineering controls, maintenance and repair of controls, and implementation of administrative controls, all of which will result in fewer miners and contract miners with exposure levels at or above the action level. MSHA projects that by Year 7, about 45,000 samples per year will be taken.

MSHA projects that starting with Year 2 following implementation, 12,631 mines will perform about 28,308 evaluations per year (FRIA Table 4-5). MSHA assumed that post-evaluation sampling remains constant at 16,953 samples per year since these samples are independent of the above-action-level sampling.

FRIA Table 4-6 below demonstrates that the decrease in samples following Year 3 is attributable to the reduction in above-action-level and corrective actions samples as compliance with the final rule reduces exceedances of the action level and PEL over time.

FRIA Table 4-6. Number of Above-Action-Level and Corrective Actions Samples by Year and Sector

Type of Sample	Year 1	Year 2 [a]	Year 3	Year 4	Year 5	Year 6	Year 7
Above-action-level and Corrective Actions Sampling							
All Mines	***7,414***	***75,622***	***125,974***	***111,748***	***97,523***	***83,297***	***72,628***
Metal/Nonmetal	--	61,133	111,933	98,158	84,382	70,606	60,274
Coal	7,414	14,490	14,040	13,590	13,141	12,691	12,354
Year-to-year change (All)	--	*68,209*	*50,351*	*-14,225*	*-14,225*	*-14,225*	*-10,669*
All types of samples							
All Mines	***41,599***	***217,460***	***146,009***	***131,783***	***117,558***	***103,332***	***92,663***
Metal/Nonmetal	--	197,985	126,983	113,207	99,432	85,656	75,324
Coal	41,599	19,475	19,025	18,576	18,126	17,676	17,339
Year-to-year change (All)	--	*175,861*	*-71,451*	*-14,225*	*-14,225*	*-14,225*	*-10,669*

Note: [a] Following year 2, first-time and second-time sampling declines to about 3,100 samples per year attributable to new mines opening; evaluation sampling remain constant at about 17,000 samples per year.

FRIA Table 4-7 below presents estimated total annualized exposure monitoring costs by type of exposure monitoring and mining sector. The five types of exposure monitoring (samplings and evaluation) are projected to cost mine operators an average of about $53.2

million (3 percent discount rate) per year over 60 years. Of the total exposure monitoring costs, about 89 percent of these costs are expected to be incurred by MNM mines and the remaining 11 percent by coal mines. By type of exposure monitoring, first-time and second-time sampling ($4.2 million per year) composes about 8 percent of monitoring costs; above-action-level sampling ($23.5 million per year) accounts for 44 percent; corrective actions sampling ($14.9 million) accounts for 28 percent; and periodic evaluations and post-evaluation sampling ($10.7 million) together account for about 20 percent.

FRIA Table 4-7. Total Annualized Exposure Monitoring Costs by Sector (in millions of 2022 dollars)

Cost Type	Total Cost over 60 Years	Annualized Costs			Percent Annualized Costs [a]
		0% Discount Rate	3% Discount Rate	7% Discount Rate	
All Mines					
First-time and second-time sampling	$170.2	$2.8	$4.2	$6.3	7.8%
Above-action-level sampling	$1,390.4	$23.2	$23.5	$23.9	44.2%
Corrective actions sampling	$884.0	$14.7	$14.9	$15.0	27.9%
Post-evaluation sampling	$426.3	$7.1	$7.0	$6.8	13.1%
Periodic evaluations	$225.0	$3.8	$3.7	$3.6	6.9%
Total	***$3,095.9***	***$51.6***	***$53.2***	***$55.6***	***100.0%***
Metal/Nonmetal					
First-time and second-time sampling	$151.3	$2.5	$3.7	$5.6	6.9%
Above-action-level sampling	$1,239.1	$20.7	$21.0	$21.4	39.4%
Corrective actions sampling	$821.4	$13.7	$13.8	$14.0	26.0%
Post-evaluation sampling	$354.6	$5.9	$5.8	$5.6	10.9%
Periodic evaluations	$201.2	$3.4	$3.3	$3.2	6.2%
Subtotal	***$2,767.6***	***$46.1***	***$47.6***	***$49.7***	***89.4%***
Coal					
First-time and second-time sampling	$18.8	$0.3	$0.5	$0.7	0.9%
Above-action-level sampling	$151.3	$2.5	$2.5	$2.5	4.8%
Corrective actions sampling	$62.6	$1.0	$1.0	$1.0	2.0%
Post-evaluation sampling	$71.7	$1.2	$1.2	$1.2	2.2%
Periodic evaluations	$23.9	$0.4	$0.4	$0.4	0.7%
Subtotal	***$328.2***	***$5.5***	***$5.6***	***$5.9***	***10.6%***

Notes: [a] At the 3 percent discount rate.

4.2.2 Compliance Costs for Exposure Control Requirements

To estimate the cost of control measures, MSHA estimated three categories of exposure controls, as described in the following sections:

- Installation costs, consisting of the costs of purchasing new engineering control equipment and installing it or purchasing new services to clean or ventilate dust from work areas.

- Maintenance and repair costs, to ensure proper use of existing engineering controls with increased frequency of dust control maintenance and repair.

- Costs of administrative controls to reduce dust exposure (for example, the costs of training or posting signage regarding new policies).

In addition, to meet the requirements of 30 CFR Part 60, mine operators may have to provide some miners with respiratory protection. The costs of respiratory protection are discussed in this section.

The assumptions and parameters used to estimate the costs of exposure controls in this section can be considered those for a "typical" mine. As such, estimated costs are not distinguished by mine size. However, for at least some control categories, cost per mine may be lower for mines that are smaller than average or higher for mines that are larger than average.

Industry-wide, a typical mine is a small surface mine, most likely to produce a MNM commodity. Such a mine would likely have a small number of buildings, such as a maintenance shop, an office, and a couple for storage. The mine likely employs fewer than 50 miners as well as managerial and office staff. Many of these mines would also likely have a crusher and screening plant, a conveyor, and several pieces of heavy equipment and haulage vehicles. The experience of MSHA mine inspectors is that smaller mines, such as the "typical" mine used in this analysis, are less likely to have adequate dust controls in place, and less likely to perform high levels of maintenance on those controls. Thus, the smaller mines considered typical in this analysis are also more likely to incur costs under the final rule.

Equipment at the mine site will vary according to a number of factors, such as the mine size and commodity, geology, and related factors such as the production rate and "stripping ratio" (ratio of waste material to ore), and site layout (depth of pit, ramp distances and gradients, distance from pit to stockpile and dump). For example, a mine would ideally match its production rate, loading rate and haulage distance to minimize equipment downtime. This will affect the operator's selection of equipment type, size, and power. Depending on commodity mined and mine layout, MSHA might expect a typical mine to have a range of heavy and haulage equipment, such as excavators, front-end loaders, bulldozers, graders, drills, and dump trucks. Each mine is unique, and the precise mix of equipment at any mine will reflect mine-specific operations and conditions. However, the type and number of pieces of equipment at a typical mine will be limited. Furthermore, while some equipment will be used very intensively, other equipment will likely be used more sporadically.

Based on its extensive experience with the mining industry, MSHA observes that the most common dust producing equipment on mine sites include conveyors, trucks, truck loading and dumping sites, and crusher and screening plants. Equipment used for grading, over-burden dozing, high wall scaling, or sweeper vehicles are also likely to produce significant dust. Drills and packaging/bagging equipment are also present on some mine sites, but less frequently than the most common equipment.

Mines Affected by Exposure Control Requirements

MSHA projects that the cost of engineering and administrative controls will primarily be a function of the number of mines that need to incur costs to reach compliance with the new PEL. MSHA focuses the analysis only on those mines that are most likely to incur such costs under this rule; that is, mines that are *expected* to be affected by the final rule.

MSHA uses data from its silica exposure datasets (MSHA 2022a, MSHA 2022b) to estimate the number of mines most likely to incur costs under this rule using the methodology described here. In addition to other criteria, this estimate is based on an analysis of individual mines, which is possible given that all inspection samples in the exposure datasets are identified by a Mine ID unique to the mine at which the sample was taken. MSHA data show which mines exceed the new PEL. The exposure datasets contain 5 years of sample data for coal mines and 15 years of data for MNM mines. The reason for the discrepancy in years of data is that Phase III of MSHA's 2014 respirable coal mine dust standard went into effect on August 1, 2016, and thus, coal mine samples taken prior to this date are not likely to be representative of current respirable crystalline silica exposure levels in these mines.[42] For most mines, the dataset includes multiple sample results as well as results from multiple inspections. The method of identifying affected mines, explained below, accounts for changes over time, whereby a previously noncompliant mine became compliant in more recent years.

To estimate the number of affected mines that will incur costs, MSHA analyzed MNM mines that were active in the 2015 – 2019 period, and coal mines that were active in the August 2016 – July 2021 period. Coal mines that closed prior to 2016 are excluded because they may not be representative of coal mines still in production, especially with regard to respirable crystalline silica concentrations and/or respirable crystalline silica controls. For consistency, MSHA evaluated MNM mine data for a comparable 5-year period (the most recent 5 years of MSHA's exposure dataset). MSHA designates mines as "active" during the 5-year period if they had at least one 3-month period during which they employed at least one full-time equivalent miner (FTE; i.e., at least 520 hours were worked in that quarter, whether by one or multiple miners).

MSHA used the 5 years of data to identify a set of mines in which MSHA had collected exposure samples, then used the proportion of those mines with at least one recorded miner exposure level over 50 μg/m^3 to estimate a factor (a ratio) that could be applied to all mines.

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[42] MSHA believes the coal dust rule impacted respirable crystalline silica exposures, in part because (a) the coal dust exposure limit is based on a formula that reduces the limit when the respirable crystalline silica content exceeds five percent, and (b) measures that coal mine operators may have taken to reduce exposures to coal dust under that rule would have also reduced exposures to other respirable hazards, including crystalline silica. Using more recent coal exposure data from 2016-21 avoids possibly attributing benefits from the coal dust rule to this rule.

With a suitable factor, MSHA estimated the portion of all mines that might be expected to have, under the final rule, a first-time sampling result exceeding the PEL of 50 μg/m^3. This is the number of mines that will require corrective actions and corrective action sampling.

MSHA used its industry profile, exposure profile, and other Agency information to estimate what parts of the industry would incur costs of complying with the new PEL. The Agency examined each mine's sampling results from the most recent day on which one or more samples were taken.[43] If the result from at least one sample on that day exceeds the new PEL, MSHA assumed that mine would incur compliance costs under the final rule. Using only the most recent day of (relatively recent) historical data, MSHA resolves the potential difficulty of interpreting changes in exposure concentrations over time and avoided counting any mine more than once (i.e., in no case was a mine was double counted because MSHA measured exposures over 50 μg/m^3 on separate occasions).

The 5-year snapshot of the mining industry' past experience provides MSHA with the best available data to estimate the numbers of mines that will incur costs under the final rule. This process does not predict *which* mines will experience an instance of exposure above the PEL. One reason for this is that MSHA requires mine operators to abate exposures above the existing PEL, meaning that the actual conditions that lead to some exposures above 50 μg/m^3 no longer exist. Therefore, while the 5-year snapshot helps MSHA estimate the portion of mines that may experience an exposure event above 50 μg/m^3, it does not represent the future conditions at specific mines.

- MSHA defines a mine as "affected" by the final rule if the mine had a single sample result from the most recent day for which sample results were available that exceeded the new PEL. The mine operator is required to take action to reduce miners' exposures to respirable crystalline silica and thereby incur costs.
- A mine that had no sample results exceeding the new PEL on the most recent day for which sample results were available is assumed not affected and thus will not incur compliance costs under the new PEL.[44]
- MSHA assumes mines that MSHA never sampled will not incur exposure control costs.

Using these criteria, MSHA tabulates the estimated number of affected mines by sector. FRIA Table 4-8 presents the estimated number of affected mines and total mines by sector, the number of miners employed in affected mines, and the average employment per affected mine.

[43] Although the mine must be active in the most recent five-year period contained in the dataset, the most recent sample(s) used to assess a mine's likelihood of incurring costs did not need to be taken within that same five-year period. In one instance, for example, the most recent sample result dated from 2005, despite the mine having been active during the most recent five-year period. See: MSHA: Proposed Method for Estimating Mine Entities Affected by MSHA's Proposed RCS Rule, July 25, 2022.

[44] A mine might not have sample results exceeding the new PEL for two reasons. First, samples might have been taken at the mine, but the results did not exceed the PEL. Second, the mine might have not been sampled because, in the judgment of an MSHA inspector, any samples would be well below the previous PEL and therefore sampling was unnecessary. In both cases, MSHA assumed that the mine would not incur compliance costs.

MSHA estimates 1,226 mines out of 12,631 total mines (9.7 percent) are expected to incur costs, or be "affected", under the final rule. Of the total affected mines, 1,096 are MNM mines, while 130 are coal mines. Although less than 10 percent of total mines are affected, nearly 16 percent of all miners (including contract miners) work in affected mines (44,937/284,778). This is because affected mines tend to be larger and employ more miners than the average mine (36.7 miners per mine compared to 22.5 miners per mine). Additionally, MSHA increased its estimates for exposure control costs. MSHA assumes an extra 10 percent of mines will incur costs to lower exposures below the action level through increased maintenance and repair and administrative controls.

FRIA Table 4-8. Estimated Number of Mines Affected by Exposure Control Requirements by Sector, 2019

Mine Sector	Number of Mines			Number of Miners Including Contract Miners			Average Miners Including Contract Miners per Mine	
	Affected	Total	Affected as Percent of Total	In Affected Mines	Total	Affected as Percent of Total	Affected	Total
Total	***1,226***	***12,631***	***9.7%***	***44,937***	***284,778***	***15.8%***	***36.7***	***22.5***
Metal/ Nonmetal	1,096	11,525	9.5%	30,823	211,203	14.6%	28.1	18.3
Coal	130	1,106	11.8%	14,114	73,576	19.2%	108.6	66.5

Engineering Controls

All operators of affected mines will incur costs when they implement additional control measures to reduce exposure levels, but MSHA expects that a subset of affected mines will incur higher costs than others because they will be required to adopt more rigorous (i.e., extensive, or advanced) engineering control measures to reduce respirable crystalline silica exposures below the new PEL of 50 µg/m^3. MSHA determined the subset of mines that may require the more rigorous control measures based on mine size (i.e., the number of employees at a mine) and an analysis of citations for violations of the existing PEL. Mine size is used because it correlates well with the amount of respirable crystalline silica dust produced, and historical mine citations are used because they document how mines implement controls to reduce respirable crystalline silica exposure. Using these two factors, MSHA is therefore able to estimate the characteristics and number of mines that will likely require additional controls under the final rule and the accompanying cost of these controls.

Utilizing historical data from its silica exposure datasets (MSHA 2022a, MSHA 2022b) and institutional knowledge, MSHA estimates that approximately 53 percent of mines were able to terminate respirable crystalline silica dust citations by implementing corrective actions such as increased maintenance and repair, and/or other basic administrative controls (discussed in more detail below). MSHA's assessment of current controls which the industry uses to meet the existing PEL and additional controls to meet the new PEL are described in the Technological Feasibility, Preamble Sections VIII.B.2.c and VIII.B.2.d. FRIA Table 4-9 depicts the number of mines that will require additional engineering controls to meet the new PEL and the level of capital investment (i.e., minimal, moderate, and larger) that will be required.[45] The rest of this section discusses examples of engineering controls, with their typical uses, potential to reduce exposure reduction, and associated capital and operating costs, by different employment size.

FRIA Table 4-9. Affected Mines by Mine Size and Control Category Incurring Additional Engineering Controls, 2019

Control Category	Mine Employment Size [a]			Total Mines
	Small Mines (≤ 20 miners)	Medium Mines (20 < miners ≤ 100)	Large Mines (> 100 miners)	
Engineering controls– Minimal capital expenditure	399	50	9	458
Engineering controls– Moderate capital expenditure	50	25	9	84
Engineering controls– Larger capital expenditure	20	8	9	38
Total	***469***	***83***	***28***	***580***

Notes: Due to rounding, some totals do not exactly equal the sum of the corresponding individual entries.
[a] Miners (excluding contract miners) and contract miners.
Controls categorized under minimal capital expenditure are relatively simple fixes with initial capital costs less than $2,000; controls with moderate capital expenditure range from roughly $2,000 to $16,000 in capital costs, while large capital control expenditures exceed $20,000.

FRIA Table 4-10 presents a selection of the types of engineering controls which mines might consider for use in meeting the PEL. NIOSH has carefully evaluated most of the dust controls used in the mining industry and found that many of the controls may be used in combination with other control options, each complementing the other. NIOSH (2019b, 2021a) has documented protective factors and exposure reductions of 30 to 90 percent or higher for many engineering and administrative controls. MSHA selected several of these that represent a wide range of options that mine operators could adopt (in addition to dust control equipment maintenance) to an even wider range of situations in which baseline conditions include some control technologies, but miner exposures still exceed the new PEL of 50 µg/m^3.

Examples of versatile, effective controls that MSHA and NIOSH (2019b, 2021a) have observed missing from baseline dust controls at mines include sealed, pressurized, and filtered operator enclosures that exclude dust and provide equipment operators with a clean place to work. NIOSH (2019b, 2021a) found that operator enclosures (including mobile equipment cabs and stationary control booths, new or renovated) reduce respirable dust levels by 90 percent or

[45] The definitions used in this analysis for the level of expected capital expenditure reflect natural groupings of controls characterized by complexity and cost rather than formal definitions. Controls categorized under "minimal capital expenditure are relatively simple fixes with initial capital costs less than $2,000; controls with moderate capital expenditure range from roughly $2,000 to $16,000 in capital costs, while large capital control expenditures exceed $20,000.

more on mobile equipment (e.g., haulage equipment, drilling rigs, tractor-mounted stone cutting equipment) and at stationary locations (e.g. longwall machine operators in underground coal mines, conveying equipment operators at surface mines).[46] In contrast, process enclosures reduce the amount of dust that escapes an enclosure containing a dusty process which is controlled by a miner working outside of said enclosure. One example is an enclosure around a primary dump hopper (i.e., a container into which dump trucks deposit mined material to be crushed).[47] NIOSH recommends adding plastic strip curtains and a concrete barricade to further enclose the opening for the dump truck. These components are not necessarily included in the original construction of the enclosure and thus, addition of these components can provide an upgrade that will further enclose dust, calm the air inside, and reduce respirable dust concentrations where miners work outside the crushing equipment. Other examples of ventilated process enclosures include cowl-based dust extractors for small drills (e.g., rock or quarry drills) and conveyor belt loading enclosures. Operator enclosures and process enclosures provide effective respirable crystalline silica control at both MNM mines and coal mines (NIOSH, 2019b, 2021a).

Mine facilities routinely contain numerous sources of dust emission such as conveyors, screening equipment, material transfer points into and out of process equipment (e.g., mills, kilns, concentrators) and, in some cases, packaging/bagging areas. Although capturing dust at its source is the most effective form of dust control, general exhaust (i.e., whole structure) ventilation is used by many mine facilities. NIOSH (2010b) recommends that facilities with whole structure ventilation maintain 10 "air changes per hour" (i.e., an hourly air flow rate that equals 10 times the cubic-foot volume of the structure), which, as an option, can be increased to 20 or even more air changes per hour. MSHA assumed that mines have the recommended 10 air changes per hour in facilities as a baseline condition, but that where exposures are modestly elevated above the new PEL and additional controls are needed, an additional 10 air changes per hour will help flush airborne dust out of the structure. NIOSH found that a ventilation rate of 17 air changes per hour reduced average respirable dust levels by 47 percent (NIOSH, 2010b). MSHA began by assuming that 10 air changes per hour would provide at least an average of 50 percent reduction in respirable dust levels (i.e., the difference between the new and existing PELs for MNM mines), then considered how much airflow would be needed to achieve that level of reduction for a model mine structure of volume 60,000 cubic feet (e.g., a

[46] These operator enclosures are best paired with administrative/work practice controls that promote consistent use of the enclosure. Operator enclosures only protect miners for the part of the shift that the miners work inside (e.g., 80 percent of the shift inside a control booth can reduce the miner exposure proportionally).

[47] The enclosure helps calm and contain the air inside so that dust released during dumping has a chance to settle, rather than billowing out of the hopper and engulfing (and thereby overexposing) the truck driver or crusher operator. Where primary dumps contribute to current overexposures, MSHA assumed that mine operators will bring these exposures down to a level below the previous PEL (MNM mines) or exposure limit (coal mines) by adjusting existing water sprays, and, if needed, installing an enclosure and/or added ventilation (NIOSH, 2019b, 2021a).

facility of 50 feet x 30 feet x 40 feet).[48] Based on this information, MSHA calculated that increasing the whole structure ventilation by 10 air changes per hour would require installing a ventilation system that draws an additional 10,000 cubic feet per minute of air flow from the structure.[49]

Bulk material loading (i.e., from conveyors to other conveyors, hoppers, bulk bags, trucks and railcars, or stockpiles) occurs throughout mines and typically releases considerable respirable dust. Spouts and chutes help minimize factors that allow dust to become airborne. For example, the distance that the material falls before reaching the destination surface is controlled by telescoping spouts. Dust suppression hoppers, which reduce air turbulence, decrease the concentration of respirable dust in the air by up to 88 percent compared to a plain rigid spout (NIOSH, 2019b). Alternatively, the materials can be made less dusty by moistening them with water applied as a spray. Achieving and maintaining 1 to 4 percent moisture is optimal for reducing dust release. MSHA assumed that most mines are already applying water spray to dusty materials as a baseline condition. However, NIOSH found that rewetting (using additional spray equipment) is necessary to maintain the moisture level needed for effective dust control (NIOSH, 2019b, 2021a). Although preventing dust from becoming airborne is preferable, other types of water spray equipment are needed to reduce miner exposure to dust that is already airborne. Consulting with a water spray professional, such as an equipment supplier's technical support representative, can help mine operators achieve their dust control goals.

When making changes to dust controls, NIOSH points out that it is helpful to be able to measure airborne dust, air and water pressure, and other dust control system functions using direct reading instruments and gauges (NIOSH, 2019b, 2021a). These tools are useful training aids that can help mine operators, mine maintenance personnel, and miners learn how modest adjustments to these critical parameters can improve dust control system performance and reduce airborne respirable dust.

All the engineering controls mentioned here (e.g., various forms of operator or equipment enclosures, dust suppression hoppers/telescoping chutes, and water sprays) are compatible and can be installed individually, or in any combination, where a mine operator identifies need for additional dust control. These example items were selected, not because they are the only options, but because they represent wider groups of similar control measures, they are efficient (i.e., able to cut airborne respirable dust by at least 50 percent), and they are flexible options that can be used to complement existing dust controls. In their series of best practices and handbooks on dust control for the mining industry, NIOSH (2019b, 2021a)

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[48] For an MNM mine a 50 percent reduction in exposure level would reduce the average airborne level of respirable crystalline silica from 85 $\mu g/m^3$ (just below the previous PEL of 100) down to a level of 43 $\mu g/m^3$. For a coal mine, a 50 percent reduction in exposure would bring a concentration of 75 $\mu g/m^3$ (just below the previous exposure level of 85.7 $\mu g/m^3$ ISO, assuming the shift was 8 hours) down to 38 $\mu g/m^3$.

[49] For a structure of volume 60,000 cubic feet, one air change per hour would be: 60,000 cubic feet per minute times 1 hour/ 60 minutes. Ten air changes per hour would be:

$(60{,}000\ Ft^3/\ 1\ \text{air change}) * (10\ \text{air changes/hour}) * (1\ \text{hour}/60\ \text{minutes}) = 10{,}000\ ft^3/\text{min air flow}$

describes these controls as well as numerous other options that are also available for mine operators to substitute while selecting the optimal combination of controls appropriate for each individual mine in achieving the new PEL.

To support the cost analysis, the sample controls mentioned in FRIA Table 4-10 are organized by level of capital investment. For each level of investment, MSHA calculates an average across all controls under consideration in that category. This is because multiple different engineering controls can achieve the necessary reductions in exposure to respirable crystalline silica dust. Thus, mine operators will choose from alternative controls based on specific conditions at their mine, mine layout, equipment in place, and other site-specific factors. Within each level of investment, MSHA assumed any specific control technology is equally likely to be selected. Therefore, without further information regarding mine operators' most likely decisions, the expected value of purchased technologies equals the simple average of the listed technologies in the given category.

Where more precise information is unavailable, MSHA assumed operating and maintenance (O&M) costs to be 35 percent of initial capital expenditure and assumed that installation cost, when appropriate, will be equal to initial capital expenditure. MSHA assumed most controls will have a 10-year service life, except where otherwise indicated in FRIA Table 4-10. For example, heavy haulage and excavating machinery are assumed to have a 15-year service life, and new or substantially renovated structural ventilation systems are assumed to have a 30-year service life. Within each tier of capital expenditures, MSHA took a simple average of the engineering control costs, inclusive of installation, maintenance, capital, and replacements costs over the 60-year analysis period and annualized them.

FRIA Table 4-10. Selected Engineering Controls to Decrease Respirable Crystalline Silica Dust Exposure by Capital Expenditure Cost Range (in 2022 dollars)

Engineering Control	Capital Cost	Installation Cost [a]	O&M Cost [b]	Expected Service Life [c] (in years)
Minimal capital expenditure				
Dust extraction kit for rock drill	$1,400	$1,400	$490	10
Upgrade water pump pressure to achieve fine mist	$1,600	$1,600	$560	10
Mini-mister, boom mounted	$1,800	$1,800	$630	10
Upgrade recirculating air filter in operator enclosure	$0	$0	$470	10
Portable HEPA wet-dry vacuum, 9 gallons	$666	$0	$600	2
Add cyclonic pre-cleaner upwind of air intake filter for operator enclosure	$816	$816	$286	10
Vacuum pressure gauge (test suction on dust collector)	$79	$79	$28	10
Water line pressure gauge (check pressure for water spray systems)	$19	$19	$6	10

Differential pressure gauge (check ventilation system component function)	$70	$70	$25	10
Hand-held real-time dust analyzer	$60	$0	$21	1
Partially enclosed crusher/truck dump hopper with plastic strip curtains and dust/truck barricade	$1,900	$1,900	$665	5
Average	***$765***	***$699***	***$344***	***8.0***
Moderate capital expenditure				
Portable or fixed vacuum, HEPA, 15+ gallon	$4,601	$0	$600	5
Repair and improve existing operator enclosure (door/ window fit/seal, fix HVAC)	$2,717	$2,717	$543	10
Operator enclosure, haulage equipment	$15,769	$15,769	$5,519	15
Replace or add cab to compact tractor	$9,635	$9,635	$3,372	15
Average	***$8,180***	***$7,030***	***$2,509***	***11.3***
Larger capital expenditure				
Add new whole building fan 10,000 CFM with baghouse/dust collector/ducts/ engineering, medium size structure	$190,439	$190,439	$66,654	30
Add Conveyor belt loading enclosure and ventilation	$31,766	$31,766	$11,118	30
Control room 10x10, with ventilation, heat/AC, HEPA filter	$25,744	$25,744	$875	15
Enclose and ventilate screening equipment, 4 x 4 ft	$28,571	$28,571	$10,000	10
Mist cannon, 25 gal/min (BossTek, 2022)	$45,000	$45,000	$15,750	10
New compact track loader with cab/heat/AC	$50,000	$50,000	$17,500	15
Truck loading, open-bed truck, telescoping spout, outer telescoping trunk with air suction, dust collector, ductwork	$27,228	$27,228	$9,530	10
Truck loading, open bed, unventilated, hopper designed to minimized turbulence in delivered material	$29,112	$29,112	$4,765	10
Average	***$53,482***	***$53,482***	***$17,024***	***16.3***

Notes: [a] Unless otherwise specified, MSHA assumed installation costs are equal to capital cost.
[b] Unless otherwise specified, MSHA assumed annual O&M costs are equal to 35 percent of capital cost.
[c] Unless otherwise specified, MSHA assumed service life to be 10 years.

Each affected mine is assigned the average value for its capital expenditure tier. MSHA assumes that installation occurs at the same time as initial capital expenditure, and O&M costs occur every year. At a 3 percent discount rate, annualized costs range from $556 per mine for the lowest cost tier of capital equipment to $24,345 per mine for the highest cost tier. The annualized cost per mine is $2,573 when averaged across all mines (FRIA Table 4-11).

FRIA Table 4-11. Estimated Annualized Costs per Mine as a Simple Average of Engineering Controls by Capital Expenditure Category (in 2022 dollars)

Control Category	Annualized Cost of Engineering Controls per Mine at Specified Real Discount Rate		
	0 Percent	3 Percent	7 Percent
All Mines Installing Engineering Controls			
Minimal capital expenditure	$548	$556	$563
Moderate capital expenditure	$3,664	$3,814	$4,010
Larger capital expenditure	$23,158	$24,345	$26,013
Average of All Mines	***$2,468***	***$2,573***	***$2,716***
Metal/Nonmetal			
Minimal capital expenditure	$548	$554	$559
Moderate capital expenditure	$3,657	$3,794	$3,965
Larger capital expenditure	$23,102	$24,182	$25,656
Average of All MNM Mines	***$2,289***	***$2,376***	***$2,489***
Coal			
Minimal capital expenditure	$554	$573	$599
Moderate capital expenditure	$3,699	$3,923	$4,246
Larger capital expenditure	$23,386	$25,012	$27,472
Average of All Coal Mines	***$3,972***	***$4,228***	***$4,610***

Note: *Calculated as the sum of annualized engineering costs over all levels of capital expenditures and commodities divided by the total number of mines.

FRIA Table 4-12 presents total estimated annualized engineering costs by sector. Total annualized engineering costs are calculated at $1.43 million (0 percent) to $1.58 million (7 percent) over 60 years.

FRIA Table 4-12. Estimated Total Annualized Engineering Costs (in thousands of 2022 dollars) by Sector and Control Category, 2022

Control Category	Number of Mines	Annualized Engineering Cost at Specified Discount Rate			
		0 Percent	3 Percent	7 Percent	Percentage of Total Costs [a]
All Engineering Controls					
Total – All	***580***	***$1,431***	***$1,492***	***$1,575***	***100.0%***
Metal/Nonmetal	518	$1,186	$1,231	$1,290	82.5%
Coal	62	$246	$262	$285	17.5%
Minimal capital expenditure					
Subtotal – Minimal	***458***	***$251.2***	***$254.6***	***$258.0***	***100.0%***
Metal/Nonmetal	417	$228.6	$231.1	$233.4	90.8%
Coal	41	$22.7	$23.5	$24.5	9.2%
Moderate capital expenditure					
Subtotal – Moderate	***84***	***$308.1***	***$320.8***	***$337.2***	***100.0%***
Metal/Nonmetal	71	$258.2	$267.8	$279.9	83.5%

Coal	14	$49.9	$53.0	$57.3	16.5%
Larger capital expenditure					
Subtotal – Larger	***38***	***$872.1***	***$916.8***	***$979.6***	***100.0%***
Metal/Nonmetal	30	$699.1	$731.8	$776.3	79.8%
Coal	7	$173.1	$185.1	$203.3	20.2%

Note: [a] Calculated at the 3 percent discount rate.

Maintenance and Repair

In NIOSH and MSHA experience, when overexposures occur, often engineering controls are in place, but the operator has neglected maintenance and repair. Beyond adopting more advanced engineering controls infrastructure, an integral method of reducing respirable crystalline silica exposure is by increasing the frequency of maintenance and repairs for dust control systems. MSHA has determined that, when the appropriate dust control systems are used, effective and regular maintenance and repair of such systems can help reduce respirable crystalline silica exposure below the new PEL. MSHA's experience suggests that miner exposures between the new PEL and the existing standards are largely due to deterioration of existing dust exposure controls. This deterioration may be intermittent due to delays in routine corrective maintenance, or persistent due to a deficiency that goes unnoticed. Where respirable crystalline silica exposure levels approach the existing PEL, MSHA believes that the existing dust control equipment is not functioning as well as intended, usually because it has not been adequately maintained. When these shortcomings are corrected, through regular maintenance or repair of the dust control equipment, respirable crystalline silica concentrations may decrease below the new PEL.

For example, underground coal mines use fluid bed scrubbers to clean ("scrub") dust and methane from air drawn from the vicinity of continuous mining machines. These scrubbers reduce dust levels by 80 to 90 percent in air downwind of continuous mining machine operations. However, NIOSH has shown that scrubber dust collection efficiency might decrease by as much as 33 percent due to filter clogging by dust generated from just one pass of the continuous mining machine along the mine face. Routine maintenance is therefore required to keep scrubbers functioning as intended.

Mines can avoid deteriorating dust controls by increasing the routine maintenance frequency of existing dust control equipment. Maintenance and repair activities are usually conducted at the beginning of each shift (or as frequently as necessary) and can be a part of existing safety and operational checks performed on most equipment. For example, drill rig operators and operators of large-powered haulage equipment typically have a pre-shift checklist (available from manufacturers, NIOSH, or industry trade associations) to follow that is designed to maintain functionality and reduce wear and tear on their equipment. If it takes 10 minutes to complete a 20 to 25 item pre-shift checklist, an experienced equipment operator might add another 2.0 to 2.5 minutes to check dust controls (e.g., ensure that cab ventilation dust filters are in place, that the fan/AC turns on when activated, that the window and door seals appear intact, that the drill deck shroud is intact and adjusted to minimize gaps, that the dust suppression spray system has a sufficient level, that the water pump responds when activated, and that the dust discharge point spray nozzles spray as expected). If the checklist is used five times per week to verify equipment condition and the dust control check adds 2.5 minutes each time, it would add a total of 163 minutes (2.5 minutes per day × 5 days × 13 weeks) to pre-shift maintenance checks per quarter.

MSHA estimates mine operators would spend 16 hours per quarter on additional inspection and maintenance at a typical mine (i.e., 64 hours per year). This is an average estimate; small mines with less equipment to check would require less than 16 hours per quarter while large mines would require more time. Furthermore, small mines are predominant in the industry as a whole and are likely to have a minimal amount of equipment (e.g., 1 to 3 pieces of equipment). The above-mentioned example of additional inspection of a drill rig suggests that, with 16 hours per quarter, a mine could perform additional inspection and maintenance on approximately 6 pieces of equipment of similar complexity ((16 hours × 60 minutes per hour)/163 minutes per piece of equipment).

To account for additional maintenance and repair costs that would result from using inspection checklists to cover maintenance and repair of dust suppression and control equipment, MSHA added 25 percent to the additional labor costs spent checking equipment. Thus, for every $1,000 mine operators spend on labor for checking equipment and additional maintenance, they will spend an additional $250 (25 percent x $1,000) on parts for extra maintenance and repairs. In general, the most common items identified for maintenance only require adjustment or purchase of small, low-cost replacement items (e.g., refill the water tank, adjust or replace a noisy fan belt, or replace a spray nozzle).

In addition, mine operators may receive other benefits from more frequent maintenance and repairs. For example, dull drilling bits not only create more dust, but also cut less efficiently. More frequent equipment checks to ensure bits are sharp would reduce generated dust and result in more efficient operations. Similarly, more frequent, albeit small, repairs, may prevent more significant breakdowns that would otherwise result in delays due to inoperable equipment. These other benefits are not quantified in the present analysis.

MSHA believes that increased maintenance and repair will be performed by employees in the following BLS Standard Occupational Classification (SOC) codes: Construction Equipment Operators (SOC 47-2070); Pipelayers, Plumbers, Pipefitters, and Steamfitters (SOC 47-2150); Helpers – Extraction Workers (SOC 47-5080); Miscellaneous Extraction Workers (SOC 47-5090); First-line Supervisors of Mechanics, Installers, and Repairers (SOC 49-1010); Bus and Truck Mechanics and Diesel Engine Specialists (SOC 49-3030); Heating, Air Conditioning, and Refrigeration Mechanics and Installers (SOC 49-9020); and Industrial Machinery Installation, Repair, and Maintenance Workers (SOC 49-9040). The value of the additional 64 hours per mine per year is calculated as an average of the loaded hourly wage rate of the specified occupations weighted by the relative employment of each occupation in the mining NAICS codes. For the purposes of cost annualization, these costs will be incurred every year over the 60-year analysis period.

FRIA Table 4-13 presents the average loaded hourly wage for the occupations specified above by sector. Differences in average hourly wages by sector account for the difference in average cost per affected mine.

FRIA Table 4-13. Estimated Increased Maintenance and Repair Costs per Mine (in 2022 dollars)

Cost Components	Mine Sector	Average Loaded Hourly Wage Rate [a]	Annual Cost Per Affected Mine [a]
Incremental costs incurred each year: ▪ 64 hours per year ▪ Hours spent by a mix of occupations (e.g., equipment operators, extraction workers, etc.) ▪ Hours valued at weighted average of loaded wage rates ▪ Value of labor hours multiplied by 1.25 to account for cost of increased maintenance and repairs	Metal/Nonmetal	$42.36	$3,389
	Coal	$59.86	$4,789

Sources: Hourly wage: BLS Occupational Employment and Wage Statistics (OEWS). National industry-specific and by ownership, May 2021; Benefits multiplier: BLS Employer Costs for Employee Compensation – December 2021; Overhead multiplier: Department of Labor (DOL). Defining and Delimiting the Exemptions for Executive, Administrative, Professional, Outside Sales and Computer Employees. Final Rule. 84 Federal Register 51230.
Note: [a] Calculations based on estimated incremental hours for performing additional inspections.

In addition to the 1,226 affected mines, MSHA anticipates that additional mines will incur increased maintenance and repair costs each year to reduce exposure below the action level in order to avoid exposure monitoring costs. In response to the comments, MSHA increased its cost estimate; MSHA assumes another 10 percent of mines (1,153 MNM mines and 111 coal mines) will incur the costs presented in FRIA Table 4-13. Because this estimate is for mines that do not need to incur costs to meet the new PEL, MSHA believes it is possible that a larger number of mines might incur smaller unit costs that results in roughly the same total costs.

Multiplying the average cost per mine by the estimated number of mines incurring costs results in total annual and annualized costs by sector.[50] FRIA Table 4-14 and FRIA Table 4-15 show an estimated 2,489 mines that are expected to incur total annual costs of $8.77 million and total annualized costs of $8.51 million for increased maintenance and repair at a 3 percent discount rate.

[50] If estimated annual costs are identical for each year over a given analytic period, then by definition, annual costs are equal to annualized costs. Annualized costs are a stream of equal periodic costs having the same PV as the original stream of costs. In this case, the stream of annualized costs for coal is identical to the original stream of annual costs and will therefore have the same PV.

FRIA Table 4-14. Annual Incremental Maintenance and Repair Control Costs (in thousands of 2022 dollars) by Sector

Mine Sector	Mines Needing Control	Annual Cost	Percent by Sector*
Incremental Costs Incurred in Year 1			
Total	***241***	***$1,152.2***	***100.0%***
Metal/Nonmetal [a]	0	$0.0	0.0%
Coal [b]	241	$1,152.2	100.0%
Incremental Costs Incurred in Year 2-60			
Total	***2,489***	***$8,772.8***	***100.0%***
Metal/Nonmetal [a]	2,249	$7,620.6	86.9%
Coal [b]	241	$1,152.2	13.1%

Notes:

[a] Annual cost in metal/nonmetal mines in year 2 through 60; cost is $0 in year 1.

[b] Annual cost in coal mines in year 1 through 60.

FRIA Table 4-15. Annualized Incremental Maintenance and Repair Control Costs (in thousands of 2022 dollars) by Sector

Mine Sector	Total Annualized Cost at Specified Discount Rate			Percent by Sector*
	0 Percent	3 Percent	7 Percent	
Total	***$8,646***	***$8,506***	***$8,266***	***100.0%***
Metal/Nonmetal	$7,493.6	$7,353.3	$7,113.3	86.5%
Coal	$1,152.2	$1,152.2	$1,152.2	13.5%

Note: * Calculated at the 3 percent discount rate.

Administrative Controls

General Controls

Administrative controls comprise a variety of methods to reduce exposure to respirable crystalline silica dust. In general, the shared characteristic of these methods is that mine operators evaluate situations in which exposure can be reduced through changes in policies and work practices, and implements those changes by informing miners through training, published announcements, procedures, instructions, and signage.

Examples of administrative controls include:

- Requiring operators of equipment with enclosed cabs to work with doors and windows shut. This not only inhibits entry of dust into the cab, but also improves effectiveness of installed ventilation and filter systems. For example, NIOSH cites a study that showed operating equipment with open cab doors and windows reduced dust exposure by less than 40 percent, but operating the same equipment with closed doors and windows might reduce dust exposure by more than 90 percent.

- Prohibiting meetings, other gatherings, and activities of miners near or downwind of dust-producing equipment (e.g., drilling rigs, crushing equipment). This removes workers from high dust areas, thereby reducing exposure in proportion to meeting time as a percentage of shift time.

- Setting speed limits and minimum distances for equipment operated on dusty haul roads. NIOSH showed that reducing equipment travel speed from 25 miles per hour (mph) to 10 mph reduced dust by 58 percent. Similarly, requiring a 20 second distance between vehicles reduced dust exposure to the driver in the following vehicle by up to 52 percent. Furthermore, these requirements also reduce exposure for miners who work near the road.

- Moving the location of dust-generating activities, such as stone cutting, to less frequented areas of the work site or scheduling such operations for times when fewer miners will be in the vicinity.

While many of these examples are applications of common-sense policies, they can be circumvented either accidently or deliberately. Administrative controls are not always effective, or as effective as they could be, because unlike engineering controls, administrative controls depend on miners' adherence to the policies and work practices. Administrative controls rank lower than engineering controls in the hierarchy of effectiveness. However, NIOSH finds that training and evaluation by mine operators can help ensure the administrative/work practice controls are observed and successful (NIOSH, 2022).

The cost of administrative controls is composed of labor hours. MSHA believes that 2,489 mines, including the 1,226 affected mines, will spend, on average, an additional 16 labor hours on administrative controls starting in Year 1 (for coal) and Year 2 (for MNM) and in each subsequent year of the 60-year analysis period. As with the estimates of additional maintenance and repair costs, this number of affected mines is based on MSHA's assumption that beyond those mines with exposure currently above the new PEL, an additional 10 percent of mines might incur increased administrative costs each year to reduce exposure to below the action level.

In addition to the time spent identifying administrative controls, mine staff need to prepare and publish training and instructional materials, and post signage and/or other informational materials to implement such controls. Thus, MSHA increases the value of labor hours by a factor of 2.0. That is, for every $1,000 a mine operator spends on identifying opportunities to reduce exposure to respirable crystalline silica through administrative means in each year, an additional $1,000 will be spent formulating new – or revising existing – policies and procedures, documenting changes in manuals and guidance, preparing instructional and training materials, and posting signage to remind miners of the changes.

MSHA expects that the additional labor hours spent on administrative controls will be performed by employees in the following occupation codes: Occupational Health and Safety Specialists and Technicians (SOC 19-5010); First-Line Supervisors of Construction Trades and

Extraction Workers (SOC 47-1010); Construction Equipment Operators (SOC 47-2070); Surface Mining Machine Operators and Earth Drillers (SOC 47-5020); Helpers – Extraction Workers (SOC 47-5080); Miscellaneous Extraction Workers (SOC 47-5090). The value of the additional 16 labor hours per mine per year is calculated as an average of the loaded hourly wage rate weighted by the relative employment of these occupations in the mining industry.

FRIA Table 4-16 presents the estimated average cost per affected mine per year for each sector based on the specifications for additional administrative controls outlined above. The differences in average costs by sector are explained by the differences in the average hourly wages between the two mining sectors.

FRIA Table 4-16. Estimated Administrative Control Costs per Mine (in 2022 dollars)

▪ 16 hours per year ▪ Hours spent by a mix of occupations (e.g., OHS technicians, 1st line supervisors, equipment operators, extraction workers, etc.) ▪ Hours valued at weighted average of loaded wage rates ▪ Value of labor hours multiplied by 2.0 to account for publishing new/revised procedures, training, signage, etc.	Metal/ Nonmetal	$1,439
	Coal	$2,222

FRIA Table 4-17 shows the estimated number of mines and annual costs expected to be incurred in Year 1 and Years 2 through 60 for administrative controls. Additionally, FRIA Table 4-18 shows that total annualized costs range from $3.7 million (0 percent discount rate) to $3.6 million (7 percent discount rate) based on the discount rate used. The higher totals for the MNM sector are attributable to the much larger number of affected mines than the coal sector.

FRIA Table 4-17. Annual Administrative Control Costs (in thousands of 2022 dollars)

Incremental costs incurred in Year 1			
Total	***241***	***$534.7***	***100.0%***
Metal/Nonmetal	0	$0.0	0.0%
Coal	241	$534.7	100.0%
Incremental costs incurred in Year 2-60			
Total	***2,489***	***$3,770.9***	***100.0%***
Metal/Nonmetal	2,249	$3,236.2	85.8%
Coal	241	$534.7	14.2%

Note: *Calculated at the 3 percent discount rate.

FRIA Table 4-18. Annualized Administrative Control Costs (in thousands of 2022 dollars)

	Total Annualized Cost at Specified Discount Rate			
Mine Sector	**0 Percent**	**3 Percent**	**7 Percent**	**Percent by Sector***

Total	***$3,717.0***	***$3,657.4***	***$3,555.5***	***100.0%***
Metal/Nonmetal	$3,182.3	$3,122.7	$3,020.8	85.4%
Coal	$534.7	$534.7	$534.7	14.6%

Note: *Calculated at the 3 percent discount rate.

Respiratory Protection Requirements

The new PEL of 50 µg/m^3 may result in an increased use of respirators by miners when compared with usage under the existing PEL of 100 µg/m^3. This additional usage will result from provisions § 60.13: Corrective actions and § 60.14: Respiratory protection. Under § 60.13, if sampling results indicate miners' exposure exceeds the new PEL, mine operators must make approved respirators available to affected miners; ensure that miners wear respirators properly during the period of overexposure; and take corrective actions to lower the concentration of respirable crystalline silica to at or below the PEL. Section 60.14(a) requires the temporary use of respirators at MNM mines when engineering controls are developed and implemented or when necessary due to the nature of work involved (e.g., entry into a hazardous atmosphere to perform maintenance). MSHA expects that additional use of respiratory protection will occur because exposure levels that were below the existing PEL will now be above the new PEL.

MSHA believes that additional respirator use is most likely to occur during the first few years after implementation of the rule until mines can consistently control sources of respirable crystalline silica dust exposure at the new PEL using engineering controls. It is likely that over time, incremental respirator use will decline as mine operators implement and improve additional controls. However, with little data to support an assumption concerning how quickly additional use might decline, MSHA chose to err on the side of overestimation and model it as constant use over the 60-year analysis period.

Under § 60.13 MSHA believes that miners who are most likely to need incremental respirator use to perform corrective actions work in specific occupations:

- Kiln, Mill, and Concentrator Workers (MNM mines)
- Mobile Workers and Jackhammer Operators (MNM mines)
- Miners in Other Occupations (MNM mines)
- Underground Miners (Coal mines)
- Surface Miners (Coal mines)

To estimate the number of miners who might be required to increase their use of respirators under § 60.13, MSHA first used sample data to estimate the number of miners in these specified occupations with respirable crystalline silica exposures between the new PEL and the existing standards (50 µg/m^3 to 100 µg/m^3 range for MNM and 50 µg/m^3 to 85.7 µg/m^3 for coal). MSHA then assumed that 20 percent of that total, about 2,109 miners, would actually increase their use of respirators as a result of the rule. MSHA thus estimates that mine operators will incur costs for increased respiratory protection by 1,984 MNM miners and 125 coal miners per year to meet the requirements of § 60.13.

Under § 60.14(a), MSHA used sample data to estimate the number of MNM miners that might need to increase their temporary use of respirators due to the rule. MSHA assumed that mine operators will need to provide additional respiratory protection for 20 percent of MNM miners with exposures between the new PEL and the existing PEL.[51] MSHA estimates MNM mine operators will need to provide additional respiratory protection to 4,945 MNM miners to meet the requirement of § 60.14.

FRIA Table 4-19 presents the estimated number of miners, including contract miners, who may require incremental respiratory protection. Together, MSHA estimates 7,054 miners might need additional respiratory protection under both § 60.13 (2,109 miners) and § 60.14 (4,945 miners). Of those miners, approximately 98 percent are in the MNM mining sector.

FRIA Table 4-19. Estimated Number of Miners Requiring Incremental Respiratory Protection, 2019

Mine Sector	Miners (including Contractors) Requiring Additional Respirator Use	Percent of Miners
Total Miners Requiring Incremental Respirator Use		
Total	***7,054***	***100.0%***
Metal/Nonmetal	6,928	98.2%
Coal	125	1.8%
Attributable to Section 60.13 Requirements [a]		
Total	***2,109***	***100.0%***
Metal/Nonmetal	1,984	94.1%
Coal	125	5.9%
Attributable to Section 60.14 Requirements [b]		
Total	***4,945***	***100.0%***
Metal/Nonmetal	4,945	100.0%
Coal	0	0%

Notes: [a] 20 percent of miners (1) in the following occupations: Kiln, Mill, and Concentrator Workers; Mobile Workers and Jackhammer Operators; and Miners in Other Occupations (MNM mines); and Underground Miners and Surface Miners (Coal mines); and (2) with exposure between the current PEL and the new PEL.
[b] 20 percent of MNM miners with exposure between the current PEL and the new PEL.

In the following subsections, MSHA estimates the subset of these mine operators who will have to be issued new respirators because of the final rule and the incremental cost of additional temporary respirator use.

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[51] MSHA is estimating the number of miners who might need additional respiratory protection from the same group of miners: those with exposures between the new PEL and the existing PEL. Although this might result in double-counting, it is likely that miners requiring additional respiratory protection to perform corrective actions under § 60.13 are not necessarily the same miners as those requiring additional respiratory protection to perform temporary work under § 60.14. To the extent double counting does occur, this will result in an overestimate of incremental respiratory protection costs.

New Respirator Purchases

MSHA believes that given the existing respiratory protection standards, most miners have already been issued respirators to deal with intermittent, temporary circumstances where exposures exceed the existing standard. However, some mine operators with miners at low risk of exceeding the existing standard may now need to purchase respirators to account for possible temporary exposures in the range between the new PEL and existing standards. It is likely that some miners newly at risk for exposure in this range will not have respirators. In addition, because respirators will be used more under the new PEL, respirators will deteriorate more quickly and need replacement. In addition to miners who did not need to wear a respirator under the existing standards but might have occasional temporary need for respiratory protection under the new PEL, some mine operators will need to replace respirators for miners more frequently due to a small increase in the need for temporary respiratory protection.

To estimate the cost of new respirators, MSHA assumed that mine operators will purchase tight-fitting, re-useable half-mask elastomeric respirators at a cost of $39.57 each plus $17.29 for filters.[52] In addition, MSHA assumed respirators are assigned to individuals, not shared equipment. Furthermore, miners issued new respirators will require an additional 2 hours of labor time for fit testing and training which is valued at the weighted average loaded wage rates of all mine workers in the given sector ($50.60 for Metal miners, $40.47 for Nonmetal miners, and $49.97 for coal miners).[53, 54] MSHA presents the estimates for the total cost of new respirators below in FRIA Table 4-20.

FRIA Table 4-20. Estimated Cost of New Respirators, Fit Testing and Training per Miner (in 2022 dollars)

Cost Components	Mine Sector	New Respirator Cost Per Miner	Fit Testing and Training	Annual Cost Per Entity- Standard Respirator Usage
-- Respirators cost $39.57 -- Respirator filters cost $17.29 -- 2 hours per miner for fit testing and training	Metal/Nonmetal	$56.86	$88.13	$144.99
	Coal	$56.86	$99.95	$156.81

[52] Based on online (non-discount) prices: Websites for Northern Safety, 2022: $29.14/each 3MSeries 6500 half mask respirator, $10.25/pair for P100 pancake filters; and Grainger, 2022: $50.00 for MSA 420 series half mask respirator, $24.32 for P100 filter cartridges (package of 2). Prices are higher end of potential range, supplier bulk discounts available from numerous other sources.

[53] OSHA APF rulemaking (update to 29 CFR 1910.134) Unit Costs: 1 hour employee training, 1 hour employee qualitative fit testing. Alternatively, 2 hours for quantitative fit testing (from costs estimated in 2001-2006; may be reduced due to efficiency of more modern quantitative fit testing equipment currently available and widely used). MSHA assumed that worker fit testing is conducted in small groups; two to four miners are fit tested during the hour, but all remain part of the group for the full hour.

[54] MSHA assumed there will be no additional labor costs for personnel conducting fit testing or training because current respiratory protection programs already require these steps.

MSHA assumes that in Year 1 following the start of implementation, coal mine operators will incur costs for new respirators for 50 percent of their coal miners who are expected to increase respirator use (i.e., 63 new respirators). In Year 2, MNM mine operators will also incur costs for new respirators for 50 percent of the total MNM miners who are expected to increase respirator use (i.e., 3,464 new respirators). In Years 2 through 60 (for coal) and Years 3 through 60 (for MNM), mine operators will incur costs for 50 percent of the total number of new respirators purchased in Year 1 (for coal) and Year 2 (for MNM). Therefore, in Year 3 and onwards, coal and MNM mine operators will purchase a total of 1,763 new respirators per year. Furthermore, MSHA assumed that all new respirator purchases in any year throughout the analysis period will require fit testing and training. These estimates are based on the Agency's experience and are designed to err on the side of overestimation.

FRIA Table 4-21 presents the estimated annual costs of purchasing new respirators for incremental respiratory protection under the new PEL for miners who did not require respiratory protection under the existing PEL. In total, mine operators are estimated to spend $9,821 in Year 1 for coal miners and $502,282 in Year 2 for MNM miners to cover corrective actions (coal and MNM) and temporary use (MNM only) where they would likely be exposed to respirable crystalline silica in the range between the new PEL and the current PEL. In subsequent years (Years 2 through 60 for coal mines; Years 3 through 60 for MNM mines), annual costs are expected to be about half of first year costs for coal and second year costs for MNM ($256,052).

FRIA Table 4-21. Estimated Annual Cost of New Respirator Purchases (in 2022 dollars)

Mine Sector	Miners Including Contract Miners	Total Annual Cost	Percent by Sector
Year 1			
Total	***63***	***$9,821***	***100.0%***
Metal/Nonmetal	0	$0	0.0%
Coal	63	$9,821	100.0%
Year 2			
Total	***3,496***	***$507,193***	***100.0%***
Metal/Nonmetal	3,464	$502,282	99.0%
Coal	31	$4,911	1.0%
Years 3-60			
Total	***1,763***	***$256,052***	***100.0%***
Metal/Nonmetal	1,732	$251,141	98.1%
Coal	31	$4,911	1.9%

Notes: [a] Incremental costs under § 60.13 only.
[b] Combined incremental costs under § 60.13 and § 60.14.

FRIA Table 4-22 summarizes the total annualized cost of new respirator purchases by sector. Overall, the new PEL is expected to lead mine operators to purchase new respirators costing an average of $256,134 (at a 0 percent discount rate) to $255,285 (at a 7 percent discount rate) per year over the 60-year analysis period.

FRIA Table 4-22. Estimated Annualized Cost of New Respirator Purchases (in 2022 dollars)

Mine Sector	Total Annualized Cost at Specified Discount Rate			Percent by Sector*
	0 Percent	3 Percent	7 Percent	
Total	***$256,134***	***$255,967***	***$255,285***	***100.0%***
Metal/Nonmetal	$251,141	$250,884	$250,047	98.0%
Coal	$4,992	$5,083	$5,238	2.0%

Note: *Calculated at the 3 percent discount rate.

Additional Respirator Use

MSHA also estimates the cost of additional respirator use under the new PEL for miners who did not need it under the existing standards. MSHA assumes the cost of this additional respirator use starting in Year 1 (for coal mines) and Year 2 (for MNM mines) will remain constant over the 60-year analysis period. On average, MSHA believes additional temporary respirator use will be necessary for 4 hours per week per miner, or an additional 208 hours per year (4 hours per week x 52 weeks per year). Thus, if the elastomeric respirator used for costing uses two filters at a time, and the filters last 8 hours before requiring replacement, then these miners will need an additional 26 pairs of filters per year (208 hours per year/8 hours per filter pair). At an average price of $17.29 per pair of filters, mine operators will spend an additional $450 per miner per year ($17.29 × 26 filter pairs) for respirator filters.

FRIA Table 4-23 and FRIA Table 4-24 present the estimated total annual and annualized cost of additional respirator usage by sector. The annual cost of additional temporary respirator use is expected to be $450 per mine per year over the 60-year analysis period and the annualized cost is expected to be $3.1 million per year.

FRIA Table 4-23. Estimated Annual Cost of Additional Respirator Use by Sector (2022 dollars)

Mine Sector	Miners Including Contractors	Annual Cost per Miner	Total Annual Cost
Year 1			
Total	***125***	***$450***	***$56,312***
Metal/Nonmetal [a]	0	$0	$0
Coal [b]	125	$450	$56,312
Years 2 - 60			
Total	***7,054***	***$450***	***$3,170,895***
Metal/Nonmetal [a]	6,928	$450	$3,114,584
Coal [b]	125	$450	$56,312

Notes: [a] Annual cost in Year 2 through 60; cost is $0 in Year 1.
[b] Annual cost in Year 1 through 60

FRIA Table 4-24. Annualized Cost of Additional Respirator Use by Sector (in thousands of 2022 dollars)

	Total Annualized Cost at Specified Discount Rate			
Mine Sector	0 Percent	3 Percent	7 Percent	Percent of Total Annualized Cost*
Total	***$3,119.0***	***$3,061.6***	***$2,963.6***	***100.0%***
Metal/Nonmetal	$3,062.7	$3,005.3	$2,907.2	98.2%
Coal	$56.3	$56.3	$56.3	1.8%

Note: *Calculated at the 3 percent discount rate.

The estimate presented in FRIA Table 4-24 may be an overestimate of the cost of respirator use. Although MSHA assumed respiratory use would remain constant over the 60-year analysis period, it is likely that the need for additional respirators will decline as mines implement and improve engineering and administrative controls. However, with little data to support an assumption concerning how quickly incremental respirator use might decline, MSHA chose to model it as constant. Second, while most mines operate year-round, some mines may operate for as little as 3 months per year. This will also decrease the need for respirators.

4.2.3 Compliance Costs for Medical Surveillance Requirements

Under the final rule, MSHA will require each MNM mine operator to provide mandatory medical examinations to miners who are new to the mining industry and voluntary periodic examinations to all currently employed miners. These new medical surveillance standards extend to MNM miners the opportunity for medical surveillance that is already available to coal miners under the existing rules.

The medical examinations will be provided by a physician or other licensed health care professional (PLHCP), or by a specialist. The medical examination will include a miner's medical and work history, a physical examination, a chest X-ray, and a pulmonary function test. For those miners new to the mining industry, the first mandatory exam must take place within 60 days after beginning employment. This must be followed by a mandatory follow-up examination at 3 years. Should the follow-up examination indicate any medical issues related to lung disease, a second mandatory follow-up examination must take place in 2 years. In addition to these mandatory examinations, mine operators must also offer voluntary periodic medical exams to all MNM miners at least every 5 years. The first periodic medical exam for existing MNM miners must be provided within 12 months of the final rule's MNM compliance date. All of the medical examinations must be provided at no cost to the miner.

Additionally, the MNM mine operator must ensure that, within 30 days of the medical examination, the PLHCP or specialist provides the results of chest X-ray classifications to NIOSH, once NIOSH establishes a reporting system. The cost of the x-ray includes the cost of preparing the report and transmitting those results to NIOSH.

To estimate the costs of compliance with the medical surveillance requirement, MSHA first estimated the "unit cost" of a single medical examination. MSHA then estimated how many examinations would occur in each year over the 60-year analysis period and multiplied the number of examinations by the unit cost to determine total costs in each year. MSHA summed the costs in each year to estimate a total cost over the full 60-year period.

Under the new requirements, miners must first be identified as being new to the mining industry. If they are new, then they must receive the first mandatory examination within 60 days. If, instead, they are not new to mining, then they are categorized as belonging to a group of workers who are eligible for an examination every 5 years. For new miners, after the additional 2-year follow-up exam, or if the 3-year follow-up examination indicates no medical concerns associated with lung disease, then these miners will enter the category of miners eligible for examinations every 5 years.

In this analysis, MSHA does not have information to accurately measure the percentage of miners who would be offered another follow-up exam 2 years after the initial 3-year follow-up exam. However, MSHA expects that it will be a small fraction of miners and, as such, MSHA assumed it to be 5 percent. The remaining 95 percent of those new miners who do not require the additional follow-up exam enter directly into the category of workers eligible for examinations every 5 years.

Unit Costs

MSHA assumed that all examinations entail the same cost elements (in decreasing order of cost): the physical examination, chest X-ray, spirometry test, lost work time while being examined, lost travel time, symptom assessment and occupational history, transportation cost, and recordkeeping of the mine operator. FRIA Table 4-25 displays estimated components in 2022 dollars, which sum to a unit cost of $628.58 per examination. MSHA's calculated unit cost the same way OSHA did in its Regulatory Economic Analysis (REA)of medical surveillance associated with the OSHA Silica Rule (OSHA, 2016b). In its silica rule REA, OSHA initially presented cost estimates in 2009 dollars, which it then converted to 2012 dollars using the consumer price index (CPI) for medical care (U.S. BLS, 2022). MSHA applied the same index to inflate those 2012 costs to 2021 dollars. Like with other costs, MSHA then inflated those 2021 costs to 2022 dollars by using the GDP implicit price deflator.[55]

[55] The original costs in 2012 dollars were multiplied by the ratio of the index in June 2021 to the index in June 2012 to convert them to 2021 dollars. This ratio was 1.259. The GDP implicit price deflator increased from 110.220 in 2021 to 117.996 in 2022, equivalent to an increase of 7.055%. The CPI for medical care was 525.276 in 2021 and 546.554 in 2022 (U.S. BLS, 2024), equivalent to a 4.05 percent increase in price of medical care. Had MSHA used this CPI to inflate medical care costs from 2021 to 2022 instead of the GDP implicit price deflator, the cost per medical examination would have increased to $610.94 in 2022 dollars, about $17.60 less than was estimated using the GDP implicit price deflator. Total annualized medical surveillance costs (and total compliance costs) would be about $530,000 less per year.

FRIA Table 4-25. Estimated Cost Per Medical Examination (in 2022 dollars)

Cost Components	Cost
Physical Examination	$158.69
Chest X-Ray	$119.20
Spirometry Test	$81.89
Symptom Assessment and Occupational History	$49.90
Lost Work Time While Being Examined	$87.29
Lost Travel Time	$87.29
Transportation Cost	$26.76
Recordkeeping of Mine Operator	$17.55
Total	$628.58

Physical Examination. MSHA applied the cost component that OSHA described as "physical examination by knowledgeable HCP, evaluation and office consultation including detailed examination" with "special emphasis on the respiratory system," which was originally $110.83 in 2012 dollars. MSHA added an additional component which OSHA listed as "other necessary tests" (e.g., a tuberculosis test) costing $66.50 in 2012, but "required by 10 percent of workers," implying an average additional cost of $6.65 per miner in 2012 dollars (OSHA, 2016a). The cost of this item is $158.69 in 2022 dollars.

Chest X-ray. MSHA applied the cost component that OSHA described as "chest X-ray, radiologic examination, chest; stereo, frontal. Costs include consultation and written report" which was originally $88.24 in 2012 dollars. The cost of this item is $119.20 in 2022 dollars.

Spirometry Test. MSHA applied the cost component that OSHA described as "Pulmonary function test, Spirometry, including measurement of forced vital capacity (FVC), forced expiratory volume at 1 second (FEV_1), and FEV_1/FVC ratio," which was originally $60.62 in 2012 dollars. The cost of this item is $81.89 in 2022 dollars.

Symptom Assessment and Occupational History. MSHA applied the cost component that OSHA described as "Complete occupational and health history survey, assumed one third of physical exam cost," which was originally $36.94 in 2012 dollars. The cost of this item is $49.90 in 2022 dollars.

Lost Work Time While Being Examined. MSHA assumed a miner's lost work time while being examined would be 2 hours, consistent with OSHA's estimated lost work time. To estimate the cost, MSHA multiplied the 2 hours by the loaded wage rate of $40.77 for an MNM miner in 2021.[56] Applying the GDP deflator, this rate increased to $43.65 in 2022.

Lost Work Time While Travelling. MSHA estimated the lost work time while travelling to and from the examination to be 2 hours (i.e., 1 hour each way). MSHA then multiplied the 2 hours by the same loaded wage rate, which explains why lost travel time was estimated to have the same cost as lost work time while being examined.

Transportation Cost. MSHA estimated the transportation cost of $25 based on the assumptions of: (a) 100 miles round trip by car, (b) a mileage rate of 20 miles per gallon (implying 5 gallons of gas would be needed), (c) a price of gasoline of $4.00 per gallon, and (d) depreciation of the car ("wear and tear") of $5.00 for each 100-mile trip. The cost of this item is $26.76 in 2022 dollars.

Recordkeeping of Mine Operator. OSHA assumed 15 minutes of labor needed for the employer's recordkeeping of the examination, including the time needed to report the results of chest X-ray classifications to NIOSH. MSHA assumed the labor involved would be that of an occupational health and safety specialist in MNM mining, whose loaded hourly rate (including overhead) was estimated at $65.56. Applying the GDP deflator, this rate increased to $70.19 in 2022. Thus, MSHA obtained the cost estimate of one-fourth of this hourly rate.[57]

Number of Examinations Per Year. MSHA used the same estimated number of full-time equivalent (FTE) employees in MNM mining that it is using in its final benefits analysis of the respirable crystalline silica rule, which is 184,615 FTE workers.[58] MSHA assumed MNM FTE employment will remain constant over the 60-year analysis period following compliance of the

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[56] This hourly rate was derived from the OEWS May 2021 survey. NAICS 212200 and 212300 were combined for Metal and Non-Metal Mining wages. MSHA multiplied the mean wage rate by a benefit factor of 1.493 to obtain the fully loaded wage rate, and 17 percent of the mean wage was also added to account for overhead cost. The occupation codes used for each occupation are as follows: 47-5022, 47-5041, 47-5043, 47-5044, 47-5049, 47-5051, 47-5081, 57-5099, 49-9071, 51-9021, 51-9192, 53-7011.
Bureau of Labor Statistics: Occupational Employment and Wage Statistics (OEWS). National industry-specific and by ownership. May 2021. Downloaded from https://www.bls.gov/oes/tables.htm on April 29, 2022. OEWS wage rates are already expressed in 2021 dollars and do not need to be adjusted for inflation.
BLS: Employer Costs for Employee Compensation – December 2021. Downloaded from: https://www.bls.gov/news.release/pdf/ecec.pdf on April 29, 2022.
Department of Labor (DOL). Defining and Delimiting the Exemptions for Executive, Administrative, Professional, Outside Sales and Computer Employees. Final Rule. 84 Federal Register 51230.
[57] The hourly wage rate was derived from the OEWS May 2021 survey. NAICS 212200 and 212300 were combined for Metal and Non-Metal Mining wages. MSHA multiplied the mean wage rate by a benefit factor of 1.488 to obtain the fully loaded wage rate, and 1 percent of the mean wage was also added to account for overhead cost. The occupation codes used was for Occupational Health and Safety Specialist (19-5011).
[58] In 2019, 211,203 miners and contract miners worked 369.2 million hours, which is equivalent to 184,615 FTE workers (= 369,230,521 hours worked ÷ 2,000 FTE hours per year). Thus, there are 1.14 employees for every 1 FTE employee (= 211,203 ÷ 184,615).

medical surveillance requirement.[59] MSHA estimates that the average length of employment as an MNM miner (before leaving the mining occupation) is 22 years, which is derived from a NIOSH survey that found the average mining experience of MNM miners is approximately 11 years.[60] Based on this estimate, MSHA assumed that each year 8,392 miners (i.e., about 1/22, or 4.55 percent, of 184,615 FTE MNM miners) would leave the industry, and be replaced by the same number of new entering workers.

Estimated Costs Under the Final Requirements. MSHA estimates total costs over the 60-year analysis period under two different scenarios due to the uncertainty of how many currently employed miners will participate in voluntary medical surveillance programs. Assuming a participation rate of 25 percent (Scenario 1), total estimated costs over 60 years range from $196 million (with a 7 percent discount rate) to $875 million (with a 0 percent discount rate). Annualized costs range from $14.0 million (with a 7 percent discount) to $14.6 million (with a 0 percent discount rate) and the annualized cost per MNM miner ranges from $76 (with 7 percent discount rate) to $79 (with a 0 percent discount rate).

In scenario 2, MSHA assumed that the participation rate is 75 percent. Total costs over the 60-year analysis period range from $332 million (7 percent discount rate) to $1.4 billion (0 percent discount rate). Annualized costs range from $23.7 million (0 percent discount rate) to $23.1 million (7 percent discount rate). The annualized cost per MNM miner range from $128.3 (0 percent discount rate) to $124.9 (7 percent discount rate). A summary of estimated medical surveillance costs under the two scenarios is presented in FRIA Table 4-26.

FRIA Table 4-26. Summary of Estimated Medical Surveillance Costs for MNM Miners by Participation Rate and Discount Rate (in millions of 2022 dollars)

	Discount Rate		
Cost Type	**0 percent**	**3 percent**	**7 percent**
Total Costs			
25 percent participation rate	$875.0	$397.2	$196.0
75 percent participation rate	$1,383.2	$645.4	$332.4
Average of participation rates	*$1,129.1*	*$521.3*	*$264.2*

[59] MSHA chose to express mine employment in FTEs for the benefits analysis because health impacts would differ between part-time miners, who would experience less exposure to respirable crystalline silica dust and thus would be less likely to experience the same negative health effects in the same amount of time as miners who worked full-time or more. A similar logic applies to miners deciding whether to accept medical exams, thus medical surveillance costs are also estimated based on FTE miners.

[60] The 2012 report by NIOSH, entitled, "National Survey of the Mining Population: Part 1: Employees," (https://www.cdc.gov/niosh/mining/works/coversheet776.html) includes the findings of its 2008 survey on mine operators and miners in the U.S. (Details on the survey methodology and results are available in the link.) The NIOSH survey found the following mine experiences for different types of MNM mines, which average to about 11 years (11.375 to be precise): metal mines, 10.7 years; nonmetal, 12.0 years; stone, 12.5 years, and sand and gravel 10.3 years. For comparison, the same survey found the average mining experience for coal miners was 16.0 years. These averages reflected the average number of years that respondent miners had worked at mines at the time the survey was conducted. MSHA considered these average mine experiences to represent approximately one half of the mining tenure these miners would have (the years in mining when they leave). Conversely, MSHA estimated miners' total expected tenure to be twice these average mining experiences.

Annualized Cost			
25 percent participation rate	$14.6	$14.4	$14.0
75 percent participation rate	$23.1	$23.3	$23.7
Average of participation rates	*$18.8*	*$18.8*	*$18.8*
Annualized Cost per MNM miner			
25 percent participation rate	$78.99	$77.74	$75.61
75 percent participation rate	$124.87	$126.32	$128.25

Summary: Estimated Annualized Costs Attributable to 30 CFR Part 60

In this section, MSHA totals the annualized costs of meeting the compliance requirements of the new PEL under the new 30 CFR Part 60. This includes the estimated costs associated with exposure monitoring, additional engineering controls, increased maintenance and repair measures, administrative controls, additional respiratory protection, and medical surveillance attributable to the final rule.

As shown in FRIA Table 4-27, MSHA projects that Part 60 annualized compliance costs will total $89.0 million per year over 60 years at a 3 percent discount rate. Exposure monitoring accounts for $53.2 million (60 percent) of this total, medical surveillance for $18.8 million (21 percent), exposure controls for another $13.7 million (15 percent), and respiratory protection for $3.3 million (4 percent).

FRIA Table 4-27. Summary of Part 60 Compliance Costs by Sector and Requirement (in millions of 2022 dollars)

	0 Percent Discount Rate		3 Percent Discount Rate		7 Percent Discount Rate	
Mine Sector	**Annualized Cost**	**Percent Subtotal**	**Annualized Cost**	**Percent Subtotal**	**Annualized Cost**	**Percent Subtotal**
All Mines						
Exposure Monitoring	$51.60	58.9%	$53.24	59.8%	$55.64	61.1%
Exposure Controls	$13.79	15.7%	$13.66	15.3%	$13.40	14.7%
Respiratory Protection	$3.38	3.9%	$3.32	3.7%	$3.22	3.5%
Medical Surveillance	$18.82	21.5%	$18.84	21.2%	$18.82	20.7%
Total, Part 60 Costs	***$87.59***	***100.0%***	***$89.05***	***100.0%***	***$91.07***	***100.0%***
As Percent of All Mines	***100.0%***		***100.0%***		***100.0%***	
Metal/Nonmetal						
Exposure Monitoring	$46.13	57.6%	$47.61	58.5%	$49.74	59.8%
Exposure Controls	$11.86	14.8%	$11.71	14.4%	$11.42	13.7%
Respiratory Protection	$3.31	4.1%	$3. 24	4.0%	$3.16	3.8%
Medical Surveillance[a]	$18.82	23.5%	$18.84	23.1%	$18.82	22.6%
Total, Part 60 Costs	***$80.12***	***100.0%***	***$81.41***	***100.0%***	***$83.14***	***100.0%***

As Percent of All Mines	***91.5%***		***91.4%***		***91.3%***	
Coal						
Exposure Monitoring	$5.47	73.3%	$5.63	73.7%	$5.89	74.3%
Exposure Controls	$1.93	25.9%	$1.95	25.5%	$1.97	24.9%
Respiratory Protection	$0.06	0.8%	$0.06	0.8%	$0.66	0.8%
Medical Surveillance[b]	NA	NA	NA	NA	NA	NA
Total, Part 60 Costs	***$7.46***	***100.0%***	***$7.64***	***100.0%***	***$7.93***	***100.0%***
As Percent of All Mines	***8.5%***		***8.6%***		***8.7%***	

Notes: [a] Medical surveillance cost is presented as the average of the assumed participation rates of 25 percent and 75 percent. Medical Surveillance costs calculated at MNM level then attributed to commodity level based on percentage of FTE Miners and contract miners working in that commodity.
[b]The Coal sector is not expected to incur medical surveillance costs because it is already required to have equivalent medical surveillance program.

4.3 Compliance Costs of Respiratory Protection Requirement

MSHA is also replacing the Agency's existing standards for respiratory protection that reference the American National Standards Institute (ANSI) Z88.2-1969 Practices for Respiratory Protection (1969 ANSI) (§§ 56.5005, 57.5005, and 72.710) with the 2019 ASTM standard to improve respiratory protection for miners from all airborne contaminants.

In this section, MSHA discusses the cost to all mines attributable to the update from the 1969 ANSI standard to the 2019 ASTM standard. These costs are estimated by provision, based on respirator use, either on a per miner or a per mine basis, as appropriate. The costs incurred by mine operators to update their respiratory protection practices will vary. This variation occurs for several reasons which are discussed below.

Mines Affected by Respiratory Protection Requirements

First, MSHA estimated the number of mines likely to update respiratory protection practices under the final rule. MSHA assumed that in any given year respirators will be used at about 20 percent of MNM mines. Some mine operators are not required to have a respiratory protection program. MSHA assumed that 20 percent of MNM mines will incur costs to meet the 2019 ASTM standard each year. MSHA assumed that all coal mines are affected by the update to the 2019 ASTM standard because existing 30 CFR 72.700(a) requires coal mine operators to make respirators available to their miners. This should be an overestimate because it is likely that many coal mines already meet the 2019 ASTM standard.

Second, under the revised § 56.5005 and § 57.5005 MSHA requires that a written respiratory protection program meet the following requirements in accordance with ASTM F3387-19: program administration; standard operating procedures; medical evaluation; respirator selection; training; fit testing; and maintenance, inspection, and storage. Among provisions that are required, several are already required under other standards and thus, mine operators will not incur additional compliance costs for these provisions. For example, mines are already required to select NIOSH-approved respirators under §§ 56.5005, 57.5005, and

72.701. Similarly, miner respirator training is already performed as part of annual health and safety training under 30 CFR parts 46 and 48.

Third, only a small subset of miners uses respirators in any given year. Based on Greskevitch *et al*. (2007), about 10 percent of miners at MNM mines and about 7.4 percent of miners at coal mines are expected to use respirators each year. Dust control has improved significantly at coal mines since the period in which Greskevitch *et al.* measured the proportion of respirator use and especially following MSHA's 2014 final rule on RCMD. Therefore, MSHA assumed that, currently and in the future, about 10 percent of MNM miners and half of the measured 7.4 percent (3.7 percent) of coal miners are expected to use respirators on an annual basis.

FRIA Table 4-28 presents the total number of mines compared to the total number of mines expected to incur compliance costs to update their respiratory protection program and practices. In Year 1, MSHA assumes that 1,106 coal mines will incur costs to update their respiratory protection program and practices to the 2019 ASTM standard, and 2,722 coal miners and contract miners are expected to wear respirators. Starting in Year 2, MSHA estimates that 3,411 mines (i.e., 20 percent of the 11,525 MNM mines and 100 percent of the 1,106 coal mines) are expected to incur. In addition, MSHA estimates 6,946 miners and contract miners wear respirators each year, which represents less than 2.5 percent of all miners including contract miners (6,946/284,778). Respirators are worn to protect miners from airborne contaminants (including respirable crystalline silica and coal dust) at only a small percentage of mines each year and only a small fraction of the miners at those mines wear respirators.[61]

FRIA Table 4-28. Mines Incurring Incremental Costs of ASTM Update, 2019

Mine Sector	Total Mines	Affected Mines	Miners Including Contract Miners in Affected Mines		Average Miners per Affected Mine	
			Total Miners	Miners Wearing Respirators	Miners	Miners Wearing Respirators
All Mines	***12,631***	***3,411***	***115,817***	***6,946***	***34.0***	***2.0***
Metal/Nonmetal	11,525	2,305	42,241	4,224	18.3	1.8
Coal	1,106	1,106	73,576	2,722	66.5	2.5

* Note: Due to rounding, some totals do not exactly equal the sum of the corresponding individual entries.

4.4 Compliance Costs of ASTM Update Requirements

Under the final rule, mine operators are required to have a written respiratory protection program in accordance with the 2019 ASTM F3387-19 standard. A written

[61] Greskevitch *et al.* was based on 2006 data, eight years before MSHA's coal dust rule was promulgated. Due to the implementation of the coal dust rule, the Agency estimates that the current rate of respirator use is half of Greskevitch *et al.*'s estimate.

respiratory protection program must include program administration; written standard operating procedures; medical evaluations; respirator selection; training; fit testing; and maintenance, inspection, and storage. Mine operators will compare the ASTM standard to their existing respiratory protection program or practices and identify the elements of their respiratory protection program or practices that need to be revised. MSHA evaluated the components of the 2019 ASTM standard that have the potential to impose additional costs on mine operators.

A comparison of the 1969 ANSI standard (which is incorporated by reference in 30 CFR 56.5005, 57.5005 and 72.710) and the 2019 ASTM standard showed that the two standards are similar in several areas. Those portions of the two standards that are the same do not require mine operators to incur additional costs when updating to the 2019 ASTM standard.

In addition, several respiratory protection industry standards, although not required by existing standards, are already widely implemented in the mining industry (e.g., conducting respirator fit testing following recognized methods and protocols).

Here, MSHA evaluates the components of the 2019 ASTM standard that may impose additional costs on mine operators, and the assumptions in estimating those costs.

Approved Respirators

Mine operators are familiar with MSHA's existing requirements for using NIOSH-approved respirators, and this analysis assumed that mine operators will not incur additional costs for these requirements. MSHA assumed recordkeeping primarily results in labor costs ranging from 4 hours in small mines, to 16 hours in medium sized mines, to 24 hours in large mines in Year 1 of compliance for their respective sectors. The time spent in subsequent years will be half that of Year 1 of compliance. Recordkeeping tasks might be performed by a Human Resources Assistant (i.e., Office Clerk) with a loaded hourly rate of $34.52 in nonmetal mining, $48.55 in metal mining, and $35.74 in coal mining. Thus, recordkeeping at a large mine is estimated to cost $928 (24 hours × weighted average hourly rate of $38.67) in Year 1 of compliance and $464 in subsequent years (12 hours × $38.67). At medium sized mines, MSHA estimates that recordkeeping will cost $589 (16 hours × $36.81) in Year 1 of compliance, and $295 in subsequent years (8 hours x $36.81). Among small mines, recordkeeping costs an average of $143 per mine in Year 1 of compliance (4 hours x $35.75), and $71 per mine (2 hours x $35.75) in subsequent years.

Program Audit

Program costs for an annual review and written report by the program administrator are included with the annual labor time ranging from 1 hour in a small mine, to 4 hours in a medium sized mine, to 8 hours in a large mine. The program administrator who performs the review and prepares the report was assumed to be a "first-line supervisor of construction trades and extraction workers" (SOC 47-1010) with an average loaded hourly rate of $61.71 in nonmental mining, $73.71 in metal mining, and $82.82 in coal mining. A second review in the form of an outside audit is conducted by a person not involved in the respirator program. This could be an internal manager or supervisor from a different department (e.g., accounting, or a "first line supervisor of maintenance and repairs") (SOC 49-1010) with an average loaded hourly rate of $74.56 in nonmetal mining, $77.52 in metal mining, and $92.93 in coal mining. Half of the original report preparation time (0.5 hours, 2 hours, and 4 hours in small, medium, and large mines, respectively) is allotted to the outside audit. The audit is to be repeated at a frequency determined by the complexity of the program. MSHA assumed 50 percent of affected mines perform the entire audit protocol in any given year, for which MSHA estimates program audit costs average about $202 per mine per year.

Written Standard Operating Procedures

In this analysis, MSHA assumed that most mines have established written Standard Operating Procedures (SOPs) that comply with the ASTM standard. Therefore, MSHA assumed that 50 percent of affected mine operators (i.e., about 1,706 mine operators (see FRIA Table 4-28), will prepare new or updated SOPs at the start of implementation. MSHA estimates large mines will require 8 hours, medium sized mines will require 6 hours, and small mines will require 4 hours of a supervisor's time to prepare new SOPs. Each hour is valued at the loaded hourly rate for a supervisor working in the mining sector.

MSHA estimates large mines will require 3 hours, medium sized mines will require 2 hours, and small mines will require 1 hour to update existing SOPs. The time to update existing SOPs will be split between a health and safety technician (two-thirds of the hours) and a supervisor (one-third of the hours). MSHA assumed that half of those mine operators updating written SOPs will provide miners with a copy of updated SOPs. MSHA assumed it will require about 2 hours of a supervisor's time at a large mine, 1 hour at a medium sized mine, and 15 minutes at small mines to provide miners with written SOPs. Each hour is valued at the loaded hourly rate for the relevant occupation and mining sector. Specifically, the loaded hourly rate for a health and safety technician ranges from $65.71 per hour in MNM mining to $81.16 per hour in coal mining. For First-Line Supervisors of Construction Trades and Extraction Workers, the loaded hourly wage ranges from $61.71 per hour in MNM mining to $82.82 per hour in coal mines.

Finally, MSHA assumed that the costs described above will be incurred at the start of implementation by current mine operators. Following this initial period, these costs will be incurred only by new mines which are estimated to enter the market at a rate of about 2 percent per year. Overall, MSHA estimates the incremental cost to mine operators for this provision as $432 per mine on average.

Medical Evaluations

Under this provision, mine operators would update the information provided to the PLHCP concerning each miner's work area, type and weight of respirator, duration and frequency of respirator use, work activities and environmental conditions, hazards, and other PPE worn. This information is assumed to be part of the miner's job description and personnel records (e.g., fit-test results; thus, MSHA includes recordkeeping costs for fit-test results in medical evaluation costs) and is likely available electronically at most mines. Therefore, from 1 hour (at a large mine) to 30 minutes (at medium and small mines) of labor from a health and safety technician are assumed necessary to document this information in the miner's records and to transmit it to the PLHCP. MSHA estimates the incremental cost to mine operators for this provision to total $37 per mine per year on average.

Respirator Selection

The provisions for respirator selection in the 2019 ASTM standard reflect the current standard of care for respirator use in the U.S. In this analysis, MSHA assumed that mine operators are already using these criteria for selecting respiratory protection. MSHA assumed that mine operators will not incur additional costs for this provision.

Mine Operator Responsibilities

The 2019 ASTM standard provides that mine operators allow miners wearing respirators to leave a hazardous atmosphere for any reason related to the respirator, including, but not limited to respirator malfunction, contaminant leakage, or increased breathing resistance. For this analysis, MSHA estimates a labor cost of 16 hours per 100 miners per year (approximately an average of 10 minutes per miner per year), which is calculated and valued at the average miner loaded hourly wage rate (ranging from $40.47 for nonmetal mining to $49.97 for coal mining).

The mine operator will also investigate the cause of respirator failures and communicate with the respirator manufacturer and government agencies about defects. Respirator failures or defects are considered rare events. To account for the potential time involved should defective respirators be encountered, this analysis adds a minimal amount of labor time. Specifically, MSHA estimates that a respiratory protection administrator must spend 0.25 hours per 100 respirator users per year for each of the 60 years of the analysis. MSHA estimates the labor cost of both provisions combined will cost a mine operator $15 per year.

Training the "Respirator Trainer"

Under the 2019 ASTM standard, the respirator trainer will provide training to others with responsibilities for implementing the mine operator's respirator program, and therefore, this person must have an appropriate training or experience. The length of the train-the-trainer programs offered by numerous organizations varies in both duration (from half-day to multi-day) and cost.[62, 63] For this analysis, a 4.5-hour labor charge from either a health and safety

[62] Nebraska Safety Council offers a 6 hour course for $799 (including a "Trainer kit" of materials designed to help the new trainer) https://nesafetycouncil.org/index.php/worker-education-and-events/training-courses/16-workplace-safety/nebraska-training-courses/92-respiratory-protection-and-fit-testing-train-the-trainer

[63] The American Association of Occupational Health Nurses offers 4-to-5-hour multi-module free online course entitled "Role of the Respiratory Protection Program Administrator," developed in conjunction with NIOSH, OSHA, and Baylor University. A course completion certificate is available at a nominal charge: http://aaohn.org/page/respiratory-protection-1278

professional or a technician and an average course plus materials cost of $214 is estimated to be incurred by each mine in Year 1 of analysis. At an average cost of about $533 per mine, this is the single most expensive provision MSHA expects mine operators to incur. For existing mines, this cost is unlikely to recur except when a respirator trainer leaves the mine operator's employment. However, it is likely to be incurred by the 2 percent of new mines entering the market in any given year.

Training for the Mine Operator/Supervisor and the Person Issuing Respirators

The mine operator or supervisor of any miner who must wear a respirator must receive training on the elements of the respiratory protection program in the SOPs and related topics. For large and medium mines, MSHA believes the training will take about 2 hours, thus costing 2 hours of a health and safety technician's time plus 2 hours for the supervisor being trained both of which are valued at their respective average loaded hourly rates. At small mines, the training is expected to require 1 hour for the health and safety technician and 1 hour for the supervisor being trained. The overall average cost in the first year of compliance is estimated to be about $169 per mine and will also be incurred in subsequent years by – at a minimum – new mines entering the market.

Miner Training

Miners required to use respirators already receive training each year under the 1969 ANSI standard and under 30 CFR Part 46 and Part 48. Most mines incorporate this into their existing annual health and training plan, and therefore MSHA estimates that there are no incremental costs attributable to this provision.

This provision will result in an additional 1 hour of special supplemental training time for miners who use self-contained breathing apparatus (SCBA) respirators. However, training on these types of respirators is specified in 30 CFR part 49. Therefore, no costs for SCBA training are attributed to this provision.

Fit Testing Frequency

The 2019 ASTM standard provides for annual respirator fit testing to ensure that the make, model, and size of the respirator issued to the miner are appropriate and the miner is still able to achieve a good face seal. MSHA assumed that, on average, miners receive annual fit testing under existing training standards. Although the current ANSI standard did not address specific fit testing methods and equipment, MSHA assumed mine operators who use respirators at baseline are already following recognized and published fit testing methods and protocols (e.g., OSHA, ASTM). For the purposes of recordkeeping, fit testing is incorporated in medical evaluation recordkeeping as described above.

However, a provision under the 2019 ASTM standard is that the fit testing must be overseen by a trained technician or supervisor. The time of the trained supervisor is an additional cost incurred under this provision. MSHA assumed fit testing will be performed in small groups of 4 and takes about 1 hour. The incremental cost of the supervisor's time is calculated as 0.25 hours multiplied by the number of miners who wear respirators at the mine. MSHA estimates the incremental cost to mine operators for this provision will range from $386 for large mines (where, on average, from 15 to 56 miners require fit testing; see FRIA Table 4-28) to $10 for small mines (where perhaps only one miner requires fit testing). The overall average cost is estimated to total $37 per mine per year.

Maintenance, Inspection, and Storage

The provisions for respirator selection in the 2019 ASTM standard reflect the current standard of care for respirator use in the U.S. In this analysis, MSHA assumed that mine operators are already using these criteria for maintaining, inspecting, and storing respirators. Therefore, MSHA assumed that mine operators will not incur additional costs for this provision.

FRIA Table 4-29 summarizes the specific components (described in detail above) of each minimally acceptable provision under the 2019 ASTM Standard Practice for Respiratory Protection that mines will adopt, and under which MSHA expects costs will be incurred. The table shows the expected average annual cost per mine in the first year of compliance and subsequent years. The costs by provision presented here are weighted averages of costs across all mines calculated by sector and mine size.

FRIA Table 4-29. Summary of ASTM (Standard Practice for Respiratory Protection) Requirements and Estimated Incremental Cost per Affected Mine (in 2022 dollars)

Summary of Provisions Assumed to be Adopted	Average Annual Cost per Mine
1. Approved Respirators No cost	NA
2. Written Standard Operating Procedures (SOP) Detailed SOP; Provide each miner with copy of SOP	$432
3. Medical Evaluations Send employees' respiratory protection records to PLHCP	$37
4. Fit Testing Frequency Trained employee's time to supervise fit testing	$37
5. Respirator Selection No cost	NA
6. Mine Operator Responsibilities Time lost due to respirator problem Time to investigate defective respirators	$15
7. Mine Worker Responsibilities No cost	NA
8. Training the Respirator Trainer Training for respiratory protection trainer	$533
9. Training for the Mine Operator/Supervisor and the Person Issuing Respirators Training for respiratory protection program manager and person issuing respirators	$169
10. Miner Training	

No cost	NA
11. Disposal	
No cost	NA
12. Recordkeeping	
Labor time to create and maintain records [a]	$246
13. Program Audit	
Time for program administrator to prepare written audit and review by third party	$202

Note: [a] Estimated recordkeeping costs in Years 2 through 60 are half the value of Year 1 costs ($123).

4.4.1 Estimated Compliance Costs of Respiratory Protection Practices Related to ASTM Update

FRIA Table 4-30 presents average compliance costs per mine by sector. In Year 1, compliance costs average about $1,700 for coal mines. In Year 2, compliance costs average about $1,200 for MNM mines. In Years 3 and following, average compliance costs per mine are smaller, ranging from $262 for MNM mines to $479 for coal mines, with an overall average of $332 per mine.

MSHA assumes that all mines are affected by the requirement to have a written respiratory protection program that meets the ASTM standard but not all mines are expected to incur costs for this requirement. MSHA estimates, in Year 1 (for coal mines) and Year 2 (for MNM mines) of compliance, only 50 percent of affected mines are expected to incur costs under provision 2 (SOPs) because many mines already have SOPs that comply with the ASTM.

In Years 2 through 60 (for coal) and Years 3 through 60 (for MNM), the number of affected mines that would incur costs is smaller than in Year 1 (for coal) and Year 2 (for MNM). This is because following Year 1 (for coal) and Year 2 (for MNM), additional compliance costs are expected to be incurred primarily by new mines entering the industry. For example, provisions related to written SOPs, Training for the Respirator Trainer, and Training for the Mine Operator and Person Responsible for Issuing Respirators are initial costs incurred in the first year of compliance. In subsequent years, those costs would generally be incurred only by the 2 percent of new mines entering the industry.

FRIA Table 4-30. Respiratory Protection Practices Costs Related to ASTM Update per Mine (in 2022 dollars)

Mine Sector	Number of Mines Incurring Costs	Total Cost	Cost per Mine
Incremental Cost in Year 1			
Total	***1,106***	***$1,911,502***	***$1,728***
Metal/Nonmetal	0	$0	--
Coal	1,106	$1,911,502	$1,728
Incremental Cost in Year 2			
Total	***3,411***	***$3,237,436***	***$949***

Metal/Nonmetal	2,305	$2,707,811	$1,175
Coal	1,106	$529,625	$479
Incremental Cost in Years 3-60			
Total	***3,411***	***$1,132,441***	***$332***
Metal/Nonmetal	2,305	$602,816	$262
Coal	1,106	$529,625	$479

As shown in FRIA Table 4-30, the total industry cost of revising respiratory protection practices to the 2019 ASTM standard are at a maximum in the year following the MNM compliance date (Year 2), but thereafter decrease by about one-third of the Year 2 amount. On an annualized basis at a 3 percent discount rate, compliance costs total $1.23 million, with 53 percent of those costs attributable to MNM mines and 47 percent attributable to coal mines (FRIA Table 4-31).

FRIA Table 4-31. Respiratory Protection Practices Related to ASTM Update Total Annualized Costs (in thousands of 2022 dollars)

Component	Mines Incurring Costs	Total Annualized Costs (thousands of dollars) per Year at Specified Discount Rate			Percentage of Total Costs*
		0 Percent	3 Percent	7 Percent	
Total	***3,411***	***$1,181***	***$1,231***	***$1,315***	***100.0%***
Metal/Nonmetal	2,305	$628	$653	$694	53.1%
Coal	1,106	$553	$578	$622	46.9%

Note: * Calculated at the 3 percent real discount rate.

4.5 Summary of Annualized Costs of the Final Rule

MSHA totals the annualized costs of each of the estimated costs examined above: exposure monitoring, exposure controls (engineering and administrative controls), respiratory protection, medical surveillance under Part 60, and ASTM updates.

Annualized total compliance costs are summarized by detailed components of each provision in FRIA Table 4-32 and by mine sector in FRIA Table 4-33. MSHA projects that, at a 3 percent discount rate, annualized compliance costs will total $90.3 million over 60 years. About 91 percent of these costs will be incurred by the MNM mine sector. By provision, exposure monitoring accounts for the majority of annualized costs at over $53.2 million per year (59 percent of total annualized costs). Annualized costs of exposure controls are $13.7 million, representing 15 percent of total annualized costs. Respiratory protection comprises only about 4 percent of total annualized compliance costs ($3.3 million). The cost of modifying respiratory protection practices to the 2019 ASTM standard adds another $1.2 million (1 percent) to the total.

FRIA Table 4-32. Summary of Annualized Compliance Costs (in thousands of 2022 dollars), by Detailed Components

Detailed Component	0 Percent	3 Percent	7 Percent
Exposure Monitoring			
First-time and second-time sampling	$2,836	$4,160	$6,316
Above-action-level sampling	$23,173	$23,516	$23,916
Corrective actions sampling	$14,733	$14,878	$15,022
Post-evaluation sampling	$7,105	$6,994	$6,805
Periodic evaluations	$3,750	$3,687	$3,580
Exposure Controls			
Engineering Control			
Capital expenditure [a]	$1,431	$1,492	$1,575
Increase Maintenance and Repair	$8,646	$8,506	$8,266
Administrative Control	$3,717	$3,657	$3,555
Respiratory Protection			
New Respirator Purchases	$256	$256	$255
Additional Respirator Use	$3,119	$3,062	$2,964
Medical Surveillance [b]	***$18,818***	***$18,836***	***$18,818***
Subtotal, Part 60 Costs	***$87,586***	***$89,045***	***$91,072***
ASTM Update			
Written Standard Operating Procedures	$27	$39	$61
Medical Evaluations	$126	$125	$122
Fit Testing	$126	$124	$122
Mine Operator Responsibilities	$52	$51	$50
Training the Respirator Trainer	$66	$97	$148
Training for the Mine Operator/Supervisor and the Person Issuing Respirators	$21	$31	$47
Recordkeeping	$422	$426	$431
Program Audit	$342	$339	$334
Subtotal, ASTM Update	***$1,181***	***$1,231***	***$1,315***
Total, All Mines	***$88,766***	***$90,277***	***$92,387***

Notes: [a] Includes annualized installation costs and O&M.

[b] Medical surveillance cost is the average cost under the assumed participation rate of 25 percent and 75 percent.

FRIA Table 4-33. Summary of Estimated Annualized Compliance Costs (in millions of 2022 dollars), by Rule Provision and Mine Sector

	0 Percent Discount Rate		3 Percent Discount Rate		7 Percent Discount Rate	
Mine Sector	**Annualized Cost**	**Percent Subtotal**	**Annualized Cost**	**Percent Subtotal**	**Annualized Cost**	**Percent Subtotal**

All Mines						
Exposure Monitoring	$51.60	58.1%	$53.24	59.0%	$55.64	60.2%
Exposure Controls	$13.79	15.5%	$13.66	15.1%	$13.40	14.5%
Respiratory Protection	$3.38	3.8%	$3.32	3.7%	$3.22	3.5%
Medical Surveillance [a]	$18.82	21.2%	$18.84	20.9%	$18.82	20.4%
Subtotal, Part 60 Costs	*$87.59*	*98.7%*	*$89.05*	*98.6%*	*$91.07*	*98.6%*
ASTM 2019	$1.18	1.3%	$1.23	1.4%	$1.32	1.4%
Total, All Mines	***$88.77***	***100.0%***	***$90.28***	***100.0%***	***$92.39***	***100.0%***
As Percent of All Mines	***100.0%***		***100.0%***		***100.0%***	
Metal/Nonmetal						
Exposure Monitoring	$46.13	57.1%	$47.61	58.0%	$49.74	59.3%
Exposure Controls	$11.86	14.7%	$11.71	14.3%	$11.42	13.6%
Respiratory Protection	$3.31	4.1%	$3.26	4.0%	$3.16	3.8%
Medical Surveillance [a]	$18.82	23.3%	$18.84	23.0%	$18.82	22.4%
Subtotal, Part 60 Costs	*$80.12*	*99.2%*	*$81.41*	*99.2%*	*$83.14*	*99.2%*
ASTM 2019	$0.63	0.8%	$0.65	0.8%	$0.69	0.8%
Total, All Mines	***$80.75***	***100.0%***	***$82.06***	***100.0%***	***$83.84***	***100.0%***
As Percent of All Mines	***91.0%***		***90.9%***		***90.7%***	
Coal						
Exposure Monitoring	$5.47	68.2%	$5.63	68.5%	$5.89	68.9%
Exposure Controls	$1.93	24.1%	$1.95	23.7%	$1.97	23.1%
Respiratory Protection	$0.06	0.8%	$0.06	0.7%	$0.06	0.7%
Medical Surveillance [b]	--	--	--	--	--	--
Subtotal, Part 60 Costs	*$7.46*	*93.1%*	*$7.64*	*93.0%*	*$7.93*	*92.7%*
ASTM 2019	$0.55	6.9%	$0.58	7.0%	$0.62	7.3%
Total, All Mines	***$8.02***	***100.0%***	***$8.22***	***100.0%***	***$8.55***	***100.0%***
As Percent of All Mines	***9.0%***		***9.1%***		***9.3%***	

Notes: [a] Medical surveillance cost is presented as the average of the assumed participation rates of 25 percent and 75 percent.
[b] No Medical Surveillance costs assigned to Coal because that sector is already required to have equivalent medical surveillance program.

5 NET BENEFITS

5.1 Overview of Net Benefits

The net benefits of the final rule are the differences between the estimated benefits and the estimated costs. FRIA Table 5-1 shows estimated net benefits using alternative discount rates of 0, 3, and 7 percent for costs. While the net benefits of the final rule vary depending on the choice of discount rate, total benefits exceed total costs under each discount rate considered. MSHA's estimate of the net annualized benefits of the final rule, using a uniform discount rate for both costs and benefits of 3 percent, is $156.6 million a year with the largest share ($143.9 million; 92.0 percent) attributable to the MNM sector.

FRIA Table 5-1. Annualized Costs, Benefits, and Net Benefits of MSHA's New Respirable Crystalline Silica Rule (in millions of 2022 dollars)

Impact Category	MNM			Coal			Total		
	0%	3%	7%	0%	3%	7%	0%	3%	7%
Benefits									
Avoided Mortality	$230.4	$141.6	$68.9	$20.5	$12.7	$6.4	$250.9	$154.3	$75.3
Avoided Morbidity Preceding Mortality	$27.1	$18.2	$10.0	$2.4	$1.6	$0.9	$29.5	$19.8	$11.0
Avoided Morbidity Not Preceding Mortality	$93.1	$66.3	$41.5	$9.0	$6.5	$4.2	$102.1	$72.8	$45.7
Total	***$350.7***	***$226.0***	***$120.4***	***$31.9***	***$20.9***	***$11.5***	***$382.6***	***$246.9***	***$131.9***
Costs									
Exposure Monitoring	$46.1	$47.6	$49.7	$5.5	$5.6	$5.9	$51.6	$53.2	$55.6
Exposure Controls	$11.9	$11.7	$11.4	$1.9	$1.9	$2.0	$13.8	$13.7	$13.4
Respiratory Protection	$3.3	$3.3	$3.2	$0.1	$0.1	$0.1	$3.4	$3.3	$3.2
Medical Surveillance	$18.8	$18.8	$18.8	--	--	--	$18.8	$18.8	$18.8
ASTM Update	$0.6	$0.7	$0.7	$0.6	$0.6	$0.6	$1.2	$1.2	$1.3
Total	***$80.7***	***$82.1***	***$83.8***	***$8.0***	***$8.2***	***$8.5***	***$88.8***	***$90.3***	***$92.4***
Net Benefits	***$270.0***	***$143.9***	***$36.6***	***$23.9***	***$12.7***	***$3.0***	***$293.8***	***$156.6***	***$39.5***

Note: Medical surveillance cost is the average cost under the assumed participation rates of 25 percent and 75 percent.

[a] For the purpose of simplifying the estimation of the monetized benefits of avoided illness and death, MSHA simply added the monetized benefits of avoided morbidity preceding mortality to the monetized benefits of mortality at the time of death, and both would be discounted at that point. In theory, however, the monetized benefits of avoided morbidity should be recognized (and discounted) at the onset of morbidity, as this is what a worker's willingness to pay is presumed to measure—that is, the risk of immediate death or an immediate period of illness that a worker is willing to pay to avoid—a practice that would increase the present value of discounted benefits from avoided morbidity. A parallel tendency toward underestimation occurs with regard to avoided morbidity not preceding mortality, since it implicitly assumes that the benefits occur at retirement, as per the Buchanan model, but many, if not most, of the 2/1+ or higher silicosis cases will have begun years before (with those classifications, in turn, preceded by a 1/0 classification). As a practical matter, however, the Agency lacks sufficient data at this time to refine the analysis in this way.

5.2 Miner Tenure Analysis

The preceding analyses assume a constant exposure level each year for 45 working years (aged 21 through 65). In this section, MSHA examines what would happen if the day-to-day exposure remains the same, but job tenure is shorter. Three alternative miner tenure scenarios are modeled, including tenures of 35 working years (miners aged 26 through 60), 25 working years (miners aged 31 through 55), and 15 working years (miners aged 36 through 50). The age ranges for each tenure scenario were selected to maintain the same average miner age of 43, consistent with average age reported by the Bureau of Labor Statistics.[64]

As in the main analysis, cumulative exposures are 0 prior to entry into the mining workforce and are maintained at a constant level after exiting the mining workforce. The survival rate always equals 1.00 at the start of the first year of mining since 100 percent of the new miner cohort is alive when they enter the workforce.

In each tenure scenario, MSHA calculated the avoided cases over the same 60-year analysis period and assumed the total mining workforce is constant in size. In the alternative worker tenure scenarios, the working cohorts are larger because there are fewer of them working in any given year. For example, when assuming a tenure of 15 working years, there are 15 distinct miner cohorts (aged 36 through 50) working at any given time. Given the constant total working miner population of 257,383 (MNM and coal combined), each of the 15 age cohorts has an initial size of approximately 17,159 miners (257,383/15). Comparatively, when assuming a tenure of 45 working years, each new mining cohort contains approximately 5,720 miners (257,383/45). Miners with shorter job tenures also have a higher turnover rate, leading to an increase in the population of surviving retired miners. Thus, for shorter tenure scenarios, miners experience less total cumulative exposure over their working life, but a greater number of individual miners are exposed during the 60-year analysis period. For example, a 45-year tenure leads to 229,467 working and retired miners alive at any given point in time.

[64] Bureau of Labor Statistics reported employment by industry and age in 2022 from the Current Population Survey, available at https://www.bls.gov/cps/cpsaat18b.htm. Assuming miners are at the middle age of each group, the average age was 43.1 years for coal miners, 43.6 years for metal miners, and 44.3 years for nonmetallic mineral mining and quarrying miners.

Comparatively, a 15-year tenure leads to 660,911 working and retired miners alive at any given point in time, which is almost three times the miners analyzed under a 45-year tenure.

FRIA Table 5-2 presents MSHA's estimates of the total avoided morbidity and mortality in each tenure scenario. In general, decreasing the miner tenure leads to fewer avoided cases of silicosis and more avoided deaths.

FRIA Table 5-2. Reduction in Excess Cases Over 60 Years Among Coal Miners due to Adopting the New Standard, by Worker Tenure Scenario

Scenario	Metric	Cases Avoided		
		MNM	Coal	Total
45 Years (21-65)	Avoided Mortality	487	44	531
	Avoided Silicosis Morbidity (total)	1,796	173	1,969
	Avoided Silicosis Morbidity (net of silicosis deaths)	1,673	162	1,836
35 Years (26-60)	Avoided Mortality	535	48	583
	Avoided Silicosis Morbidity (total)	1,214	116	1,330
	Avoided Silicosis Morbidity (net of silicosis deaths)	1,034	96	1,130
25 Years (31-55)	Avoided Mortality	586	52	639
	Avoided Silicosis Morbidity (total)	785	74	859
	Avoided Silicosis Morbidity (net of silicosis deaths)	671	62	733
15 Years (36-50)	Avoided Mortality	668	59	728
	Avoided Silicosis Morbidity (total)	498	46	543
	Avoided Silicosis Morbidity (net of silicosis deaths)	400	34	434

FRIA Table 5-3 shows the benefits and net benefits under each of the tenure scenarios. In all cases, net benefits are positive and generally fairly similar. At a 3 percent discount rate, the net benefits are between $144 million and $160 million in all four tenure scenarios.

FRIA Table 5-3. Net Benefits for Each Miner Tenure Scenario (in millions of 2022 dollars)

Scenario	Metric	Total Benefits		
		0%	3%	7%
45 Years (21-65)	Benefits from Avoided Mortality	$251	$154	$75
	Benefits from Avoided Morbidity (Preceding Mortality)	$30	$20	$11
	Benefits from Avoided Morbidity (Not Preceding Mortality)	$102	$73	$46
	Total Benefits	***$383***	***$247***	***$132***
	Total Net Benefits	***$294***	***$157***	***$40***
35 Years (26-60)	Benefits from Avoided Mortality	$277	$169	$81
	Benefits from Avoided Morbidity (Preceding Mortality)	$32	$21	$12
	Benefits from Avoided Morbidity (Not Preceding Mortality)	$63	$44	$28
	Total Benefits	***$372***	***$235***	***$120***
	Total Net Benefits	***$284***	***$144***	***$28***
	Benefits from Avoided Mortality	$306	$183	$84

25 Years (31-55)	Benefits from Avoided Morbidity (Preceding Mortality)	$36	$23	$12
	Benefits from Avoided Morbidity (Not Preceding Mortality)	$41	$29	$18
	Total Benefits	***$382***	***$235***	***$114***
	Total Net Benefits	***$293***	***$145***	***$21***
15 Years (36-50)	Benefits from Avoided Mortality	$351	$207	$91
	Benefits from Avoided Morbidity (Preceding Mortality)	$40	$26	$12
	Benefits from Avoided Morbidity (Not Preceding Mortality)	$24	$18	$11
	Total Benefits	***$415***	***$250***	***$115***
	Total Net Benefits	***$327***	***$160***	***$22***

When shortening the miner tenure, more lives are saved by the new PEL over the 60-year analysis period. A shorter miner tenure leads to higher turnover, which increases the number of exposed people during the 60-year analysis period. But while the number of people at risk increases proportionally, the number of person-years of elevated risk increases disproportionately. For example, a single miner with 45 years of tenure who starts working at the age of 21 and dies at the end of age 80 would have 60 person-years of elevated risk during the 60-year analysis period. Using a 15-year tenure assumption, this one miner is replaced by three consecutive miners (A, B, and C) who work from age 36-50 and then die at a maximum age of 80 (45 years after entering the mining industry). Over the 60-year analysis period, the first miner (A) would work from Year 1 through 15 of the analysis period and would have elevated risk from Year 1 through 45. The second miner (B) would work from Year 16 through 30 and would have elevated risk from Year 16 through 60. The third miner would work from Year 31 through 45 and have elevated risk from Year 31 through Year 60 of the 60-year analysis period. Summing across the three miners A, B, and C yields 45+45+30 = 120 person-years of elevated risk for every 60 person-years of elevated risk in the original 45-year tenure scenario. Thus, shorter miner tenures lead to an increase in person-years of elevated risk, which can increase the impact and benefits of the new PEL in terms of reduced excess risk.

For silicosis morbidity, however, shorter miner tenure leads to fewer avoided cases. This is because the exposure-response model is not linear. When assuming a 15-year tenure, miners' cumulative exposures are lower on the exposure-response curve at a location where further decreases in exposure (due to the new PEL) confer less benefit in terms of lifetime excess risk. For a group of MNM miners working full-time for 45 years with constant exposure of 100 μg/m^3 or 0.100 mg/m^3, the new PEL would reduce their cumulative exposure from 4.5 mg/m^3-yr (0.100 mg/m^3×45 yr) to 2.25 mg/m^3-yr (0.050 mg/m^3×45 yr). Using the Buchanan *et al*. (2003) model for silicosis morbidity, the lifetime excess risk Δr would decrease by 0.034 or roughly 34 avoided cases per 1,000 miners:

$$\Delta r = \frac{1}{1 + e^{4.83-0.443\times(0.1\times45)}} - \frac{1}{1 + e^{4.83-0.443\times(0.05\times45)}} = 0.0554 - 0.0212 = 0.0342$$

In contrast, when assuming a 15-year tenure, the new PEL decreases these miners' cumulative exposure from 1.5 mg/m^3-yr (0.100 mg/m^3×15 yr) to 0.75 mg/m^3-yr (0.050

mg/m^3×15 yr). This produces substantially less reduction in risk—only 4 avoided cases per 1,000 miners—because the exposure-response function is non-linear:

$$\Delta r = \frac{1}{1\ +\ e^{4.83-0.443\times(0.1\times15)}} - \frac{1}{1\ +\ e^{4.83-0.443\times(0.05\times15)}} = 0.0153 - 0.0110 = 0.0043$$

In this example, changing from a 45-year miner tenure to a 15-year miner tenure causes the reduction in lifetime excess risk attributable to the new PEL to decrease by a factor of 8 (0.0342/0.0043). This decrease in the lifetime excess risk reduction is accompanied by only a three-fold increase in the exposed population, since new cohorts would enter every 15 years instead of every 45 years. Thus, the reduction in worker tenure produces two opposing effects in the specific case of silicosis morbidity due to the non-linear Buchanan *et al.* model (2003). The decrease in risk reduction due to lower exposures dominates over the increase in the effective exposed population, and the net effect is that the new PEL avoids fewer cases of silicosis morbidity when assuming shorter work tenures.

The decrease in silicosis morbidity may be explained by research which has found that cases of chronic silicosis typically follow at least 10 years of low intensity exposure to respirable crystalline silica (Becklake, 1994; Balaan and Banks, 1998; NIOSH, 2002b; Kambouchner and Bernaudin, 2015; Cowie and Becklake, 2016; Rosental, 2017; Barnes *et al.*, 2019; Hoy and Chambers, 2020). Limiting the tenure to only 15 years may lead to fewer cases of chronic silicosis that would have progressed far enough to be detected on a chest x-ray and counted in the Buchanan *et al.* study (2003), making it more difficult to measure the benefits of the new PEL. This may partially explain the reduction in silicosis morbidity when using shorter miner tenure assumptions. Hence, to the extent that miners spend fewer than the assumed 45 years in the industry, the analysis may underestimate the true avoided mortalities and may overestimate the true avoided morbidities due to the final rule over a 60-year period following compliance with the rule.

6 ECONOMIC FEASIBILITY

MSHA considers economic feasibility in terms of industry-wide revenue and overall costs incurred by the mining industry (inclusive of MNM and coal) under a given rule. To establish economic feasibility, MSHA uses a revenue screening test—whether the estimated yearly costs of a rule are less than 1 percent of estimated revenues, or are negative (i.e., provide net cost savings)—to presumptively establish that compliance with the regulation is economically feasible for the mining industry. If annualized compliance costs comprise less than 1 percent of revenue, MSHA presumes that the affected entities can incur the compliance costs without significant economic impacts.[65]

For the MNM and coal mining sectors, MSHA estimates the projected impacts of the rule by calculating the annualized compliance costs for each sector as a percentage of total estimated revenues for the said sector. To be consistent with costs that are calculated in 2022 dollars, MSHA first inflated estimated mine revenues expressed in 2019 to their 2022 equivalent using the GDP implicit price deflator (FRIA Table 6-1).

FRIA Table 6-1. Total Mines, Estimated Revenues (in millions of 2022 dollars) and Employment by Sector

Mine Sector	2019 Number of Mines	2019 Revenues Inflated to 2022 Dollars	2019 Number of Miners Including Contract Miners [a]
Total	***12,631***	***$124,169***	***284,779***
Metal/Nonmetal	11,525	$95,070	211,203
Coal	1,106	$29,099	73,576

Note: [a] The estimated current and future number of mines and miners are based on 2019 data (MSHA, 2019a; MSHA, 2019b; MSHA, 2022d) and are assumed to have remained constant through the 60 years following the start of implementation of the rule.

FRIA Table 6-2 compares aggregate annualized compliance costs for the MNM and coal sectors at a 0 percent, 3 percent, and 7 percent discount rates to each sector's total annual revenues. At a 3 percent discount rate, total aggregate annualized compliance costs for the entire mining industry are projected to be $90.3 million (including both 30 CFR Part 60 and 2019 ASTM costs), while aggregate revenues are estimated to be $124.2 billion in 2022 dollars. Thus, the mining industry is expected to incur compliance costs that comprise 0.07 percent of total revenues.

For the MNM sector, MSHA estimates that the annualized costs of the final rule (including both 30 CFR Part 60 and 2019 ASTM costs) will be $82.1 million at a 3 percent discount rate, which is approximately 0.09 percent of the total estimated annual revenue of $95.1 billion for MNM mine operators. For the coal sector, MSHA estimates that the annualized

[65] MSHA is not required to produce hard and precise estimates of cost to establish economic feasibility. Rather, the Agency must provide a reasonable assessment of the likely range of costs of its standard and the likely effects of those costs on the industry, and it must demonstrate a reasonable likelihood that these costs will not threaten the existence or competitive structure of an industry. *See United Steelworkers of America v. Marshall*, 647 F.2d 1189, 1266, 1272 (D.C. Cir. 1980); *see also Nat'l Min. Ass'n v. Sec'y, U.S. Dep't of Lab.*, 812 F.3d 843, 881 (11th Cir. 2016).

costs of the final rule (including both 30 CFR Part 60 and 2019 ASTM update costs) will be $8.2 million at a 3 percent discount rate, which is approximately 0.03 percent of the total estimated annual revenue of $29.1 billion for coal mine operators.

As shown in FRIA Table 6-2, the ratios of the screening analysis are well below the 1.0 percent of total revenues threshold, and therefore, MSHA concludes that the requirements of the final rule are economically feasible, and no sector will likely incur a significant cost.

FRIA Table 6-2. Estimated Annualized Compliance Costs as Percent of Mine Revenues (in millions of 2022 dollars), by Sector

Mine Sector	2019 Revenues Inflated to 2022 Dollars	Annualized Costs 0 Percent Discount Rate		Annualized Costs 3 Percent Discount Rate		Annualized Costs 7 Percent Discount Rate	
		Compliance Costs	Cost as % of Revenues	Compliance Costs	Cost as % of Revenues	Compliance Costs	Cost as % of Revenues
30 CFR Part 60 Costs							
Total	***$124,169***	***$87.59***	***0.07%***	***$89.05***	***0.07%***	***$91.07***	***0.07%***
Metal/ Nonmetal	$95,070	$80.12	0.08%	$81.41	0.09%	$83.14	0.09%
Coal	$29,099	$7.46	0.03%	$7.64	0.03%	$7.93	0.03%
30 CFR Part 60 + 2019 ASTM Upgrade Costs							
Total	***$124,169***	***$88.77***	***0.07%***	***$90.28***	***0.07%***	***$92.39***	***0.07%***
Metal/ Nonmetal	$95,070	$80.75	0.08%	$82.06	0.09%	$83.84	0.09%
Coal	$29,099	$8.02	0.03%	$8.22	0.03%	$8.55	0.03%

7 REGULATORY ALTERNATIVES

The final rule presents a comprehensive approach for lowering miners' exposure to respirable crystalline silica. The rule includes the following exposure monitoring provisions: lowering miners' respirable crystalline silica exposure to a PEL of 50 μg/m^3 for a full-shift exposure, calculated as an 8-hour TWA; initial first-time and second-time sampling for miners who are reasonably expected to be exposed to respirable crystalline silica; quarterly above-action-level sampling for miners who are exposed at or above the action level of 25 μg/m^3 but at or below the new PEL of 50 μg/m^3; and periodic evaluations of changing mining processes that would reasonably be expected to result in new or increased exposures to respirable crystalline silica.

In developing the final rule, MSHA considered three regulatory alternatives. The first two alternatives contain less stringent exposure monitoring provisions than the final rule, which comparatively present a comprehensive approach for lowering miners' exposure to respirable crystalline silica and improving respiratory protection for all airborne contaminants. The first alternative includes no change to the final rule's PEL and action level, whereas the second alternative includes a more stringent PEL. The second alternative combines less stringent exposure monitoring with a more stringent PEL. The third alternative examines a different methodology for calculating miners' exposures and assessing the implications of using the full-shift TWA instead of full-shift, 8-hour TWA specified in the rule. MSHA discusses the regulatory options in the sections below.

7.1 Regulatory Alternative 1: Changes in Sampling and Evaluation Requirements

Under this alternative, the new PEL would remain unchanged at 50 μg/m^3 and the action level would remain unchanged at 25 μg/m^3. Further, mine operators would conduct exposure monitoring at a lower frequency: (1) first-time and second-time sampling for miners who may be exposed to respirable crystalline silica at or above the action level of 25 μg/m^3, (2) above-action-level sampling twice per year for miners who are at or above the action level of 25 μg/m^3 but at or below the PEL of 50 μg/m^3, and (3) annual periodic evaluation of changing mining processes or conditions that would reasonably be expected to result in new or increased exposures.

Mine operators would still be required to conduct sampling under this Regulatory Alternative and would thus incur compliance costs. However, exposure monitoring requirements under this alternative are less stringent than the exposure monitoring requirements under the final rule because under this alternative the numbers of above-action-level sampling and periodic evaluations are set at half the frequency of their respective counterparts in the final rule. Therefore, the cost of compliance would be lower under this alternative. MSHA estimates that annualized exposure monitoring costs would total $29.3 million for this alternative (at a 3 percent discount rate), compared to $53.2 million for the new monitoring requirements, resulting in an estimated difference of $24.0 million in compliance costs per year (FRIA Table 7-1).

FRIA Table 7-1. Summary of Part 60 Annualized Compliance Costs (in millions of 2022 dollars), Regulatory Alternative 1 and New Requirements: All Mines

	0 Percent Discount Rate		3 Percent Discount Rate		7 Percent Discount Rate	
Mine Sector	**Annualized Cost**	**Percent of New Requirements**	**Annualized Cost**	**Percent of New Requirements**	**Annualized Cost**	**Percent of New Requirements**
Regulatory Alternative 1: Changes in Sampling and Evaluation Requirements						
Exposure Monitoring	$27.79		$29.27		$31.56	
Exposure Controls	$13.79		$13.66		$13.40	
Respiratory Protection	$3.38		$3.32		$3.22	
Medical Surveillance	$18.82		$18.84		$18.82	
Total, Part 60 Costs	***$63.77***	***72.8%***	***$65.08***	***73.1%***	***$66.99***	***73.6%***
New Requirements						
Exposure Monitoring	$51.60		$53.24		$55.64	
Exposure Controls	$13.79		$13.66		$13.40	
Respiratory Protection	$3.38		$3.32		$3.22	
Medical Surveillance	$18.82		$18.84		$18.82	
Total, Part 60 Costs	***$87.59***	***100.0%***	***$89.05***	***100.0%***	***$91.07***	***100.0%***

Although this alternative does not completely eliminate exposure monitoring, the requirements are minimal relative to the exposure monitoring requirements under the final rule. However, MSHA believes it is necessary for mine operators to sample any miner – or a representative sample of miners - who may be reasonably expected to be exposed to respirable crystalline silica. In addition, more frequent sampling helps mine operators correlate mine conditions to miner exposure levels and see exposure trends more rapidly than would result from semi-annual or annual sampling. This enables mine operators to take necessary measures to ensure continued compliance with the new PEL. Further, more frequent monitoring enables mine operators to ensure the adequacy of controls at their mines and better protect miners' health. These benefits cannot be quantified, but they are nevertheless material benefits that increase the likelihood of compliance with the new PEL under the final rule.

MSHA also believes that requiring more frequent above-action-level sampling will provide mine operators with greater confidence that they are in compliance with the new PEL. Because of the variable nature of miner exposures to airborne concentrations of respirable crystalline silica, maintaining exposures below the action level provides mine operators with reasonable assurance that miners will not be exposed to respirable crystalline silica at levels above the PEL on days when sampling is not conducted. MSHA believes that these benefits of the new sampling requirements justify the additional costs relative to Regulatory Alternative 1 and therefore, MSHA did not select Regulatory Alternative 1.

7.2 Regulatory Alternative 2: Changes in Sampling and Evaluation Requirements and the PEL

Under this Regulatory Alternative, the new PEL would be set at 25 μg/m^3, mine operators would install whatever controls are necessary to meet this PEL, and no action level would be designated.

Further, under this Regulatory Alternative, mine operators would not be required to undertake first-time or second-time sampling, above-action-level sampling, or corrective actions sampling. However, mine operators would be required to perform periodic evaluations of changing mining processes or conditions and to sample as frequently as necessary to determine the adequacy of controls. Further, mine operators would be required to perform post-evaluation sampling when the operators determine as a result of a periodic evaluation that miners may be exposed to respirable crystalline silica at or above PEL of 25 μg/m^3. When estimating the cost of exposure monitoring requirements in the cost section, MSHA assumed that the number of samples for post-evaluation sampling are relatively small (2.5 percent of miners) because samples from sampling to determine the adequacy of controls and from MSHA can both be used to meet the requirements. Since Regulatory Alternative 2 does not require above-action-level sampling given the lack of an action level under this alternative, MSHA increases the share of samples after each evaluation to 10 percent of miners to ensure the monitoring requirements can be met.

In addition, to meet the PEL of 25 μg/m^3, mine operators would incur greater engineering control costs as compared to the estimated cost of compliance for reaching a PEL of 50 μg/m^3. To estimate these additional engineering control costs, MSHA largely uses the same methodology as for mines affected at the new PEL of 50 μg/m^3.

7.2.1 Number of Mines Affected Under Regulatory Alternative 2

MSHA first estimated the number of mines expected to incur the cost of implementing engineering controls to reach the more stringent PEL. After excluding mines that are affected at the new PEL of 50 μg/m^3 (to avoid double-counting), MSHA finds that 3,477 mines (2,991 MNM mines and 486 coal mines) operating in 2019 had at least one sample at or above 25 μg/m^3 but below 50 μg/m^3.[66]

In addition, MSHA also includes the 1,226 affected mines expected to incur costs to reach the new PEL of 50 μg/m^{3}as reported in FRIA Table 4-8. Based on its experience and knowledge, MSHA does not expect the mines that install engineering controls to meet the PEL of 50 μg/m^3 would also be able to comply with a PEL of 25 μg/m^3. For example, to comply with the new PEL of 50 μg/m^3, a mine might need to add the engineering controls necessary to achieve an additional 10 air changes per hour over that achieved by existing controls, which are costed in Section 7.2.2. However, such a mine facility would then need to add an additional 10

[66] About 8,053 of mines active in 2019 either did not have a sample > 25 μg/m^3 or did not have a sample in the last 5 years.

air changes per hour to meet the more stringent PEL of 25 μg/m^3, which is not costed in Section 7.2.2. Thus, MSHA expects that the 1,226 affected mines would incur additional costs to meet the PEL of 25 μg/m^3 specified under this alternative.

Thus, MSHA estimates a total of 4,703 mines (3,477 + 1,226) would incur costs to purchase, install, and operate engineering controls to meet the more stringent PEL of 25 μg/m^3 under this alternative. MNM accounts for 4,087 mines (87 percent) and coal accounts for the remaining 616 mines (13 percent).

7.2.2 Estimated Engineering Control Costs Under Regulatory Alternative 2

MSHA identified potential engineering controls that would enable mines with respirable crystalline silica dust exposures at or above 25 μg/m^3 but below 50 μg/m^3 categories to meet the PEL of 25 μg/m^3 for this Regulatory Alternative. While MSHA assumed that mine operators will base such decisions on site-specific conditions such as mine layout and existing infrastructure, MSHA cannot make further assumptions about the specific controls that might be adopted and instead assumed the expected value of purchased technologies should equal the simple average of the technologies listed in each control category.

As described in section 4.2.2, where more precise information is unavailable, MSHA assumed operating and maintenance (O&M) costs to be 35 percent of initial capital expenditure and any installation cost to be equal to any initial capital expenditure (FRIA Table 7-2). MSHA also assumed the larger capital expenditure controls will have a 30-year service life.

FRIA Table 7-2. Selected Engineering Controls to Decrease Respirable Crystalline Silica Dust Exposure by Capital Expenditure Cost Range Under Regulatory Alternative 2 (in 2022 dollars)

Engineering Control	Capital Cost	Installation Cost [a]	O&M Cost [b]	Expected Service Life
Minimal capital expenditure				
Stone saw enclosure	$0	$0	$1,468	1
Larger capital expenditure				
Increase facility ventilation from 20 to 30 air changes per hour	$167,263	$167,263	$9,751	30
Full length of conveyor enclosed and ventilated	$960,883	$960,883	$55,386	30
Crusher/grinder: appropriate size ventilation for air flow	$197,928	$197,928	$11,409	30
Plumbing for hose installations, floor re-sloping and troughs	$45,892	$45,892	$4,209	30
Average	***$274,393***	***$274,393***	***$16,445***	***24.2***

Notes: [a] Unless otherwise specified, MSHA assumed installation costs are equal to capital cost.
[b] Unless otherwise specified, MSHA assumed annual O&M costs are equal to 35 percent of capital cost.

However, the difficulty of meeting a PEL of 25 μg/m^3 is such that MSHA's experience suggests a single control from FRIA Table 7-2 would not be sufficient for a mine to achieve compliance. For example, respirable crystalline silica dust exposure at such a stringent level is likely to occur in more than one area of the mine. For instance, in addition to increasing ventilation to a crusher/grinder, enclosing and ventilating the mine conveyor belt would likely be necessary to reduce concentrations below this PEL. Similarly, increasing facility ventilation from 20 to 30 air changes per hour may not be adequate to meet the limit. Rather, 40 air changes per hour might be necessary. Therefore, MSHA assumed mine operators will purchase and install at least two of the engineering controls listed in FRIA Table 7-2 under this Regulatory Alternative. This assumption was made to err on the side of overestimation.

FRIA Table 7-3 presents the annualized engineering control costs per mine and total annualized engineering control costs by mining sector. At a 3 percent discount rate, the annualized engineering control costs are about $98,124 per mine, resulting in an additional cost of $461.5 million if the PEL is set at 25 µg/m^3 instead of 50 µg/m^3.

FRIA Table 7-3. Estimated Annualized Costs as a Simple Average per Mine and Total Engineering Controls per Mine Under Regulatory Alternative 2 (in 2022 dollars), by Sector

Sector	Annualized Cost of Engineering Controls at Specified Discount Rate		
	0 Percent	**3 Percent**	**7 Percent**
Annualized Engineering Control Costs per Mine by Mine Sector, Over All Controls			
Total	***$78,145***	***$98,124***	***$128,441***
MNM	$78,073	$97,714	$127,269
Coal	$78,621	$100,847	$136,218
Total Annualized Engineering Control Costs by Mine Sector (millions) [a]			
Total	***$367.5***	***$461.5***	***$604.1***
MNM	$319.1	$399.4	$520.1
Coal	$48.4	$62.1	$83.9

Note: [a] Based on an estimated 4,087 MNM and 616 Coal mines, for 4,703 total affected mines.

FRIA Table 7-4 summarizes the estimated annualized cost of this Regulatory Alternative. At a 3 percent discount rate, exposure monitoring costs less than it does for the final rule. However, this lower sampling cost is more than offset by the increased control costs necessitated by the requirement that mines maintain respirable crystalline silica exposure levels below 25 µg/m^3. At an estimated annualized cost of $520.7 million, this alternative would cost nearly six times more than the final rule requirements.

FRIA Table 7-4. Summary of Part 60 Annualized Compliance Costs (in millions of 2022 dollars) Under Regulatory Alternative 2 and New Requirements: All Mines

Mine Sector	0 Percent Discount Rate		3 Percent Discount Rate		7 Percent Discount Rate	
	Annualized Cost	Percent of New Require-ments	Annualized Cost	Percent of New Require-ments	Annualized Cost	Percent of New Require-ments
Regulatory Alternative 2: Changes in PEL Sampling and Evaluation Requirements						
Exposure Monitoring	$32.17		$31.67		$30.80	
Exposure Controls	$367.52		$461.48		$604.06	
Respiratory Protection	$8.90		$8.75		$8.50	
Medical Surveillance	$18.82		$18.84		$18.82	
Total, Part 60 Costs	***$427.41***	***488.0%***	***$520.73***	***584.8%***	***$662.17***	***727.1%***
New Requirements						
Exposure Monitoring	$51.60		$53.24		$55.6	
Exposure Controls	$13.79		$13.66		$13.40	
Respiratory Protection	$3.38		$3.32		$3.22	
Medical Surveillance	$18.82		$18.84		$18.82	
Total, Part 60 Costs	***$87.59***	***100.0%***	***$89.05***	***100.0%***	***$91.07***	***100.0%***

On the other hand, Regulatory Alternative 2 increases miner protection by establishing the PEL at 25 μg/m^3, resulting in measurable increases in avoided mortality and other health benefits as compared to the final rule. FRIA Table 7-5 presents the avoided morbidity and mortality cases over the 60-year regulatory analysis time horizon under this alternative. Under this alternative, 1,271 mortality cases are expected to be avoided, which is 2.4 times higher than 531 mortality cases expected to be avoided under the "New PEL 50" scenario. Additionally, 2,521 morbidity cases are expected to be avoided under this alternative, which is 1.4 times higher than the 1,836 morbidity cases expected to be avoided under "New PEL 50" scenario.

FRIA Table 7-5. Estimated Cases of Avoided Mortality and Morbidity over 60 Years (Regulatory Analysis Time Horizon) Following the Start of Implementation of the Rule Under Regulatory Alternative 2

Health Outcome	Total Avoided Cases During 60 Years Following the Start of Implementation of the Rule [a]		
	MNM	Coal	Total
Morbidity			
Silicosis	2,239	282	2,521
Morbidity Total (Net of Silicosis Deaths)	**2,239**	**282**	**2,521**
Mortality			
NMRD (net of silicosis mortality)	527	77	605
Silicosis	267	34	301
ESRD	249	36	286
Lung Cancer [b]	70	10	80
Mortality Total	**1,114**	**158**	**1,271**

Notes: [a] Avoided cases include both production and contract miners. Calculations show the difference between excess cases when assuming compliance with the existing limits versus assuming compliance with the new PEL of 50 μg/m^3. Estimates account for the fact that some miners during the 60-year period will have worked under the existing standards (and thus may have combination of exposures under the existing standards and the new PEL), while other new entrants into the mining workforce would be solely exposed under the new PEL.
[b] A 15-year lag between exposure and observed health effect was assumed for lung cancer estimates.

FRIA Table 7-6 presents the benefits associated with this avoided morbidity and mortality. The expected total benefits, discounted at 3 percent, are $516.3 million, which is more than twice the expected total benefits of $246.9 million under the "New PEL 50" scenario. Under this Regulatory Alternative, these benefits are made up of $369.0 million due to avoided mortality, $47.3 million due to avoided morbidity preceding mortality, and $100.0 million due to avoided morbidity not preceding mortality. However, when compared to the annualized costs of $520.7 million (3 percent) and $662.2 million (7 percent), the net benefits of this alternative are negative at a 3 percent and 7 percent discount rate.

Although the benefits associated with this avoided morbidity and mortality under Regulatory Alternative 2 are greater than those for the final rule, the net benefits of this alternative are negative at both a 3 percent and 7 percent real discount rate owing to the much higher compliance costs for this alternative as compared to those for the final rule. Further, MSHA determines that meeting a PEL of 25 μg/m^3 is not achievable for all mines. Thus, MSHA did not select Regulatory Alternative 2.

FRIA Table 7-6. Annualized Monetized Benefits over 60 Years (Regulatory Analysis Time Horizon) Following the Start of Implementation of the Rule (in millions of 2022 dollars) Under Regulatory Alternative 2, by Health Outcome and Discount Rate

Health Outcome	MNM			Coal			Total		
	0%	3%	7%	0%	3%	7%	0%	3%	7%
Avoided Morbidity (Not Preceding Mortality)									
Silicosis (Excluding Silicosis Deaths)	$124.6	$88.7	$55.5	$15.7	$11.3	$7.2	$140.3	$100.0	$62.7
Avoided Morbidity (Not Preceding Mortality) Total	**$124.6**	**$88.7**	**$55.5**	**$15.7**	**$11.3**	**$7.2**	**$140.3**	**$100.0**	**$62.7**
Avoided Mortality									
NMRD (Excluding Silicosis Deaths)	$252.9	$151.2	$69.0	$36.9	$22.2	$10.3	$289.8	$173.3	$79.3
Silicosis	$121.5	$80.1	$44.8	$15.2	$10.4	$6.1	$136.7	$90.5	$50.9
ESRD	$118.8	$72.0	$34.5	$17.2	$10.6	$5.3	$136.0	$82.6	$39.7
Lung Cancer	$34.5	$19.8	$8.1	$4.8	$2.8	$1.2	$39.3	$22.5	$9.3
Avoided Mortality Total	**$527.7**	**$323.1**	**$156.4**	**$74.1**	**$46.0**	**$22.8**	**$601.8**	**$369.0**	**$179.2**
Avoided Morbidity (Preceding Mortality)									
NMRD (Excluding Silicosis Deaths)	$29.3	$18.9	$9.6	$4.3	$2.8	$1.5	$33.6	$21.7	$11.1
Silicosis	$14.8	$10.9	$7.0	$1.9	$1.4	$1.0	$16.7	$12.3	$8.0
ESRD	$13.9	$9.2	$5.0	$2.0	$1.4	$0.8	$15.9	$10.5	$5.8
Lung Cancer	$3.9	$2.4	$1.1	$0.5	$0.3	$0.2	$4.5	$2.7	$1.2

Health Outcome	MNM			Coal			Total		
	0%	3%	7%	0%	3%	7%	0%	3%	7%
Avoided Morbidity (Preceding Mortality) Total	**$62.0**	**$41.3**	**$22.7**	**$8.8**	**$5.9**	**$3.4**	**$70.7**	**$47.3**	**$26.1**
Grand Total	**$714.2**	**$453.1**	**$234.7**	**$98.6**	**$63.2**	**$33.4**	**$812.8**	**$516.3**	**$268.0**

7.3 Regulatory Alternative 3: Changes in the Calculation of Exposure Concentrations

Under this Regulatory Alternative, a different methodology is used for calculating exposures and assessing compliance. Elsewhere in the FRA and the FRIA, the costs and benefits of the final rule are based on calculating exposure for a full shift as an 8-hour TWA. MSHA's calculation normalizes the exposure level for an extended work shift to an 8-hour shift, whereas Regulatory Alternative 3 does not make any adjustment for an extended work shift. In this alternative, MSHA calculates exposure as a full-shift, time-weighted average, called a full-shift TWA, and re-analyzes the costs and benefits of the rule.

MSHA estimated the number of mines expected to incur costs when baseline exposure concentrations are re-calculated as full-shift TWAs. Based on exposures calculated using a full-shift TWA, MSHA finds that 1,053 mines operating in 2019 would incur costs to purchase, install, and operate exposure controls under the final rule. Of this total, 955 are MNM mines and 98 are coal mines. Thus, 173 fewer mines would incur new compliance costs under a full-shift TWA than a full-shift, 8-hour TWA (1,226 affected mines).

Aside from the change to the calculation of exposure concentrations and the number of affected mines at those concentrations, MSHA does not make any additional changes in assumptions or calculations under Regulatory Alternative 3. Therefore, the cost estimates of this alternative are calculated using the same methodology as described in Section 4 of the FRIA.[67]

FRIA Table 7-7 below presents the estimated annualized compliance costs of the final rule if exposure concentrations were calculated using a full-shift TWA instead of a full-shift, 8-hour TWA. Total Part 60 annualized compliance costs are estimated at $86.4 million (at a 3 percent discount rate), with 92.3 percent of costs attributable to MNM mines and 7.7 percent attributable to coal mines. This is $2.7 million (3.0 percent) less than total Part 60 annualized compliance costs when using a full-shift, 8-hour TWA ($89.1 million). The difference is primarily

[67] Some assumptions used to estimate compliance costs under the 8-hour TWA might not hold completely when estimating compliance costs under the full-shift TWA. Specifically, MSHA estimated that 7 years following the coal compliance date, the percentage of samples exceeding the Action Level (AL) would decline from baseline to 15 percent and the percentage of samples exceeding the new PEL would decline to 8 percent under the 8-hour TWA. Because the equivalent calculated exposure concentrations are lower and easier to achieve under a full-shift TWA, it is possible that mine operators might achieve even larger reductions in the percentage of samples exceeding the AL and PEL. This would result in lower monitoring costs than estimated here. However, with no data available to support a different assumption in the reduction of samples exceeding the AL and PEL, MSHA chose to use the same assumptions as were used for the final rule analysis.

attributable to the decreased number of mines and miners who are affected by the rule under this alternative, and a decrease in samples taken as compared to the main analysis.

FRIA Table 7-7. Summary of Part 60 Annualized Compliance Costs (in millions of 2022 dollars) under Regulatory Alternative 3 and Final Rule: All Mines

Mine Sector	Annualized Cost		
	0 Percent Discount Rate	3 Percent Discount Rate	7 Percent Discount Rate
Alternative Exposure Calculated Using Full-shift TWA			
Exposure Monitoring	$50.71	$52.05	$54.02
Exposure Controls	$12.70	$12.57	$12.32
Respiratory Protection	$2.95	$2.90	$2.81
Medical Surveillance	$18.82	$18.84	$18.82
Total, Part 60 Costs	***$85.17***	***$86.35***	***$87.97***
Final Rule: Exposure Calculated Using Full-shift, 8-hour TWA			
Exposure Monitoring	$51.60	$53.24	$55.64
Exposure Controls	$13.79	$13.66	$13.40
Respiratory Protection	$3.38	$3.32	$3.22
Medical Surveillance	$18.82	$18.84	$18.82
Total, Part 60 Costs	***$87.59***	***$89.05***	***$91.07***

While compliance costs decrease when a full-shift TWA is used, the estimated benefits of the rule are also expected to decrease. When miners work shifts that are longer than 8 hours (which is not uncommon, as seen both in the exposure data and in the employment data), the full-shift, 8-hour TWA will result in a higher calculated concentration than the full-shift TWA.

FRIA Table 7-8 presents the estimated number of avoided deaths and illnesses under the alternative during the 60 years following the start of implementation of the new rule. Total avoided morbidity over the 60-year analysis period is 1,500, which is 18 percent lower under Alternative 3 than the estimate of 1,836 avoided morbidities in the main analysis (see FRIA Table 3-5). Total avoided mortality over the 60-year analysis period is 434, which is also 18 percent lower under this alternative than the estimate of 531 avoided mortalities in the main analysis (see FRIA Table 3-5).

FRIA Table 7-8. Estimated Cases of Avoided Mortality and Morbidity over 60 Years (Regulatory Analysis Time Horizon) Following the Start of Implementation of the Rule under Regulatory Alternative 3

Health Outcome	Total Avoided Cases During 60 Years Following the Start of Implementation of the Rule [a]		
	MNM	Coal	Total
Morbidity			
Silicosis	1,392	108	1,500
Morbidity Total (Net of Silicosis Deaths)	**1,392**	**108**	**1,500**
Mortality			
NMRD (net of silicosis mortality)	198	15	213
Silicosis	105	7	112
ESRD	75	5	80
Lung Cancer [b]	28	2	30
Mortality Total	**405**	**29**	**434**

Notes: [a] Avoided cases include both production and contract miners. Calculations show the difference between excess cases when assuming compliance with the existing limits versus assuming compliance with the new PEL of 50 µg/m^3. Estimates account for the fact that some miners during the 60-year period will have worked under the existing standards (and thus may have combination of exposures under the existing standards and the new PEL), while all new entrants into the mining workforce would be solely exposed under the new PEL.
[b] A 15-year lag between exposure and observed health effect was assumed for lung cancer estimates.
[c] Totals may not equal the sum of individual values due to rounding.

FRIA Table 7-9 presents the annualized benefits of the final rule under Alternative 3. The undiscounted annualized benefits under the alternative are estimated at $312.8 million, with $291.5 million attributable to MNM mines and $21.3 million attributable to coal mines. The discounted annualized benefits under the alternative are estimated at $201.9 million at a 3 percent discount rate and $107.9 million at a 7 percent discount rate. At a 3 percent discount rate, the annualized benefits are $45.0 million (18 percent) less under Alternative 3 than when using a full-shift, 8-hour TWA ($246.9 million). Annualized benefits under the alternative are also 18 percent lower at both the 0 percent and 7 percent discount rates.

FRIA Table 7-9. Annualized Monetized Benefits over 60 Years (Regulatory Analysis Time Horizon) Following the Start of Implementation of the Rule (in millions of 2022 dollars) under Regulatory Alternative 3, by Health Outcome and Discount Rate

Health Outcome	MNM			Coal			Total		
	0%	3%	7%	0%	3%	7%	0%	3%	7%
Avoided Morbidity (Not Preceding Mortality)									
Silicosis (Net of Silicosis Mortality)	$77.4	$55.2	$34.5	$6.0	$4.3	$2.8	$83.5	$59.5	$37.3
Avoided Morbidity (Not Preceding Mortality) Total	**$77.4**	**$55.2**	**$34.5**	**$6.0**	**$4.3**	**$2.8**	**$83.5**	**$59.5**	**$37.3**

Mortality									
NMRD (Excluding Silicosis Deaths)	$94.9	$56.6	$25.6	$7.1	$4.3	$1.9	$102.0	$60.9	$27.5
Silicosis	$47.6	$31.6	$18.0	$3.1	$2.1	$1.3	$50.7	$33.7	$19.3
Renal Disease	$35.4	$21.7	$10.6	$2.5	$1.5	$0.8	$37.9	$23.3	$11.4
Lung Cancer	$13.62	$7.8	$3.2	$0.99	$0.6	$0.2	$14.6	$8.4	$3.4
Avoided Mortality Total	**$191.5**	**$117.7**	**$57.4**	**$13.7**	**$8.5**	**$4.2**	**$205.2**	**$126.2**	**$61.6**
Avoided Morbidity (Preceding Mortality)									
NMRD (Excluding Silicosis Deaths)	$11.0	$7.1	$3.5	$0.8	$0.5	$0.3	$11.8	$7.6	$3.8
Silicosis	$5.8	$4.3	$2.9	$0.4	$0.3	$0.2	$6.2	$4.6	$3.1
Renal Disease	$4.2	$2.8	$1.5	$0.3	$0.2	$0.1	$4.5	$3.0	$1.7
Lung Cancer	$1.5	$0.9	$0.4	$0.1	$0.1	$0.0	$1.7	$1.0	$0.4
Avoided Morbidity (Preceding Mortality) Total	**$22.5**	**$15.1**	**$8.4**	**$1.6**	**$1.1**	**$0.6**	**$24.2**	**$16.2**	**$9.0**
Grand Total	**$291.5**	**$188.0**	**$100.2**	**$21.3**	**$13.9**	**$7.6**	**$312.8**	**$201.9**	**$107.9**

Net annualized benefits under Alternative 3 are $226.5 million (undiscounted), $114.3 million (3 percent discount rate), and $18.6 million (7 percent discount rate). The net benefits under the alternative are lower than those in the main analysis by 23 percent (0 percent discount rate), 27 percent (3 percent discount rate), and 53 percent (7 percent discount rate), because the full-shift TWA is less protective than a full-shift, 8-hour TWA.[68]

[68] There are limitations in how the risk calculations can be performed because of limitations in the underlying exposure-response models from literature. The exposure-response models were not designed to detect the impact of longer work shifts, nor were they based on longitudinal data that could track individuals' work shifts over their careers. These calculations presented in this Alternative analysis provide new estimates of avoided cases when calculating exposure as a full-shift TWA and when accounting for the fact that fewer samples would meet the threshold of the new PEL or the new action level under a full-shift TWA.

8 PUBLIC COMMENTS AND RESPONSES

Prior to promulgation of the final rule, MSHA requested public comments on the proposed rule. Below, a summary of those comments relevant to the FRIA and MSHA's responses are provided.

8.1 Comments on Benefits

National Coalition of Black Lung and Respiratory Disease Clinics (see p. 96), was concerned that the projected benefits of the proposed rule for coal miners were significantly lower than the projected benefits for MNM miners and suggested that MSHA correct for this by including dust samples from coal mines taken prior to August 1, 2016 (Document ID 1410). Similarly, the Appalachian Citizens' Law Center asserted that the benefits estimated in the PRA are low and urged MSHA to include a longer history of coal dust sampling data (Document ID 1445). MSHA believes that samples from before August 1, 2016, may not accurately reflect the current conditions in coal mines and therefore should not be used in analyzing the impact of this final rule. As discussed in Appendix A of the preamble, on August 1, 2016, Phase III of the RCMD rule went into effect, and this lowered the PEL for RCMD in coal mines. The controls put in place to achieve that new PEL impacted both RCMD with and without respirable crystalline silica dust in coal mines, and as such, these controls likely lowered concentrations of respirable crystalline silica. Using data from after the coal mine dust rule went into effect helps to ensure that benefits attributable to that rule are not attributed to this rule incorrectly. More details about the respirable crystalline silica sample dataset, including the time coverage and brief statistics, are described in "Description of MSHA Respirable Crystalline Silica Samples" (Appendix A of the preamble of Proposed Rule). In addition to the prior effects of the RCMD rule on respirable crystalline silica exposure in the coal sector, there will also be greater benefits to MNM miners owing to the medical surveillance requirements which are already existing for coal miners. However, these benefits are unquantified in the FRA and FRIA analyses and therefore, do not specifically contribute to the discrepancy mentioned by these commenters.

Further, the benefits quantified here may underestimate the true benefits to coal miners. MSHA believes this final rule will likely lower not only respirable crystalline silica concentrations, but also RCMD levels. As a result, MSHA believes this final rule will provide additional reductions in CWP, NMRD, and PMF beyond those conferred by the 2014 coal dust rule. In the 2014 final rule, NIOSH emphasized the important role respirable crystalline silica plays in causing these diseases, stating that, "in concentrating on this particular exposure-response relationship with coal mine dust, we must not forget that [coal] miners today are being exposed to excess silica levels, particularly in thinner seam and small mines, and that this situation could well get worse as the thicker seams are mined out. Hence, since silica is more toxic than mixed coal dust, tomorrow's [coal] miners could well be at greater risk, despite a reduction in the mixed coal mine dust standard."[69] While additional reductions in total RCMD would be expected due to this final rule, these reductions cannot be quantified as they depend on the particular control measures that mine operators implement. Additionally, exposure-response models for respirable crystalline silica exposure and resultant CWP are not available. Thus, the benefits quantified in this FRIA may underestimate the true benefits to coal miners, as MSHA does not account for expected reductions in CWP or in other diseases due to reduced RCMD.

8.2 Comments on Costs

8.2.1 Method for Estimating Costs

Two mining trade organizations, American Exploration and Mining Association and Nevada Mining Association, stated that MSHA's cost projections were inaccurate because they predicted fixed costs based on gross proceeds (instead of net proceeds) (Document ID 1424; 1441). MSHA did not estimate compliance costs based on either gross or net proceeds. The Agency estimated compliance costs based on a wide range of quantitative and qualitative data including sampling data on miner exposure, MSHA's experience and knowledge of typical controls, maintenance, and work practices at mines of different types and size.

These commenters also noted that because the cost model for each commodity differs, compliance costs for each commodity will differ. MSHA agrees with the commenters that compliance costs differ for each commodity for its unique labor and other costs. Compliance costs are usually correlated with commodity, mine size, processes used at the site, chemical treatments in place, site-specific geology, and other similar characteristics. In MSHA's estimation, these physical characteristics better identify likely compliance costs than proceeds (gross or net proceeds) and are only indirectly related to cost model of the operator (to the extent those characteristics are reflected differentially in the cost model). Thus, MSHA disagrees with the commenters' approach of projecting cost using proceeds and determines that the Agency's approach of using physical characteristics is more accurate at identifying costs than the approach recommended by the commenters.

One commenter, a mining-related business, stated that MSHA's cost estimates were based on flawed sampling data, that "used samples taken by MSHA inspectors and then weighted these based on the number of samples plus exposures to the current standard" (Document ID 1392). The commenter stated that powered haulage operators account for the bulk of samples, while conveyor operators account for the fewest samples, resulting in a ratio of about 1 conveyor operator to 79 powered haulage operators. The commenter further stated that in its experience, the ratio is about 1 conveyor operator to 4 haulage operators. Because

[69] National Institute for Occupational Safety and Health (NIOSH). 2010. NIOSH/OSHA Revised Comments – QRA Comments – MSHA Proposed Rule. https://arlweb.msha.gov/REGS/QRA/NIOSHQRACommentsCoalMineDust.pdf. Accessed 2023.

conveyor operators are underrepresented in the analysis, this would affect MSHA's cost estimates.

In response, MSHA notes that the samples taken by MSHA inspectors were not weighted based on the "number of samples plus exposures to the current standard," as the commenter suggested, but by the estimated number of workers in each occupational group. MSHA took this approach because the samples taken by inspectors are not representative of all the occupations at a mine. Rather, MSHA inspectors' samples are concentrated in areas where miners are deemed to have the greatest risk for dust exposure.

Furthermore, MSHA used 2019 OEWS data to estimate the number of miners in each occupational group.[70] The OEWS is a nationally representative dataset and MSHA uses it to examine labor force in the mining industry. While BLS reported the number of workers under power haulage operators, it did not report any employment in the OCC Code 53-7011 (Conveyor Operators and Tenders) due to an insufficient number of respondents identified as Conveyor Operators and Tenders.

The FRIA analysis is based on sample and employment data to provide an overview of all occupational groups and their associated risks for the mining industry.

8.2.2 Sampling Costs

Several commenters disagreed with MSHA's estimates for sampling costs in the PRIA. For example, NSSGA provided estimates from several mine operators that exposure monitoring costs would be substantially higher than those reported in MSHA's PRIA (Document ID 1448). This commenter stated that sampling costs range from a low of $139 to a maximum of $1,800 per sample, with a median of $650 per sample, which would increase costs by $34 million to $162 million for 250,000 MNM miners. This commenter further stated that sampling costs vary according to the number of miners sampled: $2,766 for one miner, but $3,247 for 3 miners (approximately $1,082 per miner). A second commenter, Vanderbilt Minerals, LLC, listed costs in excess of $11,000 for a single 3-day sampling event (Document ID 1419). A third commenter, Essential Minerals Association, stated that 400 of its 446 employees would require 1,200 individual samples over the course of one year to meet the sampling requirements (Document ID 1442). A fourth commenter, Nevada Mining Association, stated that one of its members estimated sampling costs would increase by $1.2 million for its 7,000 employees (Document ID 1441).

Costs Per Sample

MSHA acknowledges that the range of costs per sample provided by commenters likely exceeds MSHA's own estimates. As explained in detail in Section 4, MSHA's calculations of the average unit costs of sampling, sample analysis, and evaluation take into account the labor cost of sampling, laboratory fees for sample analysis, lost work time due to sampling, recordkeeping

[70] Available at https://www.bls.gov/oes/.

time, plus the cost of performing periodic evaluations (FRIA Table 4-3). MSHA assumes that the labor cost of sampling varies by commodity and mine size. MSHA estimates that mine operators will take 4.88 million samples at a cost of $2.50 billion over the 60-year analysis period.[71] MSHA estimated the weighted average (mean) cost at $510 per sample, with costs ranging from $250 per sample (for coal mines with more than 500 employees) to $750 per sample (for metal mines with 20 or fewer employees). A direct comparison with the cost estimates provided by the above commenter (NSSGA) is not possible because NSSGA presents the median but not the mean cost per sample from the organization's members who provided data. Because the distribution of costs provided by the commenter is skewed towards higher values, the mean cost is likely to exceed the median value. Thus, these data suggest the sampling costs provided by the commenter are higher than MSHA's estimates.

Several commenters' estimates for sampling costs are consistent with MSHA's cost estimates. Additionally, MSHA estimated sampling costs of a "typical" mine. NSSGA presented costs of $1,800 per sample, $2,866 for sampling one miner, and $3,247 for sampling 3 miners are not necessarily inconsistent with MSHA's cost estimates. For example, the operator who lists costs exceeding $11,000 for a 3-day sampling episode did not provide the number of miners sampled or the number of samples taken in that sampling episode. Using MSHA's lowest estimate of $330 per sample for a mine with more than 500 miners, this estimate is equivalent to about 33 samples, which is not unreasonable for three, 10-hour days of sampling in a mine of similar size. The commenter's cost estimate of $11,000 over 3 days is consistent with MSHA's estimate. Similarly, $3,247 for sampling 3 miners is equal to an average of $1,082 per sample. MSHA estimated sampling costs of $747 per miner for metal mines with 20 or fewer employees using a wage rate that is an average of an in-house IH and an IH consultant. MSHA's average cost for mines with 20 or fewer employees is nearly $1,000 per sample if an IH consultant is used.

MSHA acknowledges that some mine operators will incur higher sampling costs than the "typical" mine operator. MSHA believes that some small mine operators may experience higher sampling costs than MSHA estimates due to operating in remote areas where it may be more difficult to procure sampling services, and due to the size of the mine. MSHA estimates the labor cost per sample at a small mine will be nearly twice the cost per sample at larger MNM mines. Under MSHA estimates, the percentage of miners needed to achieve representative sampling (50 percent) is twice as large as the percentage at larger mines (25 percent or less). MSHA was unable to determine from the information provided by commenters, how they determined a representative sample and the frequency of samples taken. For example, the range of values provided by NSSGA was based on "more than 20 companies." However, there are more than 6,000 sand and gravel mines affected by the final rule, and it is unclear whether this cost data represent the whole sector.

[71] Total samples are calculated as the sum of samples in years 1 through 6, plus year 7 samples multiplied by 54 as shown in FRIA Table 4-5. MSHA also excluded the cost of process change evaluations from the total cost of exposure monitoring in FRIA Table 4-7.

MSHA's estimated cost per sample is largely influenced by a mine's need to hire a sampling professional. Some mines might perform their own sampling, others may hire a sampling professional (e.g., industrial hygienist), and others may use a combination of the two, based on sample timing, numbers of samples, and mine location. In estimating sampling costs, MSHA assumed half of the MNM samples would be collected in-house, and the other half would be collected by a sampling professional. MSHA considers that mine operators (or controllers) will evaluate the costs of available options and make the most cost-effective decision.

The Agency's estimated average cost per sample collected by a contracted industrial hygienist is nearly equivalent to the high-end cost examples provided by some commenters. Differences are attributable to assumptions made on travel time and expense, numbers of samples collected per day, and numbers of days per trip (over which travel time and expense are averaged). To the extent that more remote mines are able to coordinate through a local, state, or national industry association, insurance carrier, their common mine controller, or other affiliation, these costs can be reduced by coordinating sampling dates. In addition, organizations and associations provide training on conducting air sampling. A trained technician working under an experienced industrial hygienist can reduce sampling costs.

Total Costs

Some commenters provided estimated total sampling costs that were higher than MSHA's estimates. This is because they assume more miners would have to be sampled than the MSHA estimated under the proposed rule. For example, NSSGA estimated that at a cost per sample of $139 per sample, industry costs will increase by $34 million, while its median cost of $650 per sample will increase industry cost by $162 million (Document ID 1448). The commenter appears to have multiplied the cost per sample by its estimated number of affected miners, 250,000. Similarly, Essential Minerals Association mentioned an operator who assumes that 400 of 446 employees would be sampled, while a member cited by the Nevada Mining Association appears to assume that all, or at least the vast majority, of its 7,000 employees would be sampled (Document ID 1442; 1441).

In response to public comments, MSHA increased its estimate of the number of samples operators would need to take to meet the sampling requirements of the final rule, by increasing the number of samples that constitutes the required representative fraction (or sampling representativeness) and frequency of sampling and evaluation. For example, over the first 6 years starting from the coal sector compliance date, MSHA now estimates 758,000 samples of all types (167,000 first-time/second-time samples, 315,300 above-action-level samples, 186,300 corrective actions samples, and 89,155 post-evaluation samples) will be taken, compared to 499,000 under the proposed rule.

However, based on exposure profiles for the MNM and coal mining industries and MSHA's experience and knowledge of the mining industry, MSHA believes that operators may be overestimating the number of samples required to meet the final rule and expects that on average the ratio of samples to miners sampled will be smaller than estimated by commenters.

The final rule allows mine operators to sample a representative fraction of miners to meet the requirement of representativeness. That is, a mine operator would be required to sample a minimum of two miners where several miners perform the same tasks on the same shift and in the same work area. Thus, not all miners working in the same mine need to be sampled. Additionally, this sampling will stop when sampling results demonstrate exposure at a mine below the action level.

To demonstrate representative sampling in this context, MSHA developed two examples based on its inspectors' experience in exposure sampling at mines, and typical occupation patterns from Stebbins and Leinart (2011). A requirement of representative sampling is that where several miners perform the same tasks on the same shift and in the same work area, the mine operator may sample a representative fraction (i.e., at least two) of these miners to meet the sampling requirements. Thus, the key to determining the number of samples that must be taken at a site requires defining groups of miners who perform the same tasks on the same shift and in the same work area. In the first example, a mine employing 20 miners, miners tend to be less specialized in their jobs than miners at larger mines. They also typically work on the same single shift per day. In this example MSHA divided the miners into 3 groups:

- 6 of the 20 miners have unique specialties (for example, mechanic, heavy equipment or excavator operator, drill operator or crusher/screener operator) and thus must all be sampled.
- 8 of the 20 miners are generalists (for example: forklift operator, truck-loading station/weigh scale attendant, cleaner), all of whom are cross trained in this set of activities and are available to move to the work areas where they are most needed over the course of the shift. Thus, on any given day these miners perform the same tasks and can be considered a single group for sampling purposes. The mine operator would sample the two most likely to have the highest exposure on the sampling day.
- The remaining 6 employees are primarily dump truck drivers. These miners perform the same tasks and can be considered a single group for sampling, and the mine operator would collect two samples from this group of 6 miners.

Therefore, from a small mine with 20 miners, the mine operator might collect 10 samples (6 + 2 + 2) to fulfill the representative sampling requirements, an average of 0.5 samples per miner (see FRIA Table 8-1). For a much larger mine with about 250 miners, a total of 26 samples, about 0.15 samples per miner, may be sufficient to meet the representative sample requirements (see FRIA Table 8-2).

FRIA Table 8-1. Representative Sampling Requirements for a Hypothetical Mine with 20 Miners

Occupation	Mine with 20 Miners	
	Number of Miners	Number of Samples
Dump Truck/Haulage Drivers	6	2
Laborer (roving miner; e.g., as needed operating forklift, loader, weigh scale; clean-up)	8	2
Mechanic/maintenance	2	2
Operator of Heavy Equipment/Excavator	2	2
Crusher/Screening Equipment Operator	2	2
Total	***20***	***10***
Sample per Miner		***0.5***

Similarly, MSHA estimated the number of samples necessary to perform representative sampling at a mine assumed to produce 10,000 metric tons of ore per day with a high stripping ratio and operating two shifts per day (a production shift and a maintenance/cleaning shift). The mine employs about 250 miners based on typical occupation patterns from Stebbins and Leinart (2011). At a much larger mine with many more employees, miners can be more readily grouped by job description. In this example MSHA has identified 12 groups of miners who perform the same tasks on the same shift and in the same work area with multiple miners in each group. MSHA estimates that sampling 38 miners (15 percent of 252 miners) will be sufficient to provide a representative fraction.

FRIA Table 8-2. Representative Sampling Requirements for a Hypothetical Mine with 250 Miners

Occupation	Mine with 250 Miners	
	Number of Miners [a]	Number of Samples
Dump Truck/Haulage Drivers	61	7
Laborers, Assigned to Clean Up Duties	40	4
Maintenance & Laborers, Production Shift	35	4
Maintenance & Laborers, Maintenance/Cleaning Shift	25	3
Mechanics & Electricians, Production Shift	20	3
Mechanics & Electricians, Maintenance/Cleaning Shift	17	3
Other (e.g., Geologists, Surveyors, Etc.)	15	2
Heavy Equipment Operators	14	3
Excavator Operators	10	3
Drill Operators	5	2
Crusher, Screener, Conveyor Operators	5	2
Utility Operators	5	2
Total	***252***	***38***
Sample per Miner		***0.15***

Note: [a] Adapted from Stebbins and Leinart (2011) and MSHA knowledge and experience.

Using representative sampling, MSHA estimates that the following percentages of miners sampled by mine size will be sufficient to attain sampling goals:

- In mines with 20 or fewer miners, 50 percent of miners would need to be sampled;
- In mines with more than 20, but no more than 100 miners, 25 percent would need to be sampled;
- In mines with more than 100 miners, 15 percent would need to be sampled.

Thus, for example MSHA expects that first-time and second-time sampling for 211,200 MNM miners in year 2 will result in 124,300 samples (approximately 62,100 samples each for the first-time and second-time sampling), averaging 1.18 sample for every two miners. Applying this percentage to the commenter's estimate, to cover 250,000 miners would require about 147,100 samples. Using the commenter's estimated median cost of $650 per sample would result in costs of $95.6 million, below $162 million that the commenter claimed.

8.2.3 Exposure Control Costs

Several commenters did not agree with MSHA's exposure control estimates as applied to their mines, stating that MSHA underestimated the costs of implementing exposure controls (Document ID 1419; 1441; 1448; 1455), and/or asserted that most mine operators who meet the current PEL will need to install significant new engineering controls to meet the new PEL. For example, Nevada Mining Association stated that estimated compliance costs for one of their members was $22.7 million for the first year and $13.6 million for each following year to retrofit mobile equipment with filtered pressurized air as well as medical surveillance and exposure sampling costs (Document ID 1441). NSSGA stated that "[b]ased on communications with 13 member companies, costs for exposure controls will vary widely, but on average are $920,000 annually, with a median of $225,000" (Document ID 1448). Neither the types of controls nor the number of mines installing the controls was included with the commenter's estimate. One member of NSSGA also stated that its 2023 budget for exposure controls is approximately equal to the MSHA annual estimate for all of MNM. Another commenter, US Silica, stated that in 2023 alone, it incurred $3.6 million in capital costs on two automated projects and multiple other projects exceeding MSHA's estimate for the industry (Document ID 1455). A fifth commenter, Vanderbilt Minerals, LLC, provided expected costs of $7 million for a list of renovations to existing facilities and new equipment purchases (Document ID 1419).

MSHA assumes that all mines are currently in compliance with the existing PEL when estimating compliance cost. Costs incurred by operators are attributable to lowering exposure from the current PEL to the new PEL.

Based on its analysis of the Agency's sampling database, MSHA believes roughly 90 percent of mines will be able to meet the new PEL without incurring additional costs. In Section 4 of the standalone FRIA, MSHA estimates that about 1,230 mines are expected to incur exposure control costs to meet the new PEL based on the proportion of mines in the sampling database which had a result greater than the new PEL on the most recent day of sampling. Of these, MSHA assumes that a little more than 50 percent (about 650 mines) should be able to meet the new PEL using controls such as additional maintenance and repair, and administrative controls. The remaining 47 percent of mines (580 mines) expected to incur costs, will also implement engineering controls – in addition to increased maintenance, repair, and administrative costs – to meet the new PEL.[72] The distinction between the two types of mines is related to sample data that shows compliances with the existing PEL.

In response to public comments that MSHA underestimated the cost of implementing necessary exposure controls, MSHA increased its estimate of the number of mine operators that will have to implement additional exposure controls to meet the requirements of the final rule. In the PRIA, all 1,230 affected mines were expected to incur costs of administrative controls and maintenance and repair in the first year, but the costs declined in subsequent years. In the FRIA, MSHA assumes that the 1,230 will continue to incur additional costs of administrative controls and maintenance and repair over the whole analysis period. Additionally, MSHA includes an extra 10 percent of total mines (111 coal mines and 1,153 MNM mines) that will incur exposure control costs, including enhanced administrative controls and frequent maintenance and repair.

The estimated costs presented in the FRIA represent the average estimated compliance costs for a typical mine. MSHA acknowledges that the exposure control costs will differ depending on the size of the mine, the current level of exposure to respirable crystalline silica, existing engineering and administrative controls, the mine layout, work practices, and other variables. MSHA's price and cost estimations are based on a variety of sources including market research (ERG, 2023) and MSHA's experience and sample data. The evidence provided by the commenters was collected from members of the trade associations that provided comments. FRIA Table 2-1 demonstrates that the majority of mines are small operators with fewer than 20 employees and more than 90 percent of mines employ fewer than 100 employees. It appears that at least some of the cost estimates are from either very large mines – far larger than the "typical" mine used for MSHA cost estimates – or may reflect an estimate for all mines controlled by an operator. For example, the National Mining Association's comment that the "total amount to retrofit all underground and surface mobile equipment with filtered pressurized air, medical surveys and increased sampling is $22.7 million for the first year, and $13.6 million each year after" is from an MNM operator with 7,000 employees (Document ID 1428). If this represents a single mine, only 26 MNM mines (0.2 percent) employed more than 500 miners in 2019 (see FRIA Table 2-1). If this represents multiple mines, the anticipated compliance costs per mine could be much smaller. Because the number of mines is unknown, and because the commenter includes sampling costs (provided separately as $1.2 million per year) and medical surveillance costs in the total, it is impossible to meaningfully compare this estimate with MSHA's estimates.

Similarly, US Silica presented costs exceeding $3.6 million in capital expenditures on two automation projects; totaling all engineering control projects, US Silica states it exceeded

[72] The maintenance, repair, and administrative costed for the additional 1,260 mines are not to meet the new PEL but to reduce exposures below the action level to reduce monitoring costs.

MSHA's estimate for the entire industry (Document ID 1455). However, it is unclear how many mines owned by US Silica incurred the costs. In addition, US Silica installed two automated systems. Generally, an automated bagging operation, for example, is more costly to purchase and install than a manual bagging system. The higher capital cost of an automated system also likely results in offsetting cost savings (e.g., labor costs), and thus US Silica's estimated compliance costs likely will result in other benefits including reducing worker exposure.

Vanderbilt Minerals LLC provided expected costs of $7 million for renovations to existing facilities and new equipment purchases at a single site, including "the purchase / installation of such items as a new bagging system for 50-pound bags, new dust collectors for drying/milling equipment, renovation of a laboratory, office, break room, mill control office, and crusher operator booth, purchase of larger water trucks and an increase in paved haul roads." (Document ID 1419). In this case, the costs by the commenter are clearly higher than MSHA's estimated compliance costs for a single typical mine. However, the site in question does not appear to be typical of most of MNM mining and therefore not appropriate for extrapolating industry costs.

Finally, the commenters cited here generally provided estimates of first-year engineering control costs. Because the compliance costs of controls with an initial capital cost vary substantially over the equipment's expected life, MSHA instead presents them as annualized costs. That is, MSHA converts the stream of compliance costs that vary from year-to-year to a stream of equal annual payments with the same net present value as the stream of unequal costs, much as a mortgage amortizes the initial lump sum cost of a house into a stream of equal monthly payments over the length of the mortgage (see Section 4.1.1.1). However, because of this, first-year capital costs cannot be directly compared to annualized costs over the expected life of the investment. MSHA presents the stream of estimated exposure control costs by year from which the annualized costs were calculated in FRIA Table C - 2 of Technical Appendix C.

8.2.4 Medical Surveillance Costs

Vanderbilt Minerals LLC stated that MSHA underestimated the cost of medical surveillance and stated its program cost approximately $9,400 per site per year, plus an additional $4,000 per site per year in employee time at 3 hours per employee (Document ID 1419). Assuming an average loaded wage rate of a nonmetal sector extraction worker at $40.47 per hour), $4,000 in employee time would cover 33 employees. This suggests that average medical surveillance costs would be $406 per employee by dividing total costs of $13,400 (= $9,400 + $4,000) per site by 33 employees.[73] This is significantly lower than MSHA's estimated unit cost for medical surveillance of $629 per exam in 2022 dollars (FRIA Table 4-25 in Section 4.2.3).

[73] The commenter does not state whether employee time is valued at a loaded hourly rate (including benefits and overhead) or the raw hourly rate. If the latter rate is used ($24.34 per hour), then the commenter's program would cover 55 employees at a cost of $244 per employee.

Another commenter, National Mining Association, stated that the proposed medical surveillance requirements would impose significant costs on its members, due to the expansion to cover potentially 200,000 MNM miners at more than 11,000 mines (Document ID 1428). As mentioned above, MSHA notes that under the final rule, operators are required to conduct medical surveillance on currently employed miners and new miners (those who start to work in the mining industry for the first time). For currently employed miners MSHA considers two scenarios, the first where 25 percent of miners are assumed to participate in medical surveillance, the second where 75 percent are assumed to participate. MSHA estimates that at a 25 percent participation rate, an average of 6,700 tests per year will be performed on currently employed miners at a cost of $4.24 million per year. At the assumed 75 percent participation rate, 20,200 tests will be performed per year at an average cost of $12.7 million per year. The midpoint of the two scenarios is an average of 13,500 tests per year on currently employed miners at a cost of $8.47 million per year (undiscounted).

8.2.5 Small Business-Owned Mines

Public commenters on costs to small business largely echoed similar concerns as other commenters on compliance costs. In addition to those concerns, commenters on costs to small businesses raised some specific issues, such as:

- The cost of exposure monitoring will be relatively more burdensome to small mines than to large mines.
- Medical Surveillance will be costly, especially for mines in remote locations whose employees might have to drive a considerable distance for the appropriate checkups.
- Respirator and filter costs will be higher than MSHA estimated.
- Dust suppression will be more costly than MSHA estimated, particularly for mines operating in remote, arid locations where obtaining water is expensive.
- Cabin air filters are expensive to replace, and their equipment operators do not typically use air conditioning, which is considered a “luxury.”

MSHA acknowledges that sampling costs will be more burdensome to small MNM mine operators because the cost of using an IH will be spread over relatively few samples. MSHA estimates the labor cost per sample at a small MNM mine will be nearly twice the cost per sample at larger MNM mines. For example, MSHA estimates a cost per sample ranging from $365 to $380 at mines with more than 20 but fewer than 100 employees compared to a cost of $720 to $750 per sample at mines with 20 or fewer employees. In addition, although not all miners will require sampling, the percentage of miners needed to achieve representative sampling (50 percent) is twice as large as the percentage at larger mines (25 percent or less).

MSHA has determined that the exposure monitoring requirements in the final rule are necessary to maintain exposure levels at a safe level to ensure miners’ health. Section 8.2.2 outlines several steps mine operators can take to reduce their monitoring cost.

Many of the themes for commenters on costs to small mine operators match those of other commenters on the FRIA cost estimates, and the responses to those comments are the same (see Sections 8.2.3 and 8.2.4, for example). These include costs of respiratory protection and medical surveillance. Concerns specific to small operators include the cost of hourly wages and travel expenses for medical examinations, which will be larger than estimated by MSHA, and larger than that for many other mines. One commenter estimates it would have to pay two days' wages and overnight lodging because of the distance a miner would have to travel to the nearest city where the appropriate exams are offered (Gale Lim Construction, Document ID 1415). A second commenter states its miners would have to leave Sitka Island, where the mine is located, to a larger island for testing (K&E Alaska, Inc., Document ID 1436). MSHA acknowledges these concerns but notes that the stated costs do not appear to be significantly different from those estimated by MSHA. In addition, no evidence is provided to demonstrate that such costs will be borne by a disproportionate number of small mine operators.

Similarly, although the unit cost of respirators and filters listed by the commenters is higher than those used in the PRIA (e.g., up to $50 per respirator plus $50 for filter cartridges that would be replaced every 6 months), the replacement filter cartridges based on their data last much longer than those costed by MSHA (Section 4.3), such that the cost of a respirator plus one year's worth of filter cartridges (about $150) will be lower than MSHA's estimated cost for a respirator and one year of filter cartridges ($480) (Document ID 1411; 1415; 1427; 1435; 1436). Furthermore, the commenters assumed all employees would require new respirators, and did not account for baseline use (or availability) of respirators at the mine or calculate only the additional respirator use that comprises the cost imposed by the final rule. The final rule requires MNM mine operators to use respirator protection as a temporary measure when miners must work in concentrations of respirable crystalline silica above the PEL, when engineering control measures are being developed and implemented, or when necessitated by the nature of work involved. MSHA determined that its cost assumptions are more comprehensive and likely overestimate respirator protection costs.

Water based dust suppression, especially if combined with magnesium chloride, is likely to be more expensive at some remote mines in arid regions due to the cost of obtaining and transporting water. However, there are multiple ways of reducing exposure to respirable crystalline silica dust, some of which are presented in this FRIA and the Technological Feasibility discussions. For example, operating vehicles with windows closed, reduced vehicle speed, and wider vehicle spacing have all been shown to decrease operator exposure to dust. Although commenters cite the cost of cabin air filters and their preference to not use air conditioning, it should be noted that there may be trade-offs in the choices mine operators make to reduce exposure to dust. For example, the use of air conditioning by vehicle operators will increase costs (filters, fuel use), but will decrease exposure not just below the new PEL, but below the action level. Thus, these increased operating costs should be offset by reduced sampling costs, for example.

Comments on costs borne by operators of small mines will be discussed in more detail in the Final Regulatory Flexibility Analysis. MSHA acknowledges that exposure monitoring costs will disproportionately impact small mine operators than operators of larger mines. Exposure monitoring is an essential component of this final rule and will help all mine operators achieve compliance with the new PEL, which will better protect miners' health. Monitoring requirements are the same for all mines, regardless size. To the extent that some costs might be larger for small mines, it often appears to be attributable to mine specific characteristics, not characteristics systemic to small mine operators in general.

8.2.6 Other Costs

At least two mining trade associations, NSSGA and Illinois Association of Aggregate Producers, stated that, under the proposed rule, companies would incur millions of dollars in costs that do not benefit miners' health and safety, using as examples requiring sampling every 3 months indefinitely for exposures between 25 $\mu g/m^3$ and 50 $\mu g/m^3$, requiring that medical surveillance to be offered to miners with less than 30 days a year of exposure to respirable silica above the action level, and requiring initial sampling even for facilities that have had exposure monitoring for decades (Document ID 1448; 1456). MSHA disagrees. MSHA has determined that on-going sampling and periodic evaluations are necessary to ensure that exposures to respirable crystalline silica meet the new PEL and that miners' health is protected. Exposure monitoring, that includes an action level, provides mine operators and miners with necessary information to take actions to prevent miners' overexposures. Finally, while the final rule does not require mine operators to meet the action level, many mine operators can choose to maintain exposure below the action level through exposure controls or to continue sampling (which carries ongoing costs to operators). Allowing mine operators to cease monitoring once exposure is maintained below the action level provides operators with the incentive to reduce and maintain exposures below the action level. For medical surveillance, MSHA believes it is important for MNM operators to provide medical surveillance so that MNM miners will have information about their health to take necessary action early to prevent any further progression of disease.

A mining-related business, N-Compliance Safety Services, Inc., asserted that large mining company costs under the proposed rule would be in the millions of dollars annually, a figure that does not include the cost of citations, downtime, and contesting violations. (Document ID 1383). Stating that the proposed rule's costs would drive up the costs of commodities and impact transportation needs and expenses, the commenter said that the proposed 25 $\mu g/m^3$ action level "will place most mines in violation, as it is four times less than the current PEL and will take four times the actions to stay below the action level." All estimated compliance costs include the costs of miners' time. In response to the comment from mine operators that the action level would place most mines in violation, MSHA clarifies that mine operators are not required to maintain exposures below the action level. The purpose of the action level is to alert mine operators and miners when exposures are approaching the PEL. Mine operators will be in violation if exposures exceed the new PEL. Mine operators who maintain exposures at or above the action level and at or below the new PEL will incur sampling costs but will not be in violation of the final rule and will not be faced with citations or loss of production. In addition, MSHA notes that the commenter has provided no data to support their statement that the rule will cost large mining companies millions of dollars in compliance costs.

8.3 Comments on Regulatory Alternatives

Two mining trade associations, American Exploration and Mining Association; and National Mining Association expressed support for Regulatory Alternative 1 (Changes in Sampling and Evaluation Requirements) as a more appropriate approach than the one in the proposed rule, with one clarifying that its support for Regulatory Alternative 1 is only secondary to its primary recommendation that MSHA adopt OSHA's risk-based approach to sampling and evaluation requirements. (Document ID 1424; 1428). Specifically, these commenters supported the Regulatory Alternative 1 requirement for baseline sampling for miners whose exposure is at or above the proposed action level of 25 μg/m^3 in lieu of the requirement for baseline sampling of each miner who is or may reasonably be expected to be exposed to respirable crystalline silica of any level. Further, these commenters supported the Regulatory Alternative 1 periodic sampling requirement of twice per year for miners between the action level and the PEL, which they said was more in line with established industrial hygiene guidelines and would allow mine operators to allocate industrial hygiene resources to those areas where they are better used, including areas where there is higher risk of exposure above the PEL. Finally, these commenters supported the Regulatory Alternative 1 requirement for annual evaluation of mine processes or conditions, instead of the proposed rule's semi-annual review, stating that it would provide an equal amount of protection to miners (given that mining processes and conditions are relatively stable and non-changing), while lowering operator compliance costs.

Under the final rule, exposure monitoring requirements help mine operators assess changes in mining conditions and identify trends in miner exposures more rapidly than those outlined in Regulatory Alternative 1. This will enable mine operators to ensure the adequacy of controls at their mines and better protect miners' health. These exposure monitoring benefits cannot be quantified, but they are meaningful because they increase the likelihood of compliance. MSHA believes that the benefits of the sampling and evaluation requirements justify the additional costs relative to Regulatory Alternative 1.

A professional association, American Industrial Hygiene Association expressed support for Regulatory Alternative 2 (Changes in Sampling and Evaluation Requirements and the Proposed PEL).) (Document ID 1351). However, the commenter recommended that mine operators be required to (1) conduct baseline sampling and periodic sampling, (2) conduct semi-annual or more frequent evaluations of changing conditions, and (3) sample as frequently as necessary to determine the adequacy of controls. In addition, the commenter stated that, under this alternative, mine operators should be required to perform post-evaluation sampling when the operators determine from the semi-annual evaluation that miners are exposed at the 95-percent confidence level to respirable crystalline silica above the proposed PEL of 25 μg/m^3, referencing a NIOSH Occupational Sampling Strategy Manual. Although the benefits associated with this avoided morbidity and mortality under Regulatory Alternative 2 are greater than those for the final rule, the net benefits of this alternative are negative at both a 3 percent and 7 percent real discount rate owing to the much higher compliance costs for this alternative as compared to those for the final rule. MSHA determines that meeting a PEL of 25 μg/m^3 is not achievable for all mines and Regulatory Alternative 2 is not chosen.

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TECHNICAL APPENDIX A – ABBREVIATED HYPOTHETICAL EXAMPLE WITH SAMPLE LIFE TABLES

For illustrative purposes, a hypothetical example is provided below using abbreviated life tables to demonstrate the manner in which the number of cases avoided in a single year is estimated. In the PRIA, this example was applied only to the population of working miners, but this has been updated in the FRIA to account for future retired miners as well. Additionally, the first year showing the age of 20 was removed from the life tables to guarantee that risks are only being summed over 60 years (45 years of mining and 15 years of retirement). In these tables, a given survival rate now shows the expected proportion of the original cohort of 21-year-olds that is alive at the start of that year.

In this example, MSHA considers silicosis mortality among MNM miners. Specifically, MSHA models the risks in a given year t for the subset of 11,769 working MNM miners who are in the exposure group over 100 μg/m^3. Per cohort of 21-year-olds (of which there are 60), this equates to 262 MNM miners exposed at >100 μg/m^3. Due to the new PEL, this group would experience a drop in exposure from 100 μg/m^3 (assuming full compliance with the existing PEL) to 50 μg/m^3 (assuming full compliance with the new PEL).

Using the compliance date for coal, the first year in the 60-year analysis time period is 2025. For MNM miners, however, the compliance date is one year late in 2026. The life table below (FRIA Table A - 1) represents the oldest cohort of coal miners (cohort 1, born in 1946) still accruing risks in 2026. This group is assumed to have begun working in 1967 at the start of age 21 and to have retired in 2012 at the start of age 66. For this cohort, the new PEL would go into effect only during the final year of life, 14 years after retirement[74]:

FRIA Table A - 1. Example Life Table for Cohort 1's Silicosis Mortality Risk Under New PEL, for MNM Miners Currently Exposed to a Concentration of 100 μg/m^3 of Respirable Crystalline Silica

Calendar Year	Age, t	Cumulative Exposure, E	Silicosis Mortality Hazard, h_t (per 100,000)	All-Cause Death Hazard, d_t (per 100,000)	Survival Rate, S_t	Silicosis Death Risk, r_t
1967[a]	21	0.087	4.7	135.3	1.0000	0.00005
⋮	⋮	⋮	⋮	⋮	⋮	⋮
2011	65	3.934	44.2	1893.0	0.8014	0.00035
2012	66	3.934	44.2	1893.0	0.7862	0.00035
⋮	⋮	⋮	⋮	⋮	⋮	⋮
2025	79	3.934	44.2	4193.4	0.5347	0.00024
2026[b]	80	3.934	44.2	6808.3	0.5123	0.00023

[a] Red text represents years of exposure at 100 μg/m^3 under the existing PEL.
[b] Black text represents years during retirement.

[74] In this hypothetical example, MSHA assumed the same exposure level before and after 1973 TLV. That is, the calculation of cumulative exposure for all age cohorts follows the same approach.

[c] The final column shows that silicosis death risk is lower at age 79 than at age 66 for this particular cohort. This indicates that a smaller proportion of the cohort's starting population is expected to die from silicosis at the age of 79 than is expected to die from silicosis at the age of 66. This is partly attributable to the fact that fewer members of the cohort are alive at the age of 79 than at the age of 66.

The new PEL does not confer benefits to this cohort because they were already retired. Thus, in the calendar year 2026, the risk reduction for this *i* = 1st cohort is $\Delta r_t^{(1)} = \tilde{r}_t^{(1)} - r_t^{(1)} = 0$. Similarly, for cohorts 2 through 15, implementation of the new PEL would yield no benefits, as the new PEL would have gone into effect after these cohorts retired.

However, cohorts 38 through 42 (FRIA Table A-2), for example, do experience benefits because all of these miners would still be working in 2026 when MNM mines are required to comply with the rule. Just as the cohort labeled *i* = 1 is the oldest group of miners (born in 1946) that accumulate risk during the 60-year analysis period, the cohort labeled *i* = 38 is the 38th oldest group of miners (born in 1983) that accumulate risk during the 60-year period.

Select columns from the life tables (age and silicosis death risk) are shown below for these cohorts *i* = {38, 39, 40, 41, 42}. The tables are staggered to show synchronization of exposures by calendar year. Blue and red cells display exposures under the new and existing PELs, respectively. Black cells show years of retirement. The blue highlighted row shows the first year of implementation of the new PEL.

FRIA Table A - 2. Example Abbreviated Life Tables Showing Silicosis Mortality Risk Under New PEL for Cohorts 38 – 42 Among MNM Miners Currently Exposed to a Concentration of 100 μg/m³ of Respirable Crystalline Silica, Staggered to Show Synchronization

Calendar Year	Cohort 38		Cohort 39		Cohort 40		Cohort 41		Cohort 42	
	Age	$r_t^{(38)}$	Age	$r_t^{(39)}$	Age	$r_t^{(40)}$	Age	$r_t^{(41)}$	Age	$r_t^{(42)}$
2004	21	0.00005								
2005	22	0.00005	21	0.00005						
2006	23	0.00005	22	0.00005	21	0.00005				
2007	24	0.00005	23	0.00005	22	0.00005	21	0.00005		
2008	25	0.00005	24	0.00005	23	0.00005	22	0.00005	21	0.00005
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2024	41	0.00015	40	0.00015	39	0.00015	38	0.00015	37	0.00015
2025	42	0.00015	41	0.00015	40	0.00015	39	0.00015	38	0.00015
2026	43	0.00015	42	0.00015	41	0.00015	40	0.00015	39	0.00015
2027	44	0.00028	43	0.00015	42	0.00015	41	0.00015	40	0.00015
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2046	63	0.00024	62	0.00024	61	0.00025	60	0.00025	59	0.00025
2047	64	0.00036	63	0.00024	62	0.00024	61	0.00025	60	0.00025
2048	65	0.00035	64	0.00024	63	0.00024	62	0.00024	61	0.00025
2049	66	0.00035	65	0.00035	64	0.00024	63	0.00024	62	0.00024
2050	67	0.00034	66	0.00035	65	0.00023	64	0.00024	63	0.00024
2051	68	0.00034	67	0.00034	66	0.00023	65	0.00023	64	0.00024
2052	69	0.00033	68	0.00034	67	0.00023	66	0.00023	65	0.00023
2053	70	0.00032	69	0.00033	68	0.00022	67	0.00023	66	0.00023
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2061	78	0.00025	77	0.00026	76	0.00018	75	0.00019	74	0.00019
2062	79	0.00024	78	0.00025	77	0.00017	76	0.00018	75	0.00019
2063	80	0.00023	79	0.00024	78	0.00016	77	0.00017	76	0.00018
2064			80	0.00023	79	0.00016	78	0.00016	77	0.00017
2065					80	0.00015	79	0.00016	78	0.00016
2066							80	0.00015	79	0.00016
2067									80	0.00015

In general, the blue-colored silicosis mortality risk $r_t^{(i)}$ are lower[75] due to reduced exposures of 50 μg/m³ under the new PEL. For comparison, if the new PEL had not gone into effect, then all blue cells would be replaced by higher exposures at 100 μg/m³ (assuming full compliance with the existing MNM PEL). The silicosis mortality risks $\tilde{r}_t^{(i)}$ at year t among cohort i are shown in the FRIA Table A - 3 below assuming exposure to concentrations of 100 μg/m³ under the existing PEL.

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[75] In some cases, risk reductions are not seen until exposure reductions are accumulated over several years. Moreover, the silicosis mortality model is based on Mannetje *et al*. (2002b) and Toxachemica, Inc. (2004), which uses a step function and thus can lead to equal silicosis mortality risk in both scenarios despite lower cumulative exposures under the new PEL.

FRIA Table A - 3. Abbreviated Life Tables Showing Silicosis Mortality Risk Under Existing PEL for Cohorts 38 – 42 Among MNM Miners Currently Exposed to a Concentration of 100 µg/m³ of Respirable Crystalline Silica, Staggered to Show Synchronization

Calendar Year	Cohort 38		Cohort 39		Cohort 40		Cohort 41		Cohort 42	
	Age	$\tilde{r}_t^{(38)}$	Age	$\tilde{r}_t^{(39)}$	Age	$\tilde{r}_t^{(40)}$	Age	$\tilde{r}_t^{(41)}$	Age	$\tilde{r}_t^{(42)}$
2004	21	0.00005								
2005	22	0.00005	21	0.00005						
2006	23	0.00005	22	0.00005	21	0.00005				
2007	24	0.00005	23	0.00005	22	0.00005	21	0.00005		
2008	25	0.00005	24	0.00005	23	0.00005	22	0.00005	21	0.00005
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2024	41	0.00015	40	0.00015	39	0.00015	38	0.00015	37	0.00015
2025	42	0.00015	41	0.00015	40	0.00015	39	0.00015	38	0.00015
2026	43	0.00028	42	0.00015	41	0.00015	40	0.00015	39	0.00015
2027	44	0.00028	43	0.00028	42	0.00015	41	0.00015	40	0.00015
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2046	63	0.00036	62	0.00037	61	0.00037	60	0.00038	59	0.00038
2047	64	0.00036	63	0.00036	62	0.00037	61	0.00037	60	0.00038
2048	65	0.00035	64	0.00036	63	0.00036	62	0.00037	61	0.00037
2049	66	0.00035	65	0.00035	64	0.00036	63	0.00036	62	0.00037
2050	67	0.00034	66	0.00035	65	0.00035	64	0.00036	63	0.00036
2051	68	0.00033	67	0.00034	66	0.00035	65	0.00035	64	0.00036
2052	69	0.00033	68	0.00033	67	0.00034	66	0.00035	65	0.00035
2053	70	0.00032	69	0.00033	68	0.00033	67	0.00034	66	0.00035
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2059	78	0.00025	77	0.00026	76	0.00027	75	0.00028	74	0.00029
2060	79	0.00024	78	0.00025	77	0.00026	76	0.00027	75	0.00028
2061	80	0.00023	79	0.00024	78	0.00025	77	0.00026	76	0.00027
2062			80	0.00023	79	0.00024	78	0.00025	77	0.00026
2063					80	0.00023	79	0.00024	78	0.00025
2064							80	0.00023	79	0.00024
2065									80	0.00023

From FRIA Table A - 3, the five silicosis mortality risk columns $\tilde{r}_t^{(38)}$ are identical for the five cohorts because under the existing PEL each cohort would possess the same exposure history. Specifically, each cohort would encounter a constant exposure of 100 µg/m³ during each year of work if the existing PEL remained in effect (assuming full compliance).

Taking the difference between these two tables' risk values (existing PEL and new PEL) yields a reduction in silicosis mortality risk of $\Delta r_t^{(i)} = \tilde{r}_t^{(i)} - r_t^{(i)}$ for each of the five cohorts in a given year t. These risk reductions are shown in FRIA Table A - 4 below at each year of life for the five cohorts.

FRIA Table A - 4. Risk Reductions (Existing PEL – New PEL) by Year for Cohorts 38 – 42

Calendar Year	Cohort 38		Cohort 39		Cohort 40		Cohort 41		Cohort 42	
	Age	$\Delta d_t^{(38)}$	Age	$\Delta d_t^{(39)}$	Age	$\Delta d_t^{(40)}$	Age	$\Delta d_t^{(41)}$	Age	$\Delta d_t^{(42)}$
2004	21	0.00000								
2005	22	0.00000	21	0.00000						
2006	23	0.00000	22	0.00000	21	0.00000				
2007	24	0.00000	23	0.00000	22	0.00000	21	0.00000		
2008	25	0.00000	24	0.00000	23	0.00000	22	0.00000	21	0.00000
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2024	41	0.00000	40	0.00000	39	0.00000	38	0.00000	37	0.00000
2025	42	0.00000	41	0.00000	40	0.00000	39	0.00000	38	0.00000
2026	43	0.00013	42	0.00000	41	0.00000	40	0.00000	39	0.00000
2027	44	0.00000	43	0.00013	42	0.00000	41	0.00000	40	0.00000
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2046	63	0.00012	62	0.00012	61	0.00013	60	0.00013	59	0.00013
2047	64	0.00000	63	0.00012	62	0.00012	61	0.00013	60	0.00013
2048	65	0.00000	64	0.00012	63	0.00012	62	0.00012	61	0.00013
2049	66	0.00000	65	0.00000	64	0.00012	63	0.00012	62	0.00012
2050	67	0.00000	66	0.00000	65	0.00012	64	0.00012	63	0.00012
2051	68	0.00000	67	0.00000	66	0.00012	65	0.00012	64	0.00012
2052	69	0.00000	68	0.00000	67	0.00012	66	0.00012	65	0.00012
2053	70	0.00000	69	0.00000	68	0.00011	67	0.00012	66	0.00012
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2061	78	0.00000	77	0.00000	76	0.00009	75	0.00009	74	0.00010
2062	79	0.00000	78	0.00000	77	0.00009	76	0.00009	75	0.00009
2063	80	0.00000	79	0.00000	78	0.00008	77	0.00009	76	0.00009
2064			80	0.00000	79	0.00008	78	0.00008	77	0.00009
2065					80	0.00008	79	0.00008	78	0.00008
2066							80	0.00008	79	0.00008
2067									80	0.00008

For a single calendar year (*e.g.*, 2047, or Year 23 after the start of implementation of the rule), the total reduction in risk is the row sum across the $\Delta r_t^{(i)}$ columns for the 60 "active" cohorts who are accruing risks in that calendar year. This row sum excludes any cohorts who are not accumulating risks during that year because (a) they already died or (b) they have not yet entered the workforce. As we move down the table through successive calendar years, older miner cohorts reach their assumed end of life and cease to contribute to risk reductions, and newer miner cohorts enter the work force with no previous exposure. Assuming a uniform age distribution, 45-year-long careers, and a constant labor force, older workers are replaced by new workers who are 21 years old.

An example, this row sum can be computed and interpreted just for the five cohorts shown above. Summing the $\Delta r_t^{(i)}$ values across the row for the calendar year 2045 (in

FRIA Table A - 4) yields a total reduction in silicosis mortality risk[76] among the five cohorts of:

$$\sum_{i=38}^{42}\left(\tilde{r}^{(i)}{}_{t=2045} - r_{t=2045}^{(i)}\right) = 0.00000 + 0.00012 + 0.00012 + 0.00013 + 0.00013 \quad (\mathrm{A}-1)$$

$$\sum_{i=38}^{42}\left(\tilde{r}^{(i)}{}_{t=2045} - r_{t=2045}^{(i)}\right) = 0.00050 \quad (\mathrm{A}-2)$$

This reduction in risk is attributable to the implementation of the new PEL but only encompasses five of the 60 cohorts with surviving members during the calendar year 2047. Accordingly, we can extend the summation to include all rows for the 60 active cohorts with surviving members in the year 2047:

$$\sum_{i=22}^{81}\left(\tilde{r}^{(i)}{}_{t=2045} - r_{t=2045}^{(i)}\right) = 0.0040 \quad (\mathrm{A}-3)$$

This is the total reduction in risk in the year 2047 across the 60 active cohorts with surviving members in that calendar year. This collection of cohorts corresponds to the 11,769 MNM miners whose exposure decreases from 100 μg/m^3 to 50 μg/m^3 because of the new PEL. Among this group, the total cases avoided during the year 2047 can be computed using Eq. 1 through Eq. 9 of Section 3.2.1:

$$c_t = \frac{N}{45}\sum_{i}\left(\tilde{r}_t^{(i)} - r_t^{(i)}\right) = \frac{11{,}769}{45}(0.0040) = 1.05 \quad (\mathrm{A}-4)$$

This results in 1.05 cases of silicosis mortality avoided in the year 2047 among the group of MNM miners experiencing exposure over 100 μg/m^3 but assumed under compliance with the existing PEL to be exposed at 100 μg/m^3. Repeating this calculation for the 21,805 MNM miners who experience exposures between 50 and 100 μg/m^3 yields an estimate of 0.66 cases avoided in the year 2045. Accordingly, in Year 23 (i.e., 2047), the new PEL would avert 1.05 + 0.66 = 1.71 cases of silicosis mortality among all MNM miners, including working miners and retired miners. This estimate accounts for the 60 distinct miner cohorts with surviving members in the year 2047, which have different exposure histories and varying times under the existing vs. new PEL.

As a practical matter, however, there is no overriding reason for stopping the benefits analysis at 60 years. MSHA expects that, both in terms of cases prevented, and even regarding monetized benefits, particularly when lower discount rates are used, the estimated benefits of

[76] Here, *t* represents the implementation year (expressed as either "Year 1" or as a calendar year such as 2024). However, *t* = Year 1 does not necessarily correspond to the 1st row of each life table. In calendar year *t* = 1, the corresponding row of the life table is *i* – *t* +1, where *i* = 1 represents the oldest "active" cohort.

the new standard would be noticeably larger on an annualized basis if the analysis extended further into the future.

To compare costs to benefits, MSHA assumed that economic conditions remain constant and that annualized costs—and the underlying costs—will repeat for the entire 60-year time horizon used for the benefits analysis.

TECHNICAL APPENDIX B – LIFETIME AVOIDED CASES BY HEALTH ENDPOINT AND EXPOSURE INTERVAL ATTRIBUTABLE TO THE NEW RESPIRABLE CRYSTALLINE SILICA RULE AMONG COAL AND MNM MINERS

FRIA Table B - 1. Estimates of Lifetime Avoided Cases of Lung Cancer Mortality Among Coal Miners, by Exposure Interval

	≤ 25 µg/m3	> 25 to ≤ 50 µg/m^3	> 50 to ≤ 85.7 µg/m^3	> 85.7 to ≤ 100 µg/m^3	> 100 to ≤ 250 µg/m^3	> 250 to ≤ 500 µg/m^3	> 500 µg/m^3	Total
At-Risk Miner FTEs (with contract miners)								
Number	58,951	9,783	2,644	362	906	106	17	**72,768**
Percent of Total	81.0%	13.4%	3.6%	0.5%	1.2%	0.1%	0.0%	**100.0%**
Median Annual Cumulative Exposure [a]								
Baseline Scenario [b]	0.0122	0.0329	0.0597	0.0848	0.0848	0.0848	0.0848	
New PEL 50 µg/m^3 Scenario [c]	0.0122	0.0329	0.0495	0.0495	0.0495	0.0495	0.0495	
Average Lifetime Excess Risk (per 1,000 Miners) [d]								
Baseline Scenario	0.71	1.96	3.64	5.29	5.29	5.29	5.29	
New PEL 50 µg/m^3 Scenario	0.71	1.96	2.99	2.99	2.99	2.99	2.99	
Lifetime Excess Cases								
Baseline Scenario	55.9	25.5	12.8	2.6	6.4	0.7	0.1	**104.0**
New PEL 50 µg/m^3 Scenario	55.9	25.5	10.5	1.4	3.6	0.4	0.1	**97.4**
Lifetime Excess Cases Avoided by New PEL								**6.6**

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hours worked by miners (excluding contract miners) and contract miners.

[b] The baseline scenario caps all exposures at 100 µg/m^3 for MNM miners and at 85.7 µg/m^3 for coal miners.

[c] The New PEL 50 µg/m^3 Scenario caps all exposures at 50 µg/m^3 for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

FRIA Table B - 2. Estimates of Lifetime Avoided Cases of Silicosis Mortality Among Coal Miners, by Exposure Interval

	≤ 25 μg/m³	> 25 to ≤ 50 μg/m³	> 50 to ≤ 85.7 μg/m³	> 85.7 to ≤ 100 μg/m³	> 100 to ≤ 250 μg/m³	> 250 to ≤ 500 μg/m³	> 500 μg/m³	Total
At-Risk Miner FTEs (with contract miners)								
Number	58,951	9,783	2,644	362	906	106	17	**72,768**
Percent of Total	81.0%	13.4%	3.6%	0.5%	1.2%	0.1%	0.0%	**100.0%**
Median Annual Cumulative Exposure [a]								
Baseline Scenario [b]	0.0122	0.0329	0.0597	0.0848	0.0848	0.0848	0.0848	
New PEL 50 μg/m3 Scenario [c]	0.0122	0.0329	0.04945	0.04945	0.04945	0.04945	0.04945	
Average Lifetime Excess Risk (per 1,000 Miners) [d]								
Baseline Scenario	2.46	5.05	9.36	14.05	14.05	14.05	14.05	
New PEL 50 μg/m3 Scenario	2.46	5.05	8.11	8.11	8.11	8.11	8.11	
Lifetime Excess Cases								
Baseline Scenario	193.5	65.9	33.0	6.8	17.0	2.0	0.3	**318.5**
New PEL 50 μg/m3 Scenario	193.5	65.9	28.6	3.9	9.8	1.1	0.2	**303.0**
Lifetime Excess Cases Avoided by New PEL								**15.5**

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hours worked by miners (excluding contract miners)and contract miners.

[b] The baseline scenario caps all exposures at 100 μg/m³ for MNM miners and at 85.7 μg/m³ for coal miners.

[c] The New PEL 50 μg/m³ Scenario caps all exposures at 50 μg/m³ for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

FRIA Table B - 3. Estimates of Lifetime Avoided Cases of ESRD Mortality Among Coal Miners, by Exposure Interval

	≤ 25 μg/m³	> 25 to ≤ 50 μg/m³	> 50 to ≤ 85.7 μg/m³	> 85.7 to ≤ 100 μg/m³	> 100 to ≤ 250 μg/m³	> 250 to ≤ 500 μg/m³	> 500 μg/m³	Total
At-Risk Miner FTEs (with contract miners)								
Number	58,951	9,783	2,644	362	906	106	17	**72,768**
Percent of Total	81.0%	13.4%	3.6%	0.5%	1.2%	0.1%	0.0%	**100.0%**
Median Annual Cumulative Exposure [a]								
Baseline Scenario [b]	0.0122	0.0329	0.0597	0.0848	0.0848	0.0848	0.0848	
New PEL 50 μg/m³ Scenario [c]	0.0122	0.0329	0.0495	0.0495	0.0495	0.0495	0.0495	
Average Lifetime Excess Risk (per 1,000 Miners) [d]								
Baseline Scenario	16.82	23.77	28.88	32.27	32.27	32.27	32.27	
New PEL 50 μg/m³ Scenario	16.82	23.77	27.18	27.18	27.18	27.18	27.18	
Lifetime Excess Cases								
Baseline Scenario	1,322.0	310.0	101.8	15.6	39.0	4.6	0.7	**1,793.7**
New PEL 50 μg/m³ Scenario	1,322.0	310.0	95.8	13.1	32.8	3.8	0.6	**1,778.3**
Lifetime Excess Cases Avoided by New PEL								**15.4**

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hours worked by miners (excluding contract miners) and contract miners.

[b] The baseline scenario caps all exposures at 100 μg/m³ for MNM miners and at 85.7 μg/m³ for coal miners.

[c] The New PEL 50 μg/m³ Scenario caps all exposures at 50 μg/m³ for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

FRIA Table B - 4. Estimates of Lifetime Avoided Cases of NMRD Mortality Among Coal Miners, by Exposure Interval

	≤ 25 μg/m³	> 25 to ≤ 50 μg/m³	> 50 to ≤ 85.7 μg/m³	> 85.7 to ≤ 100 μg/m³	> 100 to ≤ 250 μg/m³	> 250 to ≤ 500 μg/m³	> 500 μg/m³	Total
At-Risk Miner FTEs (with contract miners)								
Number	58,951	9,783	2,644	362	906	106	17	**72,768**
Percent of Total	81.0%	13.4%	3.6%	0.5%	1.2%	0.1%	0.0%	**100.0%**
Median Annual Cumulative Exposure [a]								
Baseline Scenario [b]	0.0122	0.0329	0.0597	0.0848	0.0848	0.0848	0.0848	
New PEL 50 μg/m³ Scenario [c]	0.0122	0.0329	0.0495	0.0495	0.0495	0.0495	0.0495	
Average Lifetime Excess Risk (per 1,000 Miners) [d]								
Baseline Scenario	7.89	21.10	37.86	53.18	53.18	53.18	53.18	
New PEL 50 μg/m³ Scenario	7.89	21.10	31.50	31.50	31.50	31.50	31.50	
Lifetime Excess Cases								
Baseline Scenario	619.9	275.3	133.5	25.7	64.2	7.5	1.2	**1,127.2**
New PEL 50 μg/m³ Scenario	619.9	275.3	111.0	15.2	38.1	4.4	0.7	**1,064.6**
Lifetime Excess Cases Avoided by New PEL								**62.6**

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hours worked by miners (excluding contract miners) and contract miners.

[b] The baseline scenario caps all exposures at 100 μg/m³ for MNM miners and at 85.7 μg/m³ for coal miners.

[c] The New PEL 50 μg/m³ Scenario caps all exposures at 50 μg/m³ for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

FRIA Table B - 5. Estimates of Lifetime Avoided Cases of Silicosis Morbidity Among Coal Miners, by Exposure Interval

	≤ 25 μg/m³	> 25 to ≤ 50 μg/m³	> 50 to ≤ 85.7 μg/m³	> 85.7 to ≤ 100 μg/m³	> 100 to ≤ 250 μg/m³	> 250 to ≤ 500 μg/m³	> 500 μg/m³	Total
At-Risk Miner FTEs (with contract miners)								
Number	58,951	9,783	2,644	362	906	106	17	**72,768**
Percent of Total	81.0%	13.4%	3.6%	0.5%	1.2%	0.1%	0.0%	**100.0%**
Median Annual Cumulative Exposure [a]								
Baseline Scenario [b]	0.0122	0.0329	0.0597	0.0848	0.0848	0.0848	0.0848	
New PEL 50 μg/m³ Scenario [c]	0.0122	0.0329	0.0495	0.0495	0.0495	0.0495	0.0495	
Average Lifetime Excess Risk (per 1,000 Miners) [d]								
Baseline Scenario	12.82	28.79	79.46	189.90	189.90	189.90	189.90	
New PEL 50 μg/m³ Scenario	12.82	28.79	54.25	54.25	54.25	54.25	54.25	
Lifetime Excess Cases								
Baseline Scenario	1,007.3	375.6	280.1	91.7	229.4	26.8	4.2	**2,015.2**
New PEL 50 μg/m³ Scenario	1,007.3	375.6	191.2	26.2	65.5	7.7	1.2	**1,674.7**
Lifetime Excess Cases Avoided by New PEL								**340.5**

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hrs worked by miners (excluding contract miners) and contract miners.

[b] The baseline scenario caps all exposures at 100 μg/m³ for MNM miners and at 85.7 μg/m³ for coal miners.

[c] The New PEL 50 μg/m³ Scenario caps all exposures at 50 μg/m³ for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

FRIA Table B - 6. Estimates of Lifetime Avoided Cases of Lung Cancer Mortality Among MNM Miners, by Exposure Interval

	≤ 25 μg/m³	> 25 to ≤ 50 μg/m³	> 50 to ≤ 100 μg/m³	> 100 to ≤ 250 μg/m³	> 250 to ≤ 500 μg/m³	> 500 μg/m³	Total
At-Risk Miner FTEs (with contract miners)							
Number	118,672	32,369	21,805	9,185	1,825	759	**184,615**
Percent of Total	64.3%	17.5%	11.8%	5.0%	1.0%	0.4%	**100.0%**
Median Annual Cumulative Exposure [a]							
Baseline Scenario [b]	0.0061	0.0306	0.0603	0.0874	0.0874	0.0874	
New PEL 50 μg/m³ Scenario [c]	0.0061	0.0306	0.0437	0.0437	0.0437	0.0437	
Average Lifetime Excess Risk (per 1,000 Miners) [d]							
Baseline Scenario	0.36	1.82	3.68	5.47	5.47	5.47	
New PEL 50 μg/m³ Scenario	0.36	1.82	2.62	2.62	2.62	2.62	
Lifetime Excess Cases							
Baseline Scenario	56.2	78.3	106.9	66.9	13.3	5.5	**327.2**
New PEL 50 μg/m³ Scenario	56.2	78.3	76.3	32.1	6.4	2.7	**252.0**
Lifetime Excess Cases Avoided by New PEL							**75.2**

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hours worked by miners (excluding contract miners) and contract miners.

[b] The baseline scenario caps all exposures at 100 μg/m³ for MNM miners and at 85.7 μg/m³ for coal miners.

[c] The New PEL 50 μg/m³ Scenario caps all exposures at 50 μg/m³ for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

FRIA Table B - 7. Estimates of Lifetime Avoided Cases of Silicosis Mortality Among MNM Miners, by Exposure Interval

	≤ 25 μg/m³	> 25 to ≤ 50 μg/m³	> 50 to ≤ 100 μg/m³	> 100 to ≤ 250 μg/m³	> 250 to ≤ 500 μg/m³	> 500 μg/m³	Total
At-Risk Miner FTEs (with contract miners)							
Number	118,672	32,369	21,805	9,185	1,825	759	**184,615**
Percent of Total	64.3%	17.5%	11.8%	5.0%	1.0%	0.4%	**100.0%**
Median Annual Cumulative Exposure [a]							
Baseline Scenario [b]	0.0061	0.0306	0.0603	0.0874	0.0874	0.0874	
New PEL 50 μg/m³ Scenario [c]	0.0061	0.0306	0.0437	0.0437	0.0437	0.0437	
Average Lifetime Excess Risk (per 1,000 Miners) [d]							
Baseline Scenario	2.46	4.85	9.36	14.31	14.31	14.31	
New PEL 50 μg/m³ Scenario	2.46	4.85	5.90	5.90	5.90	5.90	
Lifetime Excess Cases							
Baseline Scenario	389.5	209.2	272.3	175.3	34.8	14.5	**1,095.6**
New PEL 50 μg/m³ Scenario	389.5	209.2	171.5	72.2	14.4	6.0	**862.8**
Lifetime Excess Cases Avoided by New PEL							**232.8**

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hrs worked by miners (excluding contract miners) and contract miners.

[b] The baseline scenario caps all exposures at 100 μg/m³ for MNM miners and at 85.7 μg/m³ for coal miners.

[c] The New PEL 50 μg/m³ Scenario caps all exposures at 50 μg/m³ for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

FRIA Table B - 8. Estimates of Lifetime Avoided Cases of NMRD Mortality Among MNM Miners, by Exposure Interval

	≤ 25 μg/m³	> 25 to ≤ 50 μg/m³	> 50 to ≤ 100 μg/m³	> 100 to ≤ 250 μg/m³	> 250 to ≤ 500 μg/m³	> 500 μg/m³	Total
At-Risk Miner FTEs (with contract miners)							
Number	118,672	32,369	21,805	9,185	1,825	759	**184,615**
Percent of Total	64.3%	17.5%	11.8%	5.0%	1.0%	0.4%	**100.0%**
Median Annual Cumulative Exposure [a]							
Baseline Scenario [b]	0.0061	0.0306	0.0603	0.0874	0.0874	0.0874	
New PEL 50 μg/m³ Scenario [c]	0.0061	0.0306	0.0437	0.0437	0.0437	0.0437	
Average Lifetime Excess Risk (per 1,000 Miners) [d]							
Baseline Scenario	3.97	19.65	38.24	54.78	54.78	54.78	
New PEL 50 μg/m³ Scenario	3.97	19.65	27.91	27.91	27.91	27.91	
Lifetime Excess Cases							
Baseline Scenario	628.3	847.9	1,111.7	670.8	133.3	55.5	**3,447.5**
New PEL 50 μg/m³ Scenario	628.3	847.9	811.4	341.8	67.9	28.3	**2,725.5**
Lifetime Excess Cases Avoided by New PEL							**722.0**

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hrs worked by miners (excluding contract miners) and contract miners.

[b] The baseline scenario caps all exposures at 100 μg/m³ for MNM miners and at 85.7 μg/m³ for coal miners.

[c] The New PEL 50 μg/m³ Scenario caps all exposures at 50 μg/m³ for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

FRIA Table B - 9. Estimates of Lifetime Avoided Cases of ESRD Mortality Among MNM Miners, by Exposure Interval

	≤ 25 μg/m^3	> 25 to ≤ 50 μg/m^3	> 50 to ≤ 100 μg/m^3	> 100 to ≤ 250 μg/m^3	> 250 to ≤ 500 μg/m^3	> 500 μg/m^3	Total
At-Risk Miner FTEs (with contract miners)							
Number	118,672	32,369	21,805	9,185	1,825	759	**184,615**
Percent of Total	64.3%	17.5%	11.8%	5.0%	1.0%	0.4%	**100.0%**
Median Annual Cumulative Exposure [a]							
Baseline Scenario [b]	0.0061	0.0306	0.0603	0.0874	0.0874	0.0874	
New PEL 50 μg/m^3 Scenario [c]	0.0061	0.0306	0.0437	0.0437	0.0437	0.0437	
Average Lifetime Excess Risk (per 1,000 Miners) [d]							
Baseline Scenario	12.95	23.20	28.98	32.59	32.59	32.59	
New PEL 50 μg/m^3 Scenario	12.95	23.20	26.11	26.11	26.11	26.11	
Lifetime Excess Cases							
Baseline Scenario	2,049.8	1,001.2	842.4	399.1	79.3	33.0	**4,404.8**
New PEL 50 μg/m^3 Scenario	2049.8	1001.2	759.1	319.7	63.5	26.4	**4,219.7**
Lifetime Excess Cases Avoided by New PEL							**185.0**

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hrs worked by miners (excluding contract miners) and contract miners.

[b] The baseline scenario caps all exposures at 100 μg/m^3 for MNM miners and at 85.7 μg/m^3 for coal miners.

[c] The New PEL 50 μg/m^3 Scenario caps all exposures at 50 μg/m^3 for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

FRIA Table B - 10. Estimates of Lifetime Avoided Cases of Silicosis Morbidity Among MNM Miners, by Exposure Interval

	≤ 25 μg/m³	> 25 to ≤ 50 μg/m³	> 50 to ≤ 100 μg/m³	> 100 to ≤ 250 μg/m³	> 250 to ≤ 500 μg/m³	> 500 μg/m³	Total
At-Risk Miner FTEs (with contract miners)							
Number	118,672	32,369	21,805	9,185	1,825	759	**184,615**
Percent of Total	64.3%	17.5%	11.8%	5.0%	1.0%	0.4%	**100.0%**
Median Annual Cumulative Exposure [a]							
Baseline Scenario [b]	0.0061	0.0306	0.0603	0.0874	0.0874	0.0874	
New PEL 50 μg/m³ Scenario [c]	0.0061	0.0306	0.0437	0.0437	0.0437	0.0437	
Average Lifetime Excess Risk (per 1,000 Miners) [d]							
Baseline Scenario	10.09	26.33	81.26	206.70	206.70	206.70	
New PEL 50 μg/m³ Scenario	10.09	26.33	43.63	43.63	43.63	43.63	
Lifetime Excess Cases							
Baseline Scenario	1,596.6	1,136.5	2,362.6	2,531.3	503.1	209.3	**8,339.4**
New PEL 50 μg/m³ Scenario	1596.6	1136.5	1268.4	534.3	106.2	44.2	**4,686.1**
Lifetime Excess Cases Avoided by New PEL							**3,653.3**

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hours worked by miners (excluding contract miners) and contract miners.

[b] The baseline scenario caps all exposures at 100 μg/m³ for MNM miners and at 85.7 μg/m³ for coal miners.

[c] The New PEL 50 μg/m³ Scenario caps all exposures at 50 μg/m³ for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

TECHNICAL APPENDIX C – 60-YEAR PROJECTED VALUE OF AVOIDED MORBIDITY AND MORTALITY, COMPLIANCE COSTS, AND NET BENEFITS ATTRIBUTABLE TO THE NEW RESPIRABLE CRYSTALLINE SILICA RULE AMONG COAL AND MNM MINERS

FRIA Table C - 1. Stream of Benefits over 60 Years After Compliance with the Rule for a PEL of 50 µg/m^3 Accounting for Income Growth (in millions of 2022 dollars)

Year After the Start of Rule Implementation	Value of Avoided Cases by Year (MNM and Coal Combined) Undiscounted			
	Avoided Mortality	Avoided Morbidity (Preceding Mortality)	Avoided Morbidity	Total
1 [a]	$0.22	$0.05	$0.27	**$0.54**
2	$1.49	$0.36	$3.73	**$5.58**
3	$3.19	$0.76	$7.10	**$11.06**
4	$5.36	$1.25	$10.39	**$17.00**
5	$6.36	$1.46	$13.98	**$21.81**
6	$8.88	$2.01	$17.22	**$28.10**
7	$10.94	$2.43	$20.64	**$34.01**
8	$13.77	$3.01	$24.09	**$40.87**
9	$16.97	$3.64	$27.68	**$48.28**
10	$20.53	$4.33	$30.93	**$55.79**
11	$24.48	$5.08	$34.36	**$63.92**
12	$28.99	$5.91	$37.80	**$72.70**
13	$34.06	$6.82	$41.39	**$82.27**
14	$39.69	$7.81	$44.66	**$92.16**
15	$45.88	$8.87	$48.06	**$102.81**
16	$52.71	$10.02	$51.54	**$114.26**
17	$60.95	$11.39	$54.94	**$127.27**
18	$69.46	$12.75	$58.21	**$140.41**
19	$78.24	$14.12	$61.80	**$154.16**
20	$87.31	$15.48	$65.25	**$168.05**
21	$96.68	$16.85	$68.67	**$182.20**
22	$106.34	$18.21	$71.96	**$196.52**
23	$116.31	$19.58	$75.57	**$211.46**
24	$126.59	$20.94	$79.03	**$226.57**
25	$137.20	$22.31	$82.54	**$242.04**
26	$148.13	$23.67	$86.02	**$257.82**
27	$159.39	$25.03	$89.61	**$274.04**
28	$170.99	$26.39	$92.91	**$290.30**
29	$182.94	$27.75	$96.49	**$307.18**

30	$195.23	$29.11	$99.96	**$324.31**
31	$207.89	$30.46	$103.55	**$341.90**
32	$220.89	$31.81	$106.87	**$359.57**
33	$234.25	$33.15	$110.47	**$377.87**
34	$247.97	$34.49	$113.96	**$396.42**
35	$262.06	$35.82	$117.37	**$415.25**
36	$276.52	$37.15	$120.87	**$434.55**
37	$291.31	$38.46	$124.49	**$454.26**
38	$306.42	$39.76	$127.99	**$474.17**
39	$321.86	$41.05	$131.44	**$494.34**
40	$337.64	$42.32	$134.97	**$514.92**
41	$353.75	$43.58	$138.60	**$535.93**
42	$370.10	$44.81	$142.20	**$557.10**
43	$386.68	$46.01	$145.73	**$578.41**
44	$403.49	$47.18	$149.34	**$600.02**
45	$420.55	$48.33	$153.04	**$621.93**
46	$437.84	$49.45	$156.48	**$643.77**
47	$455.20	$50.53	$159.92	**$665.66**
48	$472.64	$51.57	$163.37	**$687.57**
49	$490.15	$52.56	$166.82	**$709.53**
50	$507.74	$53.51	$170.28	**$731.52**
51	$525.37	$54.41	$173.74	**$753.53**
52	$542.77	$55.25	$177.21	**$775.23**
53	$559.94	$56.01	$180.69	**$796.64**
54	$576.87	$56.72	$184.17	**$817.75**
55	$593.55	$57.35	$187.65	**$838.56**
56	$609.96	$57.92	$191.15	**$859.03**
57	$625.68	$58.39	$194.65	**$878.72**
58	$640.73	$58.77	$198.16	**$897.66**
59	$655.11	$59.06	$201.68	**$915.84**
60	$668.82	$59.26	$205.20	**$933.28**
0% Discount Rate				
PV	**$15,053.02**	**$1,772.57**	**$6,128.86**	**$22,954.45**
Annualized	**$250.88**	**$29.54**	**$102.15**	**$382.57**
3% Discount Rate				
PV	**$4,269.73**	**$548.07**	**$2,015.67**	**$6,833.47**
Annualized	**$154.28**	**$19.80**	**$72.83**	**$246.91**
7% Discount Rate				
PV	**$1,056.52**	**$154.03**	**$641.31**	**$1,851.86**
Annualized	**$75.26**	**$10.97**	**$45.68**	**$131.91**

Note: [a] Year 1 corresponds to 2025, which is the first year the coal sector is required to comply.

FRIA Table C - 2. Projected Stream of Compliance Costs over 60 Years Post Compliance with the Rule (in millions of 2022 dollars)

Years After the Start of Rule Implementation	Total Compliance Costs by Year (MNM and Coal Combined) Undiscounted					
	Exposure Monitoring	Exposure Controls	Respiratory Protection	Medical Surveillance	ASTM Update	Total
1 [a]	$12.4	$2.9	$0.1	$0.0	$1.9	**$17.3**
2	$119.9	$18.5	$3.7	$60.7	$3.2	**$205.9**
3	$79.7	$13.6	$3.4	$5.3	$1.1	**$103.1**
4	$71.8	$13.6	$3.4	$5.3	$1.1	**$95.2**
5	$63.8	$13.6	$3.4	$10.6	$1.1	**$92.5**
6	$55.8	$13.6	$3.4	$10.6	$1.1	**$84.6**
7	$49.9	$13.8	$3.4	$53.0	$1.1	**$121.2**
8	$49.9	$13.6	$3.4	$10.8	$1.1	**$78.8**
9	$49.9	$13.6	$3.4	$10.8	$1.1	**$78.8**
10	$49.9	$13.6	$3.4	$13.3	$1.1	**$81.3**
11	$49.9	$13.9	$3.4	$13.3	$1.1	**$81.6**
12	$49.9	$15.3	$3.4	$42.5	$1.1	**$112.2**
13	$49.9	$13.6	$3.4	$13.5	$1.1	**$81.4**
14	$49.9	$13.6	$3.4	$13.5	$1.1	**$81.5**
15	$49.9	$13.6	$3.4	$16.0	$1.1	**$83.9**
16	$49.9	$13.9	$3.4	$16.0	$1.1	**$84.3**
17	$49.9	$15.3	$3.4	$31.9	$1.1	**$101.6**
18	$49.9	$13.6	$3.4	$16.1	$1.1	**$84.1**
19	$49.9	$13.6	$3.4	$16.1	$1.1	**$84.1**
20	$49.9	$13.6	$3.4	$18.6	$1.1	**$86.6**
21	$49.9	$13.9	$3.4	$18.6	$1.1	**$86.9**
22	$49.9	$15.3	$3.4	$21.4	$1.1	**$91.1**
23	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
24	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
25	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
26	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.8**
27	$49.9	$13.8	$3.4	$18.7	$1.1	**$86.9**
28	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
29	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
30	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
31	$49.9	$14.6	$3.4	$18.7	$1.1	**$87.7**
32	$49.9	$18.4	$3.4	$18.7	$1.1	**$91.5**
33	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
34	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
35	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
36	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.8**

37	$49.9	$13.9	$3.4	$18.7	$1.1	**$87.0**
38	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
39	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
40	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
41	$49.9	$13.9	$3.4	$18.7	$1.1	**$87.0**
42	$49.9	$15.2	$3.4	$18.7	$1.1	**$88.4**
43	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
44	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
45	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
46	$49.9	$13.9	$3.4	$18.7	$1.1	**$87.1**
47	$49.9	$15.3	$3.4	$18.7	$1.1	**$88.4**
48	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
49	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
50	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
51	$49.9	$13.9	$3.4	$18.7	$1.1	**$87.0**
52	$49.9	$15.3	$3.4	$18.7	$1.1	**$88.5**
53	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
54	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
55	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
56	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.8**
57	$49.9	$13.8	$3.4	$18.7	$1.1	**$86.9**
58	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
59	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
60	$49.9	$13.6	$3.4	$18.7	$1.1	**$86.7**
0% Discount Rate						
PV	$3,096	$828	$203	$1,129	$71	$5,326
Annualized	**$51.598**	**$13.794**	**$3.375**	**$18.818**	**$1.181**	**$88.766**
3% Discount Rate						
PV	$1,473	$378	$92	$521	$34	$2,498
Annualized	**$53.237**	**$13.655**	**$3.318**	**$18.836**	**$1.231**	**$90.277**
7% Discount Rate						
PV	$781	$188	$45	$264	$18	$1,297
Annualized	**$55.639**	**$13.396**	**$3.219**	**$18.818**	**$1.315**	**$92.387**

Note: [a] Year 1 corresponds to 2025, which is the first year the coal sector is required to comply.

FRIA Table C - 3. Projected Stream of Net Benefits over 60 Years After Compliance with the Rule (in millions of 2022 dollars)

Years After the Start of Rule Implementation	Value of Avoided Cases Net of Costs by Year MNM and Coal Combined Undiscounted		
	Value of Total Cases Avoided by Year	Total Compliance Costs by Year	Net Value of Total Cases Avoided by Year
1 [a]	$0.54	$17.3	-$16.73
2	$5.58	$205.9	-$200.36
3	$11.06	$103.1	-$92.05
4	$17.00	$95.2	-$78.17
5	$21.81	$92.5	-$70.65
6	$28.10	$84.6	-$56.45
7	$34.01	$121.2	-$87.20
8	$40.87	$78.8	-$37.95
9	$48.28	$78.8	-$30.51
10	$55.79	$81.3	-$25.53
11	$63.92	$81.6	-$17.71
12	$72.70	$112.2	-$39.50
13	$82.27	$81.4	$0.84
14	$92.16	$81.5	$10.71
15	$102.81	$83.9	$18.87
16	$114.26	$84.3	$29.96
17	$127.27	$101.6	$25.69
18	$140.41	$84.1	$56.32
19	$154.16	$84.1	$70.10
20	$168.05	$86.6	$81.45
21	$182.20	$86.9	$95.29
22	$196.52	$91.1	$105.41
23	$211.46	$86.7	$124.76
24	$226.57	$86.7	$139.84
25	$242.04	$86.7	$155.34
26	$257.82	$86.8	$171.07
27	$274.04	$86.9	$187.11
28	$290.30	$86.7	$203.57
29	$307.18	$86.7	$220.48
30	$324.31	$86.7	$237.58
31	$341.90	$87.7	$254.16
32	$359.57	$91.5	$268.04
33	$377.87	$86.7	$291.17

34	$396.42	$86.7	$309.70
35	$415.25	$86.7	$328.55
36	$434.55	$86.8	$347.77
37	$454.26	$87.0	$367.23
38	$474.17	$86.7	$387.45
39	$494.34	$86.7	$407.64
40	$514.92	$86.7	$428.20
41	$535.93	$87.0	$448.91
42	$557.10	$88.4	$468.73
43	$578.41	$86.7	$491.71
44	$600.02	$86.7	$513.29
45	$621.93	$86.7	$535.22
46	$643.77	$87.1	$556.70
47	$665.66	$88.4	$577.25
48	$687.57	$86.7	$600.85
49	$709.53	$86.7	$622.82
50	$731.52	$86.7	$644.79
51	$753.53	$87.0	$666.49
52	$775.23	$88.5	$686.76
53	$796.64	$86.7	$709.94
54	$817.75	$86.7	$731.02
55	$838.56	$86.7	$751.85
56	$859.03	$86.8	$772.27
57	$878.72	$86.9	$791.79
58	$897.66	$86.7	$810.93
59	$915.84	$86.7	$829.13
60	$933.28	$86.7	$846.55
0% Discount Rate			
PV	$22,954	$5,326	$17,628
Annualized	**$382.6**	**$88.8**	**$293.8**
3% Discount Rate			
PV	$6,833	$2,498	$4,335
Annualized	**$246.9**	**$90.3**	**$156.6**
7% Discount Rate			
PV	$1,852	$1,297	$555
Annualized	**$131.9**	**$92.4**	**$39.5**

Note: [a] Year 1 corresponds to 2025, which is the first year the coal sector is required to comply.