Four Corners Power Plant and
Navajo Mine Energy Project
FEIS

APPENDIX

A

AIR QUALITY AND CLIMATE CHANGE INFORMATION

Table of Contents

Tables

Figures

Appendix A
Supplemental Air Quality Information

A.1 Acid Rain

Since the 1970s, implementation of Clean Air Act (CAA) regulations has reduced emissions of NO_X, SO_2, and mercury and reduced the impact of atmospheric deposition on water quality and aquatic ecosystems. Most CAA regulations were designed to address the effect of air pollution on human health and welfare, not water quality and aquatic ecosystems. However, in spite of progress, atmospheric deposition continues to affect water quality and harm aquatic ecosystems. (GAO 2013)

Three key regulations or programs have contributed to reductions in acid rain precursors: 1) Title II emission standards for mobile sources (motor vehicles); 2) actions designed to meet primary NAAQS; and 3) the Acid Rain Program. Neither vehicle emissions standards nor actions to meet primary NAAQS are designed to address the deposition effects of NO_X and SO_2 emissions on surface waters. Vehicle emission standards limit emissions of pollutants in engine exhaust, including NO_X, to the greatest extent achievable through the application of available technology with respect to cost, energy, and safety factors. The primary NAAQS are designed to protect public health, including "sensitive" populations such as asthmatics, children, and the elderly. Secondary NAAQS are designed to safeguard human welfare, which includes land-based ecosystems, but not specifically water quality and aquatic ecosystems. In contrast, the Acid Rain Program was designed, in part, to address the effect of NO_X and SO_2 on surface waters. (GAO 2013)

A.1.1 <u>Acid Rain Program</u>

FCPP is subject to both Parts 71 and 72 as administered by the Navajo Nation EPA and EPA and is required to hold sufficient Part 73 SO2 allowances to cover annual emissions.

40 CFR Parts 72 and 73 – Acid Rain Permits and SO_2 Allowances

Part 72 establishes general provisions and operating permit requirements for affected electric power generating facilities and units under the Acid Rain Program, pursuant to Title IV of the Clean Air Act, 42 U.S.C. 7401, et seq. Some Part 72 requirements supplement, and in some cases modify, requirements under Parts 70 and 71 and other regulations implementing Title V for sources also covered by the Acid Rain Program. As such, FCPP is subject to both Parts 71 and 72 permitting requirements under the authority of the Navajo Nation EPA and EPA Region IX, respectively, and is required to hold sufficient Part 73 SO2 allowances to cover annual emissions. Section II.B of the FCPP Part 71 permit incorporates by reference Part 72 and 73 provisions of the Phase II Acid Rain permit.

40 CFR Part 75 – Continuous Emissions Monitoring

The FCPP is subject to Part 75 requirements for the monitoring, recordkeeping, and reporting of SO2, NOX, CO2 emissions, volumetric flow, and opacity data from affected units under the Acid Rain Program pursuant to 40 CFR Part 98. Part 75 also sets forth provisions for the monitoring, recordkeeping, and reporting of NOX mass emissions, which are required to be controlled in order to demonstrate compliance with a NOX mass emission reduction program. For FCPP, this is consistent with 40 CFR Part 49 – Source Specific Federal Implementation Plan for Implementing Best Available Retrofit Technology for Four Corners Power Plant: Navajo Nation. Under Part 75 (also Parts 70, 71, and 72) operating and emissions records must be retained for a minimum of five years. Section II.B of the FCPP Part 71 permit incorporates by reference Part 75 provisions of the Phase II Acid Rain permit.

Title IV of the Clean Air Act Amendments of 1990 set the goal of reducing annual SO_2 emissions by 10 million tons per year below 1980 levels. To achieve these reductions, the Act required a two-phase approach to reducing SO_2 and NO_X emissions from fossil fuel power plants. Phase I began in 1995 and affected 445 generating units, mainly at coal-fired electric utility plants located in Eastern and Midwestern states. Phase II began in 2000 and lowered annual emissions limits imposed on large, higher emitting plants and also set limits on smaller, cleaner plants fired by coal, oil, and gas, encompassing over 2,000 generating units rated 25 megawatts or greater nationwide. The Act also required a 2 million ton per year reduction in NO_X emissions by 2000 using technology such as low-NO_X burners in coal-fired units.

Except for the opt-in program, Four Corners Power plant is subject to the principal provisions of the Acid Rain Program as described below (EPA 2013a):

- *Designated Representatives.* Each source appoints an individual, the Designated Representative, to represent the owners and operators of the source in all matters relating to the holding and disposal of allowances for its units that are affected by the Clean Air Act. The Designated Representative is also responsible for all submissions pertaining to permits, compliance plans, emission monitoring reports, offset plans, compliance certification, and other necessary information. A source may also appoint an Alternate Designated Representative.
- *Permits.* The Designated Representative for each source is required to file an Acid Rain Permit application and a compliance plan to the Title V permitting authority for each affected unit at the source. Issued permits require that unit accounts hold sufficient allowances to cover SO_2 emissions in each year, comply with applicable NO_X limits, and monitor and report emissions. Permits are subject to public review and comment before approval.
- *Allowance Trading.* The Acid Rain Program represents a departure from exclusive reliance on traditional command-and-control regulations that establish specific emission limits on affected sources. The allowance trading system uses market incentives to reduce pollution. Under this system, affected units are allocated allowances based on historic fuel consumption and a specific emissions rate. Each allowance permits a unit to emit 1 short ton (2,000 pounds) of SO_2 during or after a specified year. For each ton of SO_2 emitted in a given year, one allowance is retired. Thus, allowances must be obtained annually to continue operation. Allowances may be bought, sold, or banked by organizations or individuals. However, regardless of the number of allowances a source holds, it may not emit at levels that would violate Federal or state limits set under Title I of the Act to protect public health.
- *Annual Reconciliation.* Reconciliation is the process by which EPA compares allowances held by an affected unit to its annual emissions. At the end of each year, sources are granted a 60-day reconciliation period to resolve whether sufficient allowances are held to match SO_2 emissions during the previous year. Needed allowances may be bought or excess allowances may be sold or banked for future use during the reconciliation period.
- *Allowance Tracking System.* The EPA has instituted an electronic recordkeeping and notification system to track allowance transactions and the status of allowance accounts. The Allowance Tracking System is the official tally of allowances by which EPA determines compliance with the emissions limitations. Accounts contain information on unit account balances, account representatives (which must be appointed by each trading party), and the serial number for each allowance.
- *Allowance Auctions.* The EPA holds an allowance auction annually. The auctions help to send the market a competitive price signal, as well as furnish utilities with an additional avenue for purchasing needed allowances.
- *Emissions Monitoring, Recordkeeping, and Reporting.* Under the Acid Rain Program, each source must continuously measure and record its emissions of SO_2, NO_X, and CO_2, as well as

heat input, stack volumetric flow rate, and stack opacity using a certified, quality-assured continuous emission monitoring system (CEMS). Sources electronically report hourly emissions data to EPA on a quarterly basis and reconciliation reports annually. Monitoring ensures accurate accounting of allowances and that SO_2 and NO_X emissions reduction goals are met. As Acid Rain sources are also Title V (Federal Operating Permit) sources, all monitoring and operating data records must be retained for a minimum of five years.

- *Excess Emissions.* If annual emissions exceed the number of allowances held, the owners or operators of delinquent units must pay a penalty of $2,000 per excess ton of SO_2 or NO_X emissions. In addition, violating sources must offset the excess SO_2 emissions with allowances in an amount equivalent to the excess. A source may either have allowances deducted immediately from its account or submit an excess emissions offset plan to the EPA.
- *Pollution Prevention.* The allowance trading system contains an inherent incentive for utilities to prevent pollution: for each ton of SO_2 that a utility avoids emitting, one less allowance is needed. Utilities that reduce emissions through energy efficiency and renewable energy are able to sell, use, or bank their surplus allowances. As provided in the Act, the EPA has a reserve of 300,000 allowances to stimulate energy efficiency and renewable energy generation. Utilities that either implement demand-side energy conservation programs or install renewable energy generation facilities may be eligible to receive bonus allowances from this reserve.
- *Nitrogen Oxides Reductions.* The Act set a goal of reducing NO_X by 2 million tons from 1980 levels. The Acid Rain program focuses on major sources of NO_X: coal-fired electric utility boilers. As with the SO_2 emission reduction requirements, the NO_X program was implemented in two phases, beginning in 1996 and 2000. The NO_X program embodies many of the same principles as the SO_2 program, however, it does not "cap" NO_X emissions as the SO_2 program does, nor does it utilize an allowance trading system. Rather, NO_X emission limitations for boilers provide operational flexibility by focusing on the average emission rate to be achieved (expressed in pounds of NO_X per million BTU of heat input) with two options for determining compliance.
- *Compliance Options.* The Acid Rain Program allows sources to develop their own compliance strategies within the regulatory structure. For example, to reduce SO_2 emissions an affected source may repower (overhaul) its units, use cleaner burning fuel, or reassign some of its generation capacity from older, dirtier units to newer, cleaner ones. Sources also may elect to reduce demand by adopting conservation or efficiency measures. Most options, like fuel switching, require no special prior approval, allowing the source to respond quickly to market conditions. For NO_X, the source may meet the performance standard on a unit basis, enter into an emissions averaging plan, or apply for an alternative emissions limitation.
- *Voluntary Opt-in Program.* The Opt-in Program expands EPA's Acid Rain Program to include other types of SO_2 emission sources. Recognizing that there are emission reduction opportunities in the industrial sector, Congress established the Opt-in Program under section 410 of the Act. The Opt-in Program allows sources not required to participate in the Acid Rain Program the opportunity to enter the program on a voluntary basis and receive SO_2 allowances. If participating sources can reduce their SO_2 emissions at a relatively low cost, surplus allowances can be profitably transferred to the utility sector where emission reductions can be more expensive.

A.2 PSD Permitting Requirements

Prevention of Significant Deterioration (40 CFR 51.166 and 40 CFR 52.21) provides the overall regulatory framework for the permitted operation of FCPP. As the term implies, PSD is designed to:

- Protect public health and welfare;
- Preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreational, scenic, or historic value;
- Insure that economic growth will occur in a manner consistent with the preservation of existing clean air resources; and
- Assure that any decision to permit increased air pollution in any area to which this section applies is made only after careful evaluation of all the consequences of such a decision and after adequate procedural opportunities for informed public participation in the decision making process.

PSD does not prohibit new or existing stationary sources, such as oil refineries, factories, or power plants, from increasing emissions; rather, PSD is designed to ensure that emissions increases would have no significant effect on regional air quality. (EPA 2013d)

PSD permitting applies to new major sources or major modifications at existing sources (e.g., FCPP) located in NAAQS attainment or unclassified areas for applicable pollutants. In contrast, nonattainment permitting applies to new major sources or major modifications at existing major sources located in areas of NAAQS nonattainment (e.g., major sources emitting NO_x and PM_{10} in large urban areas), and is more stringent than PSD. For example, if an area is in attainment for CO and nonattainment for ozone, PSD requirements would apply to CO emissions while nonattainment requirements would apply to NO_x.

Since FCPP is located in an NAAQS attainment area for all criteria pollutants (Section 4.1, Air Quality; Table 4.1-4, Ambient Air Monitoring Sites and Parameters in Vicinity of Proposed Action - Four Corners Area), PSD applies to emissions of NO_X, CO, SO_2, PM_{10}, $PM_{2.5}$, and lead. In general, PSD permitting requires the following (EPA 2013d):

- *Best Available Control Technology (BACT).* BACT is an emissions limitation, which is based on the maximum degree of control that can be achieved. It is a case-by-case determination that incorporates technical, energy, environmental, and economic criteria which change over time due to advancements. BACT can be add-on control equipment or modification of the production processes or methods, or combinations thereof. In some cases, BACT can be fuel cleaning or treatment and innovative fuel combustion techniques. In other cases, BACT may be a design, equipment, work practice, or operational standard if imposition of an emissions standard is infeasible. The EPA maintains an online guidance “clearinghouse” database containing up-to-date information on what has been required as BACT in air permits nationwide. Many states and air districts also maintain online BACT clearinghouses. In combination, these databases assist permit applicants in determining the latest BACT for a wide variety of industrial processes.
- *Air Quality Impact Analysis (AQIA).* The main purpose of the AQIA is to demonstrate that new emissions from a proposed major stationary source or major modification, in conjunction with other emissions increases and decreases from existing sources, will not cause or contribute to a violation of any applicable NAAQS or PSD increment. Generally, an AQIA involves: 1) an assessment of existing air quality, which may include ambient monitoring data and air quality dispersion modeling results, and 2) predictions, using dispersion modeling, of changes in ambient concentrations (i.e., PSD increments) that would result from the applicant's proposed project and future growth associated with the project. A PSD increment is the maximum allowable increase in ambient concentration above a determined baseline. Significant deterioration occurs when the amount of new pollution would exceed the PSD increment or NAAQS as applicable.

- *Additional Impacts Analysis.* The additional impacts analysis assesses the impacts of air pollution on soils, waters, vegetation, and visibility caused by any increase in emissions of any regulated pollutant from the source or modification under review, and from associated growth. Associated growth is industrial, commercial, and residential growth that will occur in the area due to the source. Particular attention is directed at visibility impacts in Class I areas. Class I areas are areas of special national or regional natural, scenic, recreational, or historic value for which the PSD regulations provide special protection. If a source would adversely impact visibility or other air quality related value (e.g., deposition) in a Class I area, a permit can be denied, even in cases where no PSD increments would be exceeded.
- *Regulatory Compliance.* The owner/operator of the new or modified source must certify that the facility will operate or is operating in compliance with all applicable air quality rules and regulations and permit conditions. Further, the owner/operator must also certify that other owned/operated facilities elsewhere are also in compliance as applicable.
- *Public Involvement.* The permitting process, whether PSD or NSR, accommodates and encourages public participation and input in several ways: 1) commenting on permit applications and draft permit conditions during public comment periods; 2) commenting on proposed rules and regulations; 3) requesting public hearings on permits for controversial projects or actions; 4) appealing permits issued pursuant to State Implementation Plans (SIPs) before a board of appeals or in court; 5) commenting on EPA actions to approve SIPs; 6) bringing enforcement actions against sources that are violating rules or permit conditions; and 7) bringing citizen lawsuits against the source, the permitting authority, and/or the EPA pursuant to Section 304 of the Clean Air Act which allows citizens to sue to enforce statutory requirements.

Relevant to the proposed Action, the above PSD permitting criteria would be requisite for a major modification at FCPP. A recent D.C. Circuit Court decision on PSD rules related to $PM_{2.5}$ increments and baselines could affect FCPP in the future (Sierra Club v. EPA, 2014 WL 2619824 [D.C. Cir. 2014]).. On January 22, 2013, the U.S. Court of Appeals for the District of Columbia Circuit granted a request from the EPA to vacate and remand portions of two PSD $PM_{2.5}$ rules, which addressed the Significant Impact Levels (SILs) so that the EPA could correct errors in the rules. The Court also vacated parts of rules establishing $PM_{2.5}$ Significant Monitoring Concentrations (SMCs) due to regulatory errors. The Court's decision became final on March 15, 2013, and the affected provisions of 40 CFR 51.166 and 52.21 were vacated. The EPA will develop replacement PSD $PM_{2.5}$ rules to correct errors and address the Court's decision. (EPA 2013d)

A.3 Monitoring Projects for EPA and National Deposition Program Sites

In support of the Regional Haze Rule, the Interagency Monitoring of Protected Visual Environments (IMPROVE) program is a cooperative measurement effort sponsored by ten Federal, regional, and state organizations including the National Park Service, U.S. Forest Service, Bureau of Land Management, U.S. Fish and Wildlife Service, and Environmental Protection Agency. The IMPROVE monitoring program was established in 1985 to aid the creation of Federal and State Implementation Plans (FIPs, SIPs) for the protection of visibility in Class I areas (currently 156 national parks, national monuments, and wilderness areas) as stipulated in the 1977 CAA amendments. The objectives of IMPROVE are (CSU 2013b):

- Establish current visibility and aerosol conditions in mandatory Class I areas;
- Identify chemical species and emission sources responsible for existing man-made visibility impairment;
- Document long-term trends for assessing progress towards the national visibility goal; and
- Provide regional haze monitoring representing all visibility-protected Federal Class I areas where practical.

IMPROVE has also been a key participant in visibility-related research, including the advancement of monitoring instrumentation, analysis techniques, visibility modeling, policy formulation, and source attribution field studies. The IMPROVE program is a tool for tracking progress towards the goal of reaching natural background visibility by 2060, which requires statistical determination of three visibility metrics (CSU 2013a):

- *Natural Conditions (ultimate goal of haze regulations).* Visibility (deciviews) for the 20 percent most-impaired and 20 percent least-impaired days that would exist if there were no anthropogenic emissions;
- *Baseline Conditions (reference point to measure progress against).* Visibility (deciviews) for the 20 percent most-impaired and 20 percent least-impaired days for the years 2000 to 2004; and
- *Current Conditions (used to determine progress made).* Visibility (deciviews) for the 20 percent most-impaired days and 20 percent least-impaired days for the most recent 5-year period.

The IMPROVE monitoring network consists of custom-built aerosol samplers and optical sensors. The network began operating in 1988 with 20 monitoring sites in Class I Areas. By 1999, the network expanded to 30 monitoring sites in Class I Areas and 40 supplemental sites using IMPROVE technology. Sites are operated by Federal and state agencies following standardized protocols. Presently, in support of the Regional Haze Rule, the IMPROVE network comprises over 160 sites nationwide. (CSU 2013b)

There are 16 Class I areas within a 300-kilometer (186-mile) radius of FCPP, ten of which host IMPROVE sites (as indicated by the 5-character ID code name):

1. Petrified Forest National Park (AZ) – PEFO1
2. Grand Canyon National Park (AZ) – GRCA2
3. Capitol Reef National Park (UT) – CAPI1
4. Canyonlands National Park (UT) – CANY1
5. Arches National Park (UT)
6. Mesa Verde National Park (CO) – MEVE1
7. Black Canyon of the Gunnison Wilderness (CO)
8. Weminuche Wilderness (CO) – WEMI1
9. La Garita Wilderness (CO)
10. West Elk Wilderness (CO)
11. Maroon Bells – Snowmass Wilderness (CO)
12. Great Sand Dunes National Monument (CO) – GRSA1
13. Wheeler Peak Wilderness (NM) – WHPE1
14. Pecos Wilderness (NM)
15. Bandelier National Monument (NM) – BAND1
16. San Pedro Parks Wilderness (NM) – SAPE1

Ten other Class I areas (outside 300 km) in the general vicinity include:

1. Mount Baldy Wilderness (AZ) – BALD1
2. Sierra Ancha Wilderness (AZ) – SIAN1
3. Mazatzal Wilderness (AZ)

4. Pine Mountain Wilderness (AZ)
5. Sycamore Canyon Wilderness (AZ)
6. Zion National Park (UT) – ZION1
7. Bryce Canyon National Park (UT) – BRCA1
8. Flat Tops Wilderness (CO)
9. Eagles Nest Wilderness (CO)
10. Bosque Del Apache Wilderness (NM) – BOAP1

Table A-1 lists details about the 15 IMPROVE sites identified above.

Table A-1 Visibility Monitoring Sites - Four Corners Region and Vicinity

Site ID Code	State	Location / Site Name	Elevation MSL meters	Elevation MSL feet	North Latitude	West Longitude	Monitoring Start Date
BALD1	Arizona	Mount Baldy Wilderness[1]	2,513	8,245	34.0584	-109.4405	2/29/2000
BAND1	New Mexico	Bandelier National Monument	1,987	6,519	35.7797	-106.2664	3/2/1988
BOAP1	New Mexico	Bosque del Apache Wilderness[1]	1,383	4,537	33.8695	-106.8520	4/5/2000
BRCA1	Utah	Bryce Canyon National Park[1]	2,477	8,127	37.6184	-112.1736	3/2/1988
CANY1	Utah	Canyonlands National Park	1,799	5,902	38.4587	-109.8209	3/2/1988
CAPI1	Utah	Capitol Reef National Park	1,890	6,201	38.3022	-111.2926	3/28/2000
GRCA2	Arizona	Grand Canyon National Park (Hance)	2,267	7,438	35.9731	-111.9841	9/24/1997
GRSA1	Colorado	Great Sand Dunes National Monument	2,504	8,215	37.7249	-105.5186	5/4/1988
MEVE1	Colorado	Mesa Verde National Park	2,177	7,142	37.1984	-108.4907	3/5/1988
PEFO1	Arizona	Petrified Forest National Park	1,767	5,797	35.0781	-109.7683	3/2/1988
SAPE1	New Mexico	San Pedro Parks Wilderness	2,919	9,577	36.0140	-106.8446	8/15/2000
SIAN1	Arizona	Sierra Ancha Wilderness[1]	1,595	5,233	34.0909	-110.9420	2/10/2000
WEMI1	Colorado	Weminuche Wilderness	2,765	9,072	37.6594	-107.7998	3/2/1988
WHPE1	New Mexico	Wheeler Peak Wilderness	3,372	11,063	36.5855	-105.4513	8/15/2000
ZION1	Utah	Zion National Park[1]	1,545	5,069	37.4591	-113.2243	3/21/2000

Source: CSU 2013c

Notes:

[1] Indicates location is outside 300 kilometer radius of FCPP, data not used in 10-site summaries

IMPROVE = Interagency Monitoring of Protected Visual Environments

A.3.2 Measurements Technology

Every IMPROVE site utilizes a 4-channel aerosol sampler to measure, via laboratory analysis of exposed filter media, speciated fine aerosols and particulates mass. The IMPROVE aerosol sampler was developed specifically for the program and has been in use since 1987 with ongoing refinements. Measured parameters include PM_{10}, $PM_{2.5}$, optical absorption, hydrogen, multiple metals, nitrate, chloride, sulfate, nitrite, and carbon (elemental and organically-bound). Samples are periodically collected on four different types of filter media (channels) by passing a known volume of air across each filter. Exposed filters are sent to specialized laboratories for chemical speciation analysis using several different analytical methods. An elaborate quality assurance and quality control (QA/QC) program ensures the precision, accuracy, and validity of each measurement from filter change to final results. (CSU 2013b)

Selected IMPROVE sites are also equipped with optical instruments: transmissometers to measure light extinction, nephelometers to measure light scattering, and automatic cameras to record the visible scene. A long-path transmissometer continuously measures the light extinction coefficient by measuring the attenuation of light from a source of known intensity passing through a fixed distance in air. An integrating nephelometer continuously determines the atmospheric scattering coefficient by directly measuring light scattered by aerosols and gases in a known volume of air. These instruments are also managed with a defined QA/QC program to ensure reliability and data quality. (CSU 2013b)

A.3.3 Special Studies

Pursuant to the 1980 visibility regulations, source attribution analyses may be required for Class I areas where it is believed that one or more sources substantially contribute to the visibility impairment. When routine monitoring data are insufficient for the attribution analysis, IMPROVE special studies may be performed. These studies are designed to obtain the necessary air quality, meteorological, and emissions data to identify and characterize sources contributing to the visibility impairment. In addition to source attribution, IMPROVE special studies have been performed to enhance the science of visibility monitoring and aerosol physio-chemical-optical properties. (CSU 2013b)

A.3.4 Haze and Visibility Environment

The IMPROVE program publishes monitoring data summaries which can be used to assess visibility impacts of emissions sources in the Four Corners region. Due to the wide array of analytic and calculation methods employed, a large amount of data is generated by the program which is used by researchers and agencies to assess visibility and haze impacts of stationary and mobile source emissions in Class I areas as described above. For this public discussion, six IMPROVE parameters are the most relevant (CSU 2013b, 2013c):

- Particulate matter (PM) light extinction for particulate matter in units of inverse megameters (Mm^{-1}). Light extinction is the ability of particles in the air to scatter and absorb photons, thus reducing viewing distance. The higher the extinction coefficient, the poorer the visibility.
- Total light extinction (adds Rayleigh scattering value for gases to PM light extinction) in units of inverse megameters (Mm^{-1}). Atmospheric gases (see Table 3.2-1 in Section 3.2) also scatter and absorb photons on the molecular and atomic levels. The blue color of the daytime sky is due to Rayleigh scattering, as is the orange color of sunlight at dawn and dusk. The higher the extinction coefficient, the poorer the visibility.
- Deciview in dimensionless units (dV). One deciview represents the minimal perceptible change in visibility to the human eye and is proportional to the logarithm of the light extinction coefficient. As such, it is linear with respect to perceived visual changes over its entire range, analogous to the decibel scale for sound. A 1-dV change represents about a 10 percent change in the extinction coefficient. The higher the deciview value, the poorer the visibility (corollary to higher pollutant concentrations which worsen air quality).

- Standard visual range (SVR) in units of kilometers (km) and miles (mi). The lower the SVR, the poorer the visibility.
- Fine reconstructed mass in units of micrograms per cubic meter ($\mu g/m^3$). Generally analogous to $PM_{2.5}$, this parameter is calculated by adding results for several individual analytes together. The higher the mass concentration, the poorer the air quality and visibility.
- Total reconstructed mass in units of micrograms per cubic meter ($\mu g/m^3$). Generally analogous to PM_{10}, this parameter is calculated by adding results for several individual analytes together. The higher the mass concentration, the poorer the air quality and visibility.

Gravimetric $PM_{2.5}$ and PM_{10} are also parameters, however, for consistency with other calculated parameters, reconstructed mass results are provided here. Tables A-2 through A-16 summarize 11 years of historic IMPROVE data for 15 sites comprising the six parameters described above (some sites did not operate for all 11 years or have missing data, however, data gaps are minor, not more than 10 percent overall).

The deciview (dV) is a linearized and conveniently scaled unit of measure for quantifying visibility, similar to the decibel (dB) scale for quantifying sound. A 1-deciview change on a 20-deciview day (moderate visibility) is perceived to be the same as a 1-deciview change on a 5-deciview day (excellent visibility). This is not the case for light extinction or visual range, which are non-linear (CIRA 1999). For the IMPROVE program, deciviews and standard visual range (SVR in units of kilometers or miles) are correlated to the light extinction coefficient (β_{ext} in units of inverse megameters, Mm^{-1}) using the following equations:

$$\text{dV, dimensionless} = 10 \ln (\beta_{ext} / 10)$$

$$\text{SVR, kilometers} = 3910 / \beta_{ext}$$

Table A-2 IMPROVE Summary Results - Mt. Baldy Wilderness

Site ID Code	Year	Group Code	Light Extinction PM Mm^{-1}	Light Extinction Total Mm^{-1}	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine $\mu g/m^3$	Reconstructed Mass Total $\mu g/m^3$
BALD1	2003	10	4.0	13.0	2.61	174	281	0.9	1.6
BALD1	2004	10	4.3	13.3	2.82	171	275	1.1	1.6
BALD1	2005	10	4.6	13.6	3.03	168	271	1.1	2.0
BALD1	2006	10	4.7	13.7	3.15	166	267	1.1	2.1
BALD1	2007	10	4.1	13.1	2.66	174	280	1.0	2.1
BALD1	2008	10	4.1	13.1	2.66	174	280	1.0	1.9
BALD1	2009	10	4.6	13.6	3.03	168	270	1.1	2.1
BALD1	2010	10	4.3	13.3	2.81	171	275	0.9	2.3
		Lowest 20% dv Days	**4.4**	**13.4**	**2.85**	**171**	**275**	**1.0**	**2.0**
BALD1	2003	90	27.5	36.5	12.63	69	110	7.1	13.4
BALD1	2004	90	19.9	28.9	10.38	85	136	5.0	8.5
BALD1	2005	90	27.9	36.9	12.39	71	114	6.5	10.6
BALD1	2006	90	17.4	26.4	9.66	90	144	4.8	10.2
BALD1	2007	90	23.8	32.8	11.55	76	122	5.8	12.4
BALD1	2008	90	34.2	43.2	14.10	60	97	8.5	18.8
BALD1	2009	90	27.3	36.3	11.25	81	130	6.3	13.8
BALD1	2010	90	15.7	24.7	8.95	96	155	3.8	8.4
		Highest 20% dv Days	**24.2**	**33.2**	**11.36**	**78**	**126**	**6.0**	**12.0**
BALD1	2003	100	13.2	22.2	7.27	118	190	3.4	6.7
BALD1	2004	100	10.9	19.9	6.47	125	201	2.8	5.2
BALD1	2005	100	13.6	22.6	7.40	116	187	3.3	5.9
BALD1	2006	100	10.4	19.4	6.36	125	201	2.6	5.6

Site ID Code	Year	Group Code	Light Extinction PM Mm^{-1}	Light Extinction Total Mm^{-1}	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine $\mu g/m^3$	Reconstructed Mass Total $\mu g/m^3$
BALD1	2007	100	12.1	21.1	6.89	121	195	3.0	6.3
BALD1	2008	100	15.4	24.4	7.96	112	181	4.0	8.1
BALD1	2009	100	12.2	21.2	6.57	125	201	3.1	6.3
BALD1	2010	100	9.4	18.4	5.85	131	210	2.3	5.1
		Average dv Days	**12.2**	**21.2**	**6.85**	**122**	**196**	**3.1**	**6.1**

Source: CSU 2013c

Notes:

Light extinction units are inverse megameters (Mm^{-1})

PM light extinction for particulate matter in air; Total light extinction adds Rayleigh scattering value (gases)

Deciview units are dimensionless (dv); Reconstructed mass units are micrograms per cubic meter ($\mu g/m^3$)

Fine reconstructed mass analogous to $PM_{2.5}$; Total reconstructed mass analogous to PM_{10}

Table A-3 IMPROVE Summary Results - Bandelier National Monument

Site ID Code	Year	Group Code	Light Extinction PM Mm[1]	Light Extinction Total Mm[1]	Deciview dv	Standard Visual Range Miles	Standard Visual Range km	Reconstructed Mass Fine µg/m³	Reconstructed Mass Total µg/m³
BAND1	2000	10	7.5	16.5	4.95	140	225	1.7	3.4
BAND1	2001	10	7.4	16.4	4.89	141	226	1.8	3.5
BAND1	2002	10	7.6	16.6	5.03	139	224	1.8	3.5
BAND1	2003	10	7.4	16.4	4.94	140	225	1.7	3.3
BAND1	2004	10	7.5	16.5	4.95	140	226	1.8	3.0
BAND1	2005	10	6.1	15.1	4.09	152	245	1.3	2.8
BAND1	2006	10	6.9	15.9	4.63	144	232	1.6	3.2
BAND1	2007	10	6.8	15.8	4.49	146	236	1.6	2.9
BAND1	2008	10	5.8	14.8	3.91	154	248	1.4	2.4
BAND1	2009	10	5.4	14.4	3.64	158	255	1.3	2.5
BAND1	2010	10	5.1	14.1	3.38	162	261	1.2	2.4
		Lowest 20% dv Days	**6.7**	**15.7**	**4.45**	**147**	**237**	**1.6**	**3.0**
BAND1	2000	90	58.6	67.6	14.58	63	101	11.0	15.1
BAND1	2001	90	21.5	30.5	11.06	78	126	5.1	9.4
BAND1	2002	90	26.8	35.8	12.28	71	114	6.3	12.1
BAND1	2003	90	28.7	37.7	12.72	68	110	6.5	12.2
BAND1	2004	90	19.7	28.7	10.49	83	133	4.7	9.1
BAND1	2005	90	25.8	34.8	12.28	70	113	5.9	10.4
BAND1	2006	90	23.2	32.2	11.58	75	120	5.4	11.0
BAND1	2007	90	29.7	38.7	12.78	69	111	6.1	9.4
BAND1	2008	90	22.8	31.8	11.54	74	120	6.1	13.4

Site ID Code	Year	Group Code	Light Extinction PM Mm[1]	Light Extinction Total Mm[1]	Deciview dv	Standard Visual Range Miles	Standard Visual Range km	Reconstructed Mass Fine µg/m³	Reconstructed Mass Total µg/m³
BAND1	2009	90	23.1	32.1	11.03	81	130	5.6	11.5
BAND1	2010	90	17.8	26.8	9.69	90	145	4.1	11.3
		Highest 20% dv Days	**27.1**	**36.1**	**11.82**	**75**	**120**	**6.1**	**11.4**
BAND1	2000	100	22.4	31.4	9.09	100	161	4.7	7.4
BAND1	2001	100	13.5	22.5	7.86	108	174	3.2	6.3
BAND1	2002	100	15.2	24.2	8.39	104	167	3.6	6.9
BAND1	2003	100	15.4	24.4	8.40	104	168	3.7	6.9
BAND1	2004	100	13.2	22.2	7.76	109	175	3.2	5.8
BAND1	2005	100	14.2	23.2	7.96	109	175	3.2	5.9
BAND1	2006	100	13.5	22.5	7.79	109	176	3.2	6.7
BAND1	2007	100	15.2	24.2	8.17	107	172	3.5	6.2
BAND1	2008	100	13.1	22.1	7.57	112	181	3.4	6.8
BAND1	2009	100	12.5	21.5	7.14	117	188	3.1	6.2
BAND1	2010	100	10.6	19.6	6.47	123	199	2.5	5.8
		Average dv Days	**14.4**	**23.4**	**7.87**	**109**	**176**	**3.4**	**6.4**

Source: CSU 2013c

Notes:

Light extinction units are inverse megameters (Mm^{-1})

PM light extinction for particulate matter in air; Total light extinction adds Rayleigh scattering value (gases)

Deciview units are dimensionless (dv); Reconstructed mass units are micrograms per cubic meter ($\mu g/m^3$)

Fine reconstructed mass analogous to $PM_{2.5}$; Total reconstructed mass analogous to PM_{10}

Table A-4 IMPROVE Summary Results - Bosque del Apache Wilderness

Site ID Code	Year	Group Code	Light Extinction PM Mm[1]	Light Extinction Total Mm[1]	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine µg/m³	Reconstructed Mass Total µg/m³
BOAP1	2002	10	9.3	19.3	6.53	127	205	2.0	5.2
BOAP1	2003	10	9.8	19.8	6.77	124	200	2.2	5.4
BOAP1	2004	10	7.5	17.5	5.53	140	226	1.8	3.4
BOAP1	2005	10	8.1	18.1	5.86	136	219	1.8	4.4
BOAP1	2006	10	8.8	18.8	6.31	130	209	2.0	5.0
BOAP1	2007	10	8.1	18.1	5.86	136	219	1.9	3.9
BOAP1	2008	10	6.9	16.9	5.18	145	234	1.5	3.4
BOAP1	2009	10	7.5	17.5	5.54	140	226	1.7	4.2
BOAP1	2010	10	5.9	15.9	4.62	154	247	1.4	3.5
		Lowest 20% dv Days	**8.0**	**18.0**	**5.80**	**137**	**220**	**1.8**	**4.3**
BOAP1	2002	90	34.7	44.7	14.60	58	94	8.4	21.1
BOAP1	2003	90	30.5	40.5	13.88	61	99	6.6	20.4
BOAP1	2004	90	27.5	37.5	12.91	68	110	6.2	13.2
BOAP1	2005	90	32.1	42.1	14.27	59	95	7.2	16.1
BOAP1	2006	90	31.8	41.8	13.86	63	101	7.0	16.9
BOAP1	2007	90	35.7	45.7	14.15	62	100	6.9	14.3
BOAP1	2008	90	26.5	36.5	12.82	68	110	6.4	18.1
BOAP1	2009	90	22.9	32.9	11.88	74	120	5.1	13.3
BOAP1	2010	90	19.7	29.7	10.87	82	132	4.4	11.7
		Highest 20% dv Days	**29.1**	**39.1**	**13.25**	**66**	**107**	**6.5**	**16.1**
BOAP1	2002	100	18.7	28.7	10.06	93	149	4.4	11.3
BOAP1	2003	100	19.3	29.3	10.42	89	143	4.2	12.2

Site ID Code	Year	Group Code	Light Extinction PM Mm1	Light Extinction Total Mm1	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine μg/m3	Reconstructed Mass Total μg/m3
BOAP1	2004	100	15.4	25.4	8.89	103	166	3.6	7.9
BOAP1	2005	100	17.4	27.4	9.60	97	156	4.0	8.7
BOAP1	2006	100	17.4	27.4	9.61	96	155	4.0	9.8
BOAP1	2007	100	17.5	27.5	9.37	99	160	3.9	8.5
BOAP1	2008	100	15.4	25.4	8.94	103	166	3.8	9.3
BOAP1	2009	100	14.3	24.3	8.62	105	169	3.4	8.6
BOAP1	2010	100	12.5	22.5	7.86	114	183	3.0	7.4
		Average dv Days	**16.4**	**26.4**	**9.26**	**100**	**161**	**3.8**	**9.3**

Source: CSU 2013c

Notes:

Light extinction units are inverse megameters (Mm^{-1})

PM light extinction for particulate matter in air; Total light extinction adds Rayleigh scattering value (gases)

Deciview units are dimensionless (dv); Reconstructed mass units are micrograms per cubic meter ($\mu g/m^3$)

Fine reconstructed mass analogous to $PM_{2.5}$; Total reconstructed mass analogous to PM_{10}

Table A-5 IMPROVE Summary Results - Bryce Canyon National Park

Site ID Code	Year	Group Code	Light Extinction PM Mm[1]	Light Extinction Total Mm[1]	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine µg/m³	Reconstructed Mass Total µg/m³
BRCA1	2000	10	4.5	13.5	3.00	168	270	1.0	1.9
BRCA1	2001	10	4.6	13.6	3.07	167	269	0.9	2.1
BRCA1	2002	10	4.0	13.0	2.62	174	280	0.8	1.5
BRCA1	2003	10	3.7	12.7	2.35	178	287	0.8	1.7
BRCA1	2004	10	4.3	13.3	2.80	172	276	1.0	1.6
BRCA1	2005	10	3.1	12.1	1.90	186	300	0.7	1.2
BRCA1	2006	10	3.7	12.7	2.36	178	287	0.8	1.4
BRCA1	2007	10	3.8	12.8	2.40	178	286	0.9	1.6
BRCA1	2008	10	2.8	11.8	1.65	190	306	0.6	1.2
BRCA1	2009	10	3.4	12.4	2.14	182	293	0.8	1.4
BRCA1	2010	10	2.6	11.6	1.48	193	311	0.6	1.0
		Lowest 20% dv Days	**3.7**	**12.7**	**2.34**	**179**	**288**	**0.8**	**1.5**
BRCA1	2000	90	21.0	30.0	10.84	80	129	5.2	9.5
BRCA1	2001	90	24.0	33.0	11.26	80	128	5.5	10.7
BRCA1	2002	90	29.8	38.8	13.23	65	104	7.1	17.2
BRCA1	2003	90	24.8	33.8	11.11	81	130	5.9	13.1
BRCA1	2004	90	24.4	33.4	11.82	74	119	5.5	12.1
BRCA1	2005	90	24.8	33.8	11.78	75	120	6.0	10.1
BRCA1	2006	90	20.4	29.4	10.68	81	131	5.0	9.3
BRCA1	2007	90	28.9	37.9	12.71	69	111	6.7	11.6
BRCA1	2008	90	21.9	30.9	10.96	81	130	6.4	12.6

Site ID Code	Year	Group Code	Light Extinction PM Mm^{1}	Light Extinction Total Mm^{1}	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine µg/m^3	Reconstructed Mass Total µg/m^3
BRCA1	2009	90	34.7	43.7	13.29	69	110	7.7	13.8
BRCA1	2010	90	16.9	25.9	9.23	95	153	3.9	8.1
		Highest 20% dv Days	**24.7**	**33.7**	**11.54**	**77**	**124**	**5.9**	**11.6**
BRCA1	2000	100	11.5	20.5	6.77	121	195	2.8	5.3
BRCA1	2001	100	12.5	21.5	7.04	119	192	3.0	5.9
BRCA1	2002	100	13.5	22.5	7.25	119	192	3.2	7.4
BRCA1	2003	100	11.4	20.4	6.31	128	206	2.7	5.7
BRCA1	2004	100	12.4	21.4	7.03	120	193	2.9	5.8
BRCA1	2005	100	11.5	20.5	6.46	127	205	2.8	4.8
BRCA1	2006	100	10.7	19.7	6.35	127	204	2.7	4.9
BRCA1	2007	100	13.3	22.3	7.14	120	194	3.2	6.1
BRCA1	2008	100	10.6	19.6	6.11	131	211	2.9	5.7
BRCA1	2009	100	13.3	22.3	6.65	127	205	3.2	6.1
BRCA1	2010	100	8.9	17.9	5.36	139	223	2.2	4.5
		Average dv Days	**11.8**	**20.8**	**6.59**	**125**	**202**	**2.9**	**5.7**

Source: CSU 2013c

Notes:

Light extinction units are inverse megameters (Mm^{-1})

PM light extinction for particulate matter in air; Total light extinction adds Rayleigh scattering value (gases)

Deciview units are dimensionless (dv); Reconstructed mass units are micrograms per cubic meter (µg/m^3)

Fine reconstructed mass analogous to $PM_{2.5}$; Total reconstructed mass analogous to PM_{10}

Table A-6 IMPROVE Summary Results - Canyonlands National Park

Site ID Code	Year	Group Code	Light Extinction PM Mm^{-1}	Light Extinction Total Mm^{-1}	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine $\mu g/m^3$	Reconstructed Mass Total $\mu g/m^3$
CANY1	2000	10	5.4	14.4	3.62	159	255	1.2	3.0
CANY1	2001	10	6.1	15.1	4.07	152	245	1.6	3.4
CANY1	2002	10	6.3	15.3	4.20	151	242	1.5	3.3
CANY1	2003	10	5.0	14.0	3.33	163	262	1.1	2.5
CANY1	2004	10	5.3	14.3	3.52	160	258	1.4	2.6
CANY1	2005	10	3.7	12.7	2.34	179	288	0.8	1.8
CANY1	2006	10	4.1	13.1	2.69	173	279	0.9	1.9
CANY1	2007	10	4.6	13.6	3.04	168	270	1.0	2.6
CANY1	2008	10	4.2	13.2	2.71	173	278	0.9	1.9
CANY1	2009	10	4.9	13.9	3.27	164	264	1.2	2.7
CANY1	2010	10	4.0	13.0	2.58	175	282	0.9	1.9
		Lowest 20% dv Days	**4.9**	**13.9**	**3.21**	**165**	**266**	**1.1**	**2.5**
CANY1	2000	90	22.6	31.6	11.18	79	127	4.9	10.7
CANY1	2001	90	21.4	30.4	10.95	80	128	5.3	10.4
CANY1	2002	90	27.9	36.9	12.69	68	110	7.5	17.6
CANY1	2003	90	24.2	33.2	11.78	74	119	5.7	12.6
CANY1	2004	90	17.5	26.5	9.63	90	145	4.1	8.2
CANY1	2005	90	20.2	29.2	10.56	83	133	4.6	9.7
CANY1	2006	90	19.9	28.9	10.51	83	133	4.8	10.6
CANY1	2007	90	23.8	32.8	11.39	77	125	5.3	10.8
CANY1	2008	90	22.7	31.7	11.12	80	128	5.8	18.7

Site ID Code	Year	Group Code	Light Extinction PM Mm^{-1}	Light Extinction Total Mm^{-1}	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine $\mu g/m^3$	Reconstructed Mass Total $\mu g/m^3$
CANY1	2009	90	26.2	35.2	11.51	79	126	5.8	14.8
CANY1	2010	90	21.4	30.4	10.57	85	136	4.5	12.0
		Highest 20% dv Days	**22.5**	**31.5**	**11.08**	**80**	**128**	**5.3**	**12.4**
CANY1	2000	100	12.4	21.4	7.18	117	188	2.9	6.2
CANY1	2001	100	12.6	21.6	7.36	114	184	3.1	6.4
CANY1	2002	100	14.3	23.3	7.91	110	177	3.8	8.3
CANY1	2003	100	12.1	21.1	6.94	120	193	2.8	6.6
CANY1	2004	100	10.5	19.5	6.44	124	199	2.6	5.2
CANY1	2005	100	10.8	19.8	6.39	126	203	2.5	5.3
CANY1	2006	100	11.1	20.1	6.60	123	198	2.6	5.9
CANY1	2007	100	12.4	21.4	7.08	118	191	2.9	6.6
CANY1	2008	100	11.6	20.6	6.69	123	198	2.9	8.0
CANY1	2009	100	11.5	20.5	6.36	127	205	2.7	6.8
CANY1	2010	100	10.4	19.4	6.09	130	209	2.5	6.3
		Average dv Days	**11.8**	**20.8**	**6.82**	**121**	**195**	**2.9**	**6.5**

Source: CSU 2013c

Notes:

Light extinction units are inverse megameters (Mm^{-1})

PM light extinction for particulate matter in air; Total light extinction adds Rayleigh scattering value (gases)

Deciview units are dimensionless (dv); Reconstructed mass units are micrograms per cubic meter ($\mu g/m^3$)

Fine reconstructed mass analogous to $PM_{2.5}$; Total reconstructed mass analogous to PM_{10}

Table A-7 IMPROVE Summary Results - Capitol Reef National Park

Site ID Code	Year	Group Code	Light Extinction PM Mm^{-1}	Light Extinction Total Mm^{-1}	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine µg/m^3	Reconstructed Mass Total µg/m^3
CAPI1	2003	10	4.7	13.7	3.12	166	267	1.2	2.3
CAPI1	2004	10	6.2	15.2	4.12	151	244	1.6	2.8
CAPI1	2005	10	4.0	13.0	2.57	175	282	0.9	1.6
CAPI1	2007	10	4.7	13.7	3.15	166	267	1.1	2.2
CAPI1	2008	10	3.9	12.9	2.50	176	283	0.8	1.8
CAPI1	2009	10	4.2	13.2	2.71	173	278	0.9	2.0
CAPI1	2010	10	3.2	12.2	1.96	185	298	0.8	1.4
		Lowest 20% dv Days	**4.4**	**13.4**	**2.88**	**170**	**274**	**1.1**	**2.0**
CAPI1	2003	90	16.7	25.7	9.38	92	148	4.0	8.6
CAPI1	2004	90	20.1	29.1	10.56	82	133	5.0	8.6
CAPI1	2005	90	24.4	33.4	11.82	74	119	5.4	10.4
CAPI1	2007	90	25.7	34.7	11.68	76	122	5.9	12.2
CAPI1	2008	90	23.2	32.2	11.41	77	124	6.2	14.7
CAPI1	2009	90	21.1	30.1	10.28	87	140	5.1	12.4
CAPI1	2010	90	17.2	26.2	9.49	92	148	3.5	7.2
		Highest 20% dv Days	**21.2**	**30.2**	**10.66**	**83**	**133**	**5.0**	**10.6**
CAPI1	2003	100	10.0	19.0	6.15	127	205	2.4	5.0
CAPI1	2004	100	12.1	21.1	7.17	116	186	3.2	5.4
CAPI1	2005	100	12.4	21.4	7.02	120	193	2.9	5.5
CAPI1	2007	100	12.6	21.6	7.02	120	192	3.0	6.3
CAPI1	2008	100	11.5	20.5	6.61	124	200	2.9	6.7

Site ID Code	Year	Group Code	Light Extinction PM Mm^{-1}	Light Extinction Total Mm^{-1}	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine $\mu g/m^3$	Reconstructed Mass Total $\mu g/m^3$
CAPI1	2009	100	10.8	19.8	6.25	128	205	2.7	6.2
CAPI1	2010	100	9.4	18.4	5.75	133	215	2.2	4.7
		Average dv Days	**11.2**	**20.2**	**6.57**	**124**	**200**	**2.7**	**5.7**

Source: CSU 2013c

Notes:

Light extinction units are inverse megameters (Mm^{-1})

PM light extinction for particulate matter in air; Total light extinction adds Rayleigh scattering value (gases)

Deciview units are dimensionless (dv); Reconstructed mass units are micrograms per cubic meter ($\mu g/m^3$)

Fine reconstructed mass analogous to $PM_{2.5}$; Total reconstructed mass analogous to PM_{10}

Table A-8 IMPROVE Summary Results - Grand Canyon National Park

Site ID Code	Year	Group Code	Light Extinction PM Mm^{-1}	Light Extinction Total Mm^{-1}	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine µg/m^3	Reconstructed Mass Total µg/m^3
GRCA2	2000	10	4.4	13.4	2.89	170	273	1.0	2.0
GRCA2	2002	10	3.3	12.3	1.98	185	298	0.7	1.3
GRCA2	2003	10	3.0	12.0	1.82	188	302	0.7	1.3
GRCA2	2004	10	3.2	12.2	1.98	185	297	0.7	1.4
GRCA2	2005	10	3.4	12.4	2.09	183	295	0.7	1.4
GRCA2	2006	10	3.8	12.8	2.39	178	287	0.8	1.6
GRCA2	2007	10	3.9	12.9	2.52	176	283	0.8	1.9
GRCA2	2008	10	2.8	11.8	1.63	191	307	0.6	1.3
GRCA2	2009	10	3.5	12.5	2.16	182	292	0.7	1.4
GRCA2	2010	10	2.9	11.9	1.73	189	304	0.7	1.4
		Lowest 20% dv Days	**3.4**	**12.4**	**2.12**	**183**	**294**	**0.7**	**1.5**
GRCA2	2000	90	21.7	30.7	11.12	78	125	5.4	11.5
GRCA2	2002	90	24.1	33.1	11.62	76	122	6.3	12.6
GRCA2	2003	90	31.8	40.8	12.74	71	113	7.3	13.4
GRCA2	2004	90	24.8	33.8	11.18	81	130	5.6	10.3
GRCA2	2005	90	29.2	38.2	12.60	70	113	7.0	11.2
GRCA2	2006	90	21.7	30.7	11.09	78	126	5.5	10.1
GRCA2	2007	90	24.1	33.1	11.70	75	120	6.7	12.6
GRCA2	2008	90	20.4	29.4	10.63	82	132	5.8	12.3

Site ID Code	Year	Group Code	Light Extinction PM Mm^{-1}	Light Extinction Total Mm^{-1}	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine $\mu g/m^3$	Reconstructed Mass Total $\mu g/m^3$
GRCA2	2009	90	35.1	44.1	13.83	64	103	7.7	13.2
GRCA2	2010	90	23.1	32.1	9.67	94	151	4.9	9.2
		Highest 20% dv Days	**25.6**	**34.6**	**11.62**	**77**	**124**	**6.2**	**11.6**
GRCA2	2000	100	11.8	20.8	6.88	121	194	2.8	6.2
GRCA2	2002	100	11.4	20.4	6.46	127	205	2.9	5.9
GRCA2	2003	100	12.9	21.9	6.64	127	204	3.0	6.0
GRCA2	2004	100	11.4	20.4	6.34	128	206	2.7	5.3
GRCA2	2005	100	12.6	21.6	6.75	125	201	3.0	5.2
GRCA2	2006	100	11.1	20.1	6.50	125	202	2.7	5.5
GRCA2	2007	100	12.5	21.5	7.10	119	191	3.2	6.5
GRCA2	2008	100	10.3	19.3	6.05	131	211	2.7	5.6
GRCA2	2009	100	14.2	23.2	7.25	120	194	3.4	6.6
GRCA2	2010	100	10.1	19.1	5.47	138	222	2.4	4.6
		Average dv Days	**11.8**	**20.8**	**6.54**	**126**	**203**	**2.9**	**5.7**

Source: CSU 2013c

Notes:

Light extinction units are inverse megameters (Mm^{-1})

PM light extinction for particulate matter in air; Total light extinction adds Rayleigh scattering value (gases)

Deciview units are dimensionless (dv); Reconstructed mass units are micrograms per cubic meter ($\mu g/m^3$)

Fine reconstructed mass analogous to $PM_{2.5}$; Total reconstructed mass analogous to PM_{10}

Table A-9 IMPROVE Summary Results - Great Sand Dunes National Park

Site ID Code	Year	Group Code	Light Extinction PM Mm^{-1}	Light Extinction Total Mm^1	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine $\mu g/m^3$	Reconstructed Mass Total $\mu g/m^3$
GRSA1	2000	10	6.6	15.6	4.45	147	236	1.4	3.3
GRSA1	2001	10	6.8	15.8	4.53	146	234	1.6	3.8
GRSA1	2002	10	7.5	16.5	4.98	140	225	1.7	3.9
GRSA1	2003	10	6.7	15.7	4.48	146	235	1.6	3.7
GRSA1	2004	10	6.0	15.0	4.06	152	245	1.5	2.5
GRSA1	2005	10	4.9	13.9	3.26	164	264	1.1	2.3
GRSA1	2006	10	5.9	14.9	3.94	154	248	1.4	2.9
GRSA1	2007	10	5.3	14.3	3.56	160	257	1.3	2.4
GRSA1	2008	10	5.2	14.2	3.42	162	260	1.2	2.3
GRSA1	2009	10	5.4	14.4	3.64	158	255	1.3	2.2
GRSA1	2010	10	5.0	14.0	3.32	163	262	1.3	2.4
		Lowest 20% dv Days	**5.9**	**14.9**	**3.97**	**154**	**247**	**1.4**	**2.9**
GRSA1	2000	90	33.0	42.0	14.10	59	95	7.5	23.2
GRSA1	2001	90	23.2	32.2	11.40	77	124	5.7	15.3
GRSA1	2002	90	35.3	44.3	14.34	59	95	8.7	26.7
GRSA1	2003	90	27.7	36.7	12.88	66	106	7.2	17.9
GRSA1	2004	90	22.1	31.1	11.18	78	125	5.8	12.0
GRSA1	2005	90	26.8	35.8	12.48	69	111	6.3	16.1
GRSA1	2006	90	23.5	32.5	11.56	75	121	5.5	14.8
GRSA1	2007	90	21.3	30.3	11.01	79	127	4.5	11.2
GRSA1	2008	90	23.0	32.0	11.37	77	124	5.9	15.5

Site ID Code	Year	Group Code	Light Extinction PM Mm^{-1}	Light Extinction Total Mm^{1}	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine $\mu g/m^3$	Reconstructed Mass Total $\mu g/m^3$
GRSA1	2009	90	20.7	29.7	10.79	80	129	5.5	12.9
GRSA1	2010	90	18.4	27.4	9.79	90	145	5.1	12.1
		Highest 20% dv Days	**25.0**	**34.0**	**11.90**	**74**	**118**	**6.2**	**16.2**
GRSA1	2000	100	16.7	25.7	8.79	102	164	3.8	10.4
GRSA1	2001	100	14.2	23.2	8.05	107	172	3.2	8.6
GRSA1	2002	100	17.2	26.2	8.88	101	162	4.2	11.1
GRSA1	2003	100	14.8	23.8	8.15	107	173	3.7	8.7
GRSA1	2004	100	12.8	21.8	7.45	113	182	3.3	6.3
GRSA1	2005	100	13.7	22.7	7.60	114	183	3.3	7.2
GRSA1	2006	100	13.2	22.2	7.54	113	182	3.1	7.3
GRSA1	2007	100	12.5	21.5	7.31	115	185	2.9	6.0
GRSA1	2008	100	13.1	22.1	7.51	113	182	3.3	7.4
GRSA1	2009	100	12.0	21.0	7.09	117	188	3.1	6.2
GRSA1	2010	100	10.7	19.7	6.43	124	200	2.8	6.0
		Average dv Days	**13.7**	**22.7**	**7.71**	**111**	**179**	**3.3**	**7.7**

Source: CSU 2013c

Notes:

Light extinction units are inverse megameters (Mm^{-1})

PM light extinction for particulate matter in air; Total light extinction adds Rayleigh scattering value (gases)

Deciview units are dimensionless (dv); Reconstructed mass units are micrograms per cubic meter ($\mu g/m^3$)

Fine reconstructed mass analogous to $PM_{2.5}$; Total reconstructed mass analogous to PM_{10}

Table A-10 IMPROVE Summary Results - Mesa Verde National Park

Site ID Code	Year	Group Code	Light Extinction PM Mm^1	Light Extinction Total Mm^1	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine $\mu g/m^3$	Reconstructed Mass Total $\mu g/m^3$
MEVE1	2000	10	6.5	15.5	4.35	148	238	1.4	2.4
MEVE1	2001	10	5.9	14.9	3.98	153	247	1.3	2.8
MEVE1	2002	10	7.0	16.0	4.68	144	231	1.7	3.4
MEVE1	2003	10	7.1	16.1	4.70	144	231	1.7	3.1
MEVE1	2004	10	5.8	14.8	3.92	154	248	1.4	2.0
MEVE1	2005	10	4.6	13.6	2.98	169	271	1.1	1.6
MEVE1	2006	10	5.4	14.4	3.57	160	257	1.3	2.0
MEVE1	2007	10	5.0	14.0	3.34	163	262	1.1	2.0
MEVE1	2008	10	4.3	13.3	2.83	171	275	0.9	1.7
MEVE1	2009	10	4.5	13.5	3.00	168	270	1.0	1.8
MEVE1	2010	10	4.4	13.4	2.88	170	273	1.1	1.7
		Lowest 20% dv Days	**5.5**	**14.5**	**3.66**	**158.4**	**254.9**	**1.3**	**2.2**
MEVE1	2000	90	35.4	44.4	12.97	69	111	7.8	14.2
MEVE1	2001	90	19.6	28.6	10.48	83	133	4.8	10.6
MEVE1	2002	90	36.1	45.1	14.65	57	91	8.9	24.8
MEVE1	2003	90	52.0	61.0	16.76	48	78	11.3	32.6
MEVE1	2004	90	19.3	28.3	10.30	84	136	4.5	9.5
MEVE1	2005	90	26.2	35.2	12.05	73	118	6.2	12.9
MEVE1	2006	90	20.7	29.7	10.67	82	132	5.5	10.9
MEVE1	2007	90	21.1	30.1	10.91	80	128	4.9	9.0
MEVE1	2008	90	21.8	30.8	11.02	80	128	5.7	15.0
MEVE1	2009	90	25.1	34.1	11.73	75	121	6.4	19.0
MEVE1	2010	90	27.3	36.3	11.64	78	126	7.7	25.1

Site ID Code	Year	Group Code	Light Extinction PM Mm1	Light Extinction Total Mm1	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine µg/m3	Reconstructed Mass Total µg/m3
		Highest 20% dv Days	**27.7**	**36.7**	**12.11**	**73.6**	**118.5**	**6.7**	**16.7**
MEVE1	2000	100	16.0	25.0	8.02	109	176	3.7	6.5
MEVE1	2001	100	12.7	21.7	7.48	112	181	3.1	6.1
MEVE1	2002	100	17.3	26.3	8.93	101	162	4.3	10.6
MEVE1	2003	100	20.5	29.5	9.30	100	161	4.7	12.1
MEVE1	2004	100	11.5	20.5	6.92	118	191	2.8	5.5
MEVE1	2005	100	12.5	21.5	6.95	121	195	2.9	5.5
MEVE1	2006	100	11.7	20.7	6.93	119	191	3.0	5.6
MEVE1	2007	100	12.1	21.1	7.12	117	189	2.9	5.3
MEVE1	2008	100	11.6	20.6	6.80	121	195	2.9	6.6
MEVE1	2009	100	11.9	20.9	6.74	123	198	3.0	7.3
MEVE1	2010	100	12.2	21.2	6.63	124	200	3.2	8.2
		Average dv Days	**13.6**	**22.6**	**7.44**	**115.1**	**185.2**	**3.3**	**7.2**

Source: CSU 2013c

Notes:

Light extinction units are inverse megameters (Mm^{-1})

PM light extinction for particulate matter in air; Total light extinction adds Rayleigh scattering value (gases)

Deciview units are dimensionless (dv); Reconstructed mass units are micrograms per cubic meter ($\mu g/m^3$)

Fine reconstructed mass analogous to $PM_{2.5}$; Total reconstructed mass analogous to PM_{10}

Table A-11 IMPROVE Summary Results - Petrified Forest National Park

Site ID Code	Year	Group Code	Light Extinction PM Mm[1]	Light Extinction Total Mm[1]	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine μg/m[3]	Reconstructed Mass Total μg/m[3]
PEFO1	2000	10	7.6	16.6	5.04	139	223	1.8	3.2
PEFO1	2001	10	7.5	16.5	4.98	140	225	1.8	3.7
PEFO1	2002	10	7.7	16.7	5.09	139	223	1.8	3.6
PEFO1	2003	10	8.3	17.3	5.43	134	216	1.9	3.6
PEFO1	2004	10	6.9	15.9	4.59	145	233	1.6	2.9
PEFO1	2005	10	6.8	15.8	4.54	146	234	1.7	2.7
PEFO1	2006	10	8.1	17.1	5.35	135	217	2.1	3.7
PEFO1	2007	10	7.4	16.4	4.90	141	227	1.7	3.7
PEFO1	2008	10	6.1	15.1	4.07	152	245	1.4	2.8
PEFO1	2009	10	6.3	15.3	4.23	150	241	1.5	3.5
PEFO1	2010	10	6.2	15.2	4.14	151	244	1.5	3.3
		Lowest 20% dv Days	**7.2**	**16.2**	**4.76**	**143**	**230**	**1.7**	**3.3**
PEFO1	2000	90	27.0	36.0	12.73	67	107	6.5	14.9
PEFO1	2001	90	20.9	29.9	10.85	80	129	5.3	11.7
PEFO1	2002	90	31.4	40.4	13.49	63	102	7.5	20.1
PEFO1	2003	90	43.5	52.5	16.10	49	79	8.8	34.6
PEFO1	2004	90	35.5	44.5	12.90	71	113	7.3	15.0
PEFO1	2005	90	38.2	47.2	14.03	62	99	9.1	18.6
PEFO1	2006	90	24.8	33.8	12.11	71	114	6.4	15.9
PEFO1	2007	90	26.9	35.9	12.68	67	108	6.8	14.8
PEFO1	2008	90	25.6	34.6	12.26	70	113	7.1	18.9
PEFO1	2009	90	37.8	46.8	14.04	63	101	8.5	22.5
PEFO1	2010	90	23.1	32.1	11.37	77	124	5.1	17.5

Site ID Code	Year	Group Code	Light Extinction PM Mm1	Light Extinction Total Mm1	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine µg/m3	Reconstructed Mass Total µg/m3
		Highest 20% dv Days	**30.4**	**39.4**	**12.96**	**67**	**108**	**7.1**	**18.6**
PEFO1	2000	100	16.1	25.1	8.82	100	161	3.9	7.8
PEFO1	2001	100	13.5	22.5	7.87	108	174	3.3	7.0
PEFO1	2002	100	16.5	25.5	8.80	101	162	4.1	9.5
PEFO1	2003	100	20.8	29.8	10.02	92	147	4.5	13.9
PEFO1	2004	100	16.7	25.7	8.38	105	169	3.8	7.8
PEFO1	2005	100	17.7	26.7	8.78	102	164	4.2	8.3
PEFO1	2006	100	15.1	24.1	8.51	102	164	3.8	8.3
PEFO1	2007	100	15.7	24.7	8.66	101	163	3.9	8.4
PEFO1	2008	100	14.4	23.4	8.06	108	173	3.7	8.5
PEFO1	2009	100	16.4	25.4	8.23	108	174	3.8	9.3
PEFO1	2010	100	13.2	22.2	7.56	112	181	3.1	8.3
		Average dv Days	**16.0**	**25.0**	**8.52**	**104**	**167**	**3.8**	**8.8**

Source: CSU 2013c

Notes:

Light extinction units are inverse megameters (Mm^{-1})

PM light extinction for particulate matter in air; Total light extinction adds Rayleigh scattering value (gases)

Deciview units are dimensionless (dv); Reconstructed mass units are micrograms per cubic meter ($\mu g/m^3$)

Fine reconstructed mass analogous to $PM_{2.5}$; Total reconstructed mass analogous to PM_{10}

Table A-12 IMPROVE Summary Results - San Pedro Parks Wilderness

Site ID Code	Year	Group Code	Light Extinction PM Mm[1]	Light Extinction Total Mm[1]	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine µg/m[3]	Reconstructed Mass Total µg/m[3]
SAPE1	2001	10	4.1	12.1	1.89	173	278	1.0	1.4
SAPE1	2002	10	3.2	11.2	1.07	186	299	0.7	1.2
SAPE1	2003	10	3.6	11.6	1.38	181	291	0.8	1.5
SAPE1	2004	10	3.6	11.6	1.47	179	288	0.8	1.2
SAPE1	2005	10	3.0	11.0	0.87	189	304	0.7	1.2
SAPE1	2006	10	3.6	11.6	1.43	180	289	0.8	1.3
SAPE1	2007	10	3.1	11.1	0.99	187	300	0.7	1.2
SAPE1	2008	10	2.8	10.8	0.76	191	307	0.7	1.2
SAPE1	2009	10	3.2	11.2	1.12	185	297	0.7	1.3
SAPE1	2010	10	2.8	10.8	0.76	190	306	0.7	1.2
		Lowest 20% dv Days	**3.3**	**11.3**	**1.17**	**184**	**296**	**0.8**	**1.3**
SAPE1	2001	90	17.6	25.6	9.27	90	145	5.0	8.3
SAPE1	2002	90	21.9	29.9	10.56	81	130	5.9	10.2
SAPE1	2003	90	26.6	34.6	11.62	75	121	6.3	13.3
SAPE1	2004	90	17.6	25.6	9.25	90	145	4.6	8.1
SAPE1	2005	90	22.2	30.2	10.77	79	127	5.6	9.1
SAPE1	2006	90	19.6	27.6	9.74	87	140	4.9	8.8
SAPE1	2007	90	22.3	30.3	10.71	80	129	5.5	9.7
SAPE1	2008	90	19.4	27.4	10.01	84	135	5.8	11.2

Site ID Code	Year	Group Code	Light Extinction PM Mm1	Light Extinction Total Mm1	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine µg/m3	Reconstructed Mass Total µg/m3
SAPE1	2009	90	14.9	22.9	8.21	99	159	4.1	8.0
SAPE1	2010	90	15.7	23.7	8.48	97	156	4.4	10.6
		Highest 20% dv Days	**19.8**	**27.8**	**9.86**	**86**	**139**	**5.2**	**9.7**
SAPE1	2001	100	10.3	18.3	5.69	127	204	2.7	4.4
SAPE1	2002	100	11.0	19.0	5.80	127	205	2.9	5.0
SAPE1	2003	100	12.3	20.3	6.19	124	200	3.1	6.1
SAPE1	2004	100	9.9	17.9	5.45	130	209	2.6	4.4
SAPE1	2005	100	10.9	18.9	5.71	129	207	2.7	4.5
SAPE1	2006	100	10.0	18.0	5.36	131	211	2.5	4.6
SAPE1	2007	100	10.8	18.8	5.64	129	208	2.7	4.9
SAPE1	2008	100	10.4	18.4	5.60	129	208	2.9	5.5
SAPE1	2009	100	8.5	16.5	4.71	138	222	2.3	4.4
SAPE1	2010	100	8.9	16.9	4.83	137	220	2.4	4.9
		Average dv Days	**10.3**	**18.3**	**5.50**	**130**	**209**	**2.7**	**4.9**

Source: CSU 2013c

Notes:

Light extinction units are inverse megameters (Mm^{-1})

PM light extinction for particulate matter in air; Total light extinction adds Rayleigh scattering value (gases)

Deciview units are dimensionless (dv); Reconstructed mass units are micrograms per cubic meter ($\mu g/m^3$)

Fine reconstructed mass analogous to $PM_{2.5}$; Total reconstructed mass analogous to PM_{10}

Table A-13 IMPROVE Summary Results - Sierra Ancha Wilderness

Site ID Code	Year	Group Code	Light Extinction PM Mm[1]	Light Extinction Total Mm[1]	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine µg/m³	Reconstructed Mass Total µg/m³
SIAN1	2001	10	8.7	18.7	6.22	131	211	2.2	3.8
SIAN1	2002	10	9.2	19.2	6.49	128	205	2.3	3.9
SIAN1	2003	10	8.4	18.4	6.06	133	214	2.1	3.8
SIAN1	2004	10	8.0	18.0	5.87	135	218	2.0	3.2
SIAN1	2005	10	7.1	17.1	5.27	144	232	1.7	2.8
SIAN1	2009	10	5.9	15.9	4.61	154	248	1.4	2.9
SIAN1	2010	10	7.4	17.4	5.50	140	226	1.9	3.5
		Lowest 20% dv Days	**7.8**	**17.8**	**5.72**	**138**	**222**	**1.9**	**3.4**
SIAN1	2001	90	24.4	34.4	12.20	73	117	6.6	14.8
SIAN1	2002	90	31.5	41.5	14.12	60	96	8.2	16.9
SIAN1	2003	90	37.6	47.6	15.09	56	90	9.3	23.0
SIAN1	2004	90	31.1	41.1	13.27	67	108	7.3	16.1
SIAN1	2005	90	41.2	51.2	14.97	58	94	9.1	15.9
SIAN1	2009	90	22.9	32.9	11.80	75	121	6.2	15.0
SIAN1	2010	90	24.9	34.9	11.63	80	128	5.7	10.6
		Highest 20% dv Days	**30.5**	**40.5**	**13.30**	**67**	**108**	**7.5**	**16.0**
SIAN1	2001	100	15.7	25.7	9.19	99	160	4.2	8.5
SIAN1	2002	100	19.0	29.0	10.27	90	145	5.0	10.5
SIAN1	2003	100	19.5	29.5	10.16	93	149	4.8	10.7
SIAN1	2004	100	16.3	26.3	9.08	102	164	4.0	7.9
SIAN1	2005	100	19.1	29.1	9.63	99	159	4.5	8.4

Site ID Code	Year	Group Code	Light Extinction PM Mm[1]	Light Extinction Total Mm[1]	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine µg/m³	Reconstructed Mass Total µg/m³
SIAN1	2009	100	13.5	23.5	8.21	110	178	3.6	7.9
SIAN1	2010	100	13.4	23.4	8.00	112	181	3.3	6.7
		Average dv Days	**16.6**	**26.6**	**9.22**	**101**	**162**	**4.2**	**8.6**

Source: CSU 2013c

Notes:

Light extinction units are inverse megameters (Mm^{-1})

PM light extinction for particulate matter in air; Total light extinction adds Rayleigh scattering value (gases)

Deciview units are dimensionless (dv); Reconstructed mass units are micrograms per cubic meter ($\mu g/m^3$)

Fine reconstructed mass analogous to $PM_{2.5}$; Total reconstructed mass analogous to PM_{10}

Table A-14 IMPROVE Summary Results - Weminuche Wilderness

Site ID Code	Year	Group Code	Light Extinction PM Mm[1]	Light Extinction Total Mm[1]	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine µg/m³	Reconstructed Mass Total µg/m³
WEMI1	2001	10	4.9	13.9	3.25	164	265	1.1	2.1
WEMI1	2002	10	4.9	13.9	3.26	164	264	1.0	2.3
WEMI1	2003	10	4.5	13.5	2.93	169	272	0.9	2.2
WEMI1	2004	10	4.6	13.6	3.02	168	270	1.0	1.9
WEMI1	2005	10	4.0	13.0	2.61	174	280	0.9	1.6
WEMI1	2006	10	4.4	13.4	2.92	169	272	0.9	1.9
WEMI1	2007	10	3.6	12.6	2.30	179	289	0.8	1.8
WEMI1	2008	10	3.4	12.4	2.16	182	292	0.7	1.7
WEMI1	2009	10	3.4	12.4	2.12	182	293	0.8	1.8
WEMI1	2010	10	3.0	12.0	1.77	188	303	0.7	1.3
		Lowest 20% dv Days	**4.1**	**13.1**	**2.63**	**174**	**280**	**0.9**	**1.9**
WEMI1	2001	90	17.2	26.2	9.55	91	146	4.5	7.9
WEMI1	2002	90	22.7	31.7	11.18	79	127	5.7	12.5
WEMI1	2003	90	26.6	35.6	11.32	80	128	6.2	12.3
WEMI1	2004	90	16.9	25.9	9.28	94	151	4.1	7.8
WEMI1	2005	90	18.2	27.2	9.95	87	140	4.5	8.2
WEMI1	2006	90	16.1	25.1	9.16	94	151	4.2	8.6
WEMI1	2007	90	19.9	28.9	10.28	86	138	4.8	9.5
WEMI1	2008	90	22.5	31.5	10.81	83	133	5.6	11.6

Site ID Code	Year	Group Code	Light Extinction PM Mm[1]	Light Extinction Total Mm[1]	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine µg/m³	Reconstructed Mass Total µg/m³
WEMI1	2009	90	19.3	28.3	9.99	89	143	5.4	11.3
WEMI1	2010	90	20.2	29.2	9.50	95	154	5.8	18.7
		Highest 20% dv Days	**20.0**	**29.0**	**10.10**	**88**	**141**	**5.1**	**10.8**
WEMI1	2001	100	10.6	19.6	6.48	123	199	2.5	4.8
WEMI1	2002	100	11.6	20.6	6.72	122	197	2.8	5.9
WEMI1	2003	100	12.3	21.3	6.67	124	199	2.9	5.8
WEMI1	2004	100	9.9	18.9	6.09	128	206	2.4	4.5
WEMI1	2005	100	9.9	18.9	6.04	130	209	2.3	4.3
WEMI1	2006	100	10.0	19.0	6.15	128	205	2.3	4.9
WEMI1	2007	100	10.3	19.3	6.08	130	209	2.4	4.9
WEMI1	2008	100	10.9	19.9	6.24	129	207	2.7	5.5
WEMI1	2009	100	9.7	18.7	5.75	134	216	2.6	5.2
WEMI1	2010	100	9.5	18.5	5.45	138	222	2.5	6.6
		Average dv Days	**10.5**	**19.5**	**6.16**	**129**	**207**	**2.5**	**5.2**

Source: CSU 2013c

Notes:

Light extinction units are inverse megameters (Mm^{-1})

PM light extinction for particulate matter in air; Total light extinction adds Rayleigh scattering value (gases)

Deciview units are dimensionless (dv); Reconstructed mass units are micrograms per cubic meter (µg/m³)

Fine reconstructed mass analogous to $PM_{2.5}$; Total reconstructed mass analogous to PM_{10}

Table A-15 IMPROVE Summary Results - Wheeler Peak Wilderness

Site ID Code	Year	Group Code	Light Extinction PM Mm1	Light Extinction Total Mm1	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine µg/m3	Reconstructed Mass Total µg/m3
WHPE1	2002	10	3.2	11.2	1.10	185	298	0.7	1.5
WHPE1	2003	10	3.7	11.7	1.52	179	287	0.8	1.8
WHPE1	2004	10	3.1	11.1	1.05	186	299	0.7	1.3
WHPE1	2005	10	2.7	10.7	0.63	192	310	0.6	1.2
WHPE1	2006	10	3.4	11.4	1.29	182	293	0.8	1.3
WHPE1	2007	10	3.4	11.4	1.24	183	294	0.7	1.5
WHPE1	2009	10	2.4	10.4	0.37	197	317	0.6	0.9
		Lowest 20% dv Days	**3.1**	**11.1**	**1.03**	**186**	**300**	**0.7**	**1.4**
WHPE1	2002	90	24.7	32.7	11.12	78	126	6.0	11.5
WHPE1	2003	90	26.4	34.4	11.38	77	124	6.7	13.0
WHPE1	2004	90	16.2	24.2	8.75	94	151	4.6	6.6
WHPE1	2005	90	19.9	27.9	10.08	84	135	5.1	8.2
WHPE1	2006	90	17.1	25.1	9.16	90	145	4.4	8.6
WHPE1	2007	90	15.9	23.9	8.62	95	153	3.8	6.9
WHPE1	2009	90	16.0	24.0	8.65	95	153	4.1	7.9
		Highest 20% dv Days	**19.5**	**27.5**	**9.68**	**88**	**141**	**4.9**	**8.9**
WHPE1	2002	100	11.8	19.8	6.03	126	202	2.9	5.7
WHPE1	2003	100	11.9	19.9	5.98	126	203	2.9	5.7
WHPE1	2004	100	9.2	17.2	5.02	135	217	2.5	3.8
WHPE1	2005	100	10.0	18.0	5.28	133	214	2.4	4.2
WHPE1	2006	100	9.7	17.7	5.31	131	211	2.4	4.4

Site ID Code	Year	Group Code	Light Extinction PM Mm1	Light Extinction Total Mm1	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine μg/m3	Reconstructed Mass Total μg/m3
WHPE1	2007	100	9.1	17.1	5.03	134	216	2.2	4.2
WHPE1	2009	100	8.4	16.4	4.50	141	228	2.1	3.9
		Average dv Days	**10.0**	**18.0**	**5.31**	**132**	**213**	**2.5**	**4.6**

Source: CSU 2013c

Notes:

Light extinction units are inverse megameters (Mm^{-1})

PM light extinction for particulate matter in air; Total light extinction adds Rayleigh scattering value (gases)

Deciview units are dimensionless (dv); Reconstructed mass units are micrograms per cubic meter ($\mu g/m^3$)

Fine reconstructed mass analogous to $PM_{2.5}$; Total reconstructed mass analogous to PM_{10}

Table A-16 IMPROVE Summary Results - Zion National Park

Site ID Code	Year	Group Code	Light Extinction PM Mm^{1}	Light Extinction Total Mm^{-1}	Deciview dv	Standard Visual Range miles	Standard Visual Range km	Reconstructed Mass Fine $\mu g/m^3$	Reconstructed Mass Total $\mu g/m^3$
ZION1	2001	10	7.5	17.5	5.56	140	225	1.8	4.2
ZION1	2002	10	6.2	16.2	4.81	151	243	1.3	3.2
ZION1	2003	10	5.8	15.8	4.51	155	250	1.2	2.8
		Lowest 20% dv Days	**6.5**	**16.5**	**4.96**	**149**	**239**	**1.4**	**3.4**
ZION1	2001	90	28.8	38.8	13.28	66	106	5.9	13.2
ZION1	2002	90	31.3	41.3	13.94	62	99	7.2	18.9
ZION1	2003	90	25.8	35.8	12.50	71	114	6.3	11.6
		Highest 20% dv Days	**28.6**	**38.6**	**13.24**	**66**	**106**	**6.4**	**14.5**
ZION1	2001	100	15.8	25.8	9.02	102	165	3.5	8.4
ZION1	2002	100	15.8	25.8	8.89	105	169	3.6	9.2
ZION1	2003	100	13.8	23.8	8.22	111	179	3.4	6.7
		Average dv Days	**15.1**	**25.1**	**8.71**	**106**	**171**	**3.5**	**8.1**

Source: CSU 2013c

Notes:

Light extinction units are inverse megameters (Mm^{-1})

PM light extinction for particulate matter in air; Total light extinction adds Rayleigh scattering value (gases)

Deciview units are dimensionless (dv); Reconstructed mass units are micrograms per cubic meter ($\mu g/m^3$)

Fine reconstructed mass analogous to $PM_{2.5}$; Total reconstructed mass analogous to PM_{10}

Lookup Table A-17 shows the calculated relationships between light extinction, deciviews, and standard visual range using the above formulae for β_{ext} ranging from 10 to 2000 Mm^1 (ARS 1993, CSU 1999).

Table A-18 ranks historic deciview data for the 15 sites listed in Table A-1 into the lowest 20 percent of days (good visibility), the highest 20 percent of days (poor visibility), and the average of all days (typical visibility) for 2000 through 2010 (some sites did not operate for all 11 years or have missing data).

Table A-19 aggregates data shown in Table A-18 for the 10 sites within 300 kilometers (186 miles) of FCPP for 2000 through 2010. Since the aggregated data represents regional averages and trends, missing data (11 out of 110 sets) was substituted by interpolation for continuity and uniformity consistent with 90 percent data capture. Mean (average) and median (mid-point) values are shown for comparison purposes. As can be seen from the data, means and medians are in reasonable agreement. Overall deciview improvements are about 1.2 to 1.4 for the lowest 20 percent, highest 20 percent, and average of all days in a year. This correlates to approximately 30 percent, 10 percent, and 15 percent visibility improvements, respectively, over the 11-year period.

Table A-17 Visibility Metrics - IMPROVE Program

Extinction Mm^{-1}	Deciview dV	Standard Visual Range kilometers	Standard Visual Range miles
10	0.0	391	243
12	1.8	326	202
14	3.4	279	174
16	4.7	244	152
18	5.9	217	135
20	6.9	196	121
30	11.0	130	81
40	13.9	98	61
50	16.1	78	49
60	17.9	65	40
70	19.5	56	35
80	20.8	49	30
90	22.0	43	27
100	23.0	39	24
200	30.0	20	12
300	34.0	13	8.1
400	36.9	9.8	6.1
500	39.1	7.8	4.9
600	40.9	6.5	4.0
700	42.5	5.6	3.5
800	43.8	4.9	3.0
900	45.0	4.3	2.7
1000	46.1	3.9	2.4
2000	53.0	2.0	1.2

Sources: ARS 1993, CSU 1999

Table A-18 Historic IMPROVE Visibility Rankings - 15 Class I Areas

Site ID Code	Ranking Days	2000 dV	2001 dV	2002 dV	2003 dV	2004 dV	2005 dV	2006 dV	2007 dV	2008 dV	2009 dV	2010 dV	Last 3 Years
BALD1*	Lowest 20%	—	—	—	2.61	2.82	3.03	3.15	2.66	2.66	3.03	2.81	**2.8**
BALD1*	Highest 20%	—	—	—	12.63	10.38	12.39	9.66	11.55	14.10	11.25	8.95	**11.4**
BALD1*	Average	—	—	—	7.27	6.47	7.40	6.36	6.89	7.96	6.57	5.85	**6.8**
BAND1	Lowest 20%	4.95	4.89	5.03	4.94	4.95	4.09	4.63	4.49	3.91	3.64	3.38	**3.6**
BAND1	Highest 20%	14.58	11.06	12.28	12.72	10.49	12.28	11.58	12.78	11.54	11.03	9.69	**10.8**
BAND1	Average	9.09	7.86	8.39	8.40	7.76	7.96	7.79	8.17	7.57	7.14	6.47	**7.1**
BOAP1*	Lowest 20%	—	—	6.53	6.77	5.53	5.86	6.31	5.86	5.18	5.54	4.62	**5.1**
BOAP1*	Highest 20%	—	—	14.60	13.88	12.91	14.27	13.86	14.15	12.82	11.88	10.87	**11.9**
BOAP1*	Average	—	—	10.06	10.42	8.89	9.60	9.61	9.37	8.94	8.62	7.86	**8.5**
BRCA1*	Lowest 20%	3.00	3.07	2.62	2.35	2.80	1.90	2.36	2.40	1.65	2.14	1.48	**1.8**
BRCA1*	Highest 20%	10.84	11.26	13.23	11.11	11.82	11.78	10.68	12.71	10.96	13.29	9.23	**11.2**
BRCA1*	Average	6.77	7.04	7.25	6.31	7.03	6.46	6.35	7.14	6.11	6.65	5.36	**6.0**
CANY1	Lowest 20%	3.62	4.07	4.20	3.33	3.52	2.34	2.69	3.04	2.71	3.27	2.58	**2.9**
CANY1	Highest 20%	11.18	10.95	12.69	11.78	9.63	10.56	10.51	11.39	11.12	11.51	10.57	**11.1**
CANY1	Average	7.18	7.36	7.91	6.94	6.44	6.39	6.60	7.08	6.69	6.36	6.09	**6.4**
CAPI1	Lowest 20%	—	—	—	3.12	4.12	2.57	—	3.15	2.50	2.71	1.96	**2.4**
CAPI1	Highest 20%	—	—	—	9.38	10.56	11.82	—	11.68	11.41	10.28	9.49	**10.4**
CAPI1	Average	—	—	—	6.15	7.17	7.02	—	7.02	6.61	6.25	5.75	**6.2**
GRCA2	Lowest 20%	2.89	—	1.98	1.82	1.98	2.09	2.39	2.52	1.63	2.16	1.73	**1.8**
GRCA2	Highest 20%	11.12	—	11.62	12.74	11.18	12.60	11.09	11.70	10.63	13.83	9.67	**11.4**
GRCA2	Average	6.88	—	6.46	6.64	6.34	6.75	6.50	7.10	6.05	7.25	5.47	**6.3**
GRSA1	Lowest 20%	4.45	4.53	4.98	4.48	4.06	3.26	3.94	3.56	3.42	3.64	3.32	**3.5**
GRSA1	Highest 20%	14.10	11.40	14.34	12.88	11.18	12.48	11.56	11.01	11.37	10.79	9.79	**10.6**
GRSA1	Average	8.79	8.05	8.88	8.15	7.45	7.60	7.54	7.31	7.51	7.09	6.43	**7.0**

Site ID Code	Ranking Days	2000 dV	2001 dV	2002 dV	2003 dV	2004 dV	2005 dV	2006 dV	2007 dV	2008 dV	2009 dV	2010 dV	Last 3 Years
MEVE1	Lowest 20%	4.35	3.98	4.68	4.70	3.92	2.98	3.57	3.34	2.83	3.00	2.88	**2.9**
MEVE1	Highest 20%	12.97	10.48	14.65	16.76	10.30	12.05	10.67	10.91	11.02	11.73	11.64	**11.5**
MEVE1	Average	8.02	7.48	8.93	9.30	6.92	6.95	6.93	7.12	6.80	6.74	6.63	**6.7**
PEFO1	Lowest 20%	5.04	4.98	5.09	5.43	4.59	4.54	5.35	4.90	4.07	4.23	4.14	**4.1**
PEFO1	Highest 20%	12.73	10.85	13.49	16.10	12.90	14.03	12.11	12.68	12.26	14.04	11.37	**12.6**
PEFO1	Average	8.82	7.87	8.80	10.02	8.38	8.78	8.51	8.66	8.06	8.23	7.56	**7.9**
SAPE1	Lowest 20%	—	1.89	1.07	1.38	1.47	0.87	1.43	0.99	0.76	1.12	0.76	**0.9**
SAPE1	Highest 20%	—	9.27	10.56	11.62	9.25	10.77	9.74	10.71	10.01	8.21	8.48	**8.9**
SAPE1	Average	—	5.69	5.80	6.19	5.45	5.71	5.36	5.64	5.60	4.71	4.83	**5.0**
SIAN1*	Lowest 20%	—	6.22	6.49	6.06	5.87	5.27	—	—	—	4.61	5.50	**5.1**
SIAN1*	Highest 20%	—	12.20	14.12	15.09	13.27	14.97	—	—	—	11.80	11.63	**11.7**
SIAN1*	Average	—	9.19	10.27	10.16	9.08	9.63	—	—	—	8.21	8.00	**8.1**
WEMI1	Lowest 20%	—	3.25	3.26	2.93	3.02	2.61	2.92	2.30	2.16	2.12	1.77	**2.0**
WEMI1	Highest 20%	—	9.55	11.18	11.32	9.28	9.95	9.16	10.28	10.81	9.99	9.50	**10.1**
WEMI1	Average	—	6.48	6.72	6.67	6.09	6.04	6.15	6.08	6.24	5.75	5.45	**5.8**
WHPE1	Lowest 20%	—	—	1.10	1.52	1.05	0.63	1.29	1.24	—	0.37	—	**0.4**
WHPE1	Highest 20%	—	—	11.12	11.38	8.75	10.08	9.16	8.62	—	8.65	—	**8.6**
WHPE1	Average	—	—	6.03	5.98	5.02	5.28	5.31	5.03	—	4.50	—	**4.5**
ZION1*	Lowest 20%	—	5.56	4.81	4.51	—	—	—	—	—	—	—	**—**
ZION1*	Highest 20%	—	13.28	13.94	12.50	—	—	—	—	—	—	—	**—**
ZION1*	Average	—	9.02	8.89	8.22	—	—	—	—	—	—	—	**—**

Source: CSU 2013c

Notes:

* Indicates location is outside 300 kilometer radius of FCPP

3-Year trend is average (mean) of 2008-2010 data

Table A-19 Historic Composite Visibility - 10 IMPROVE Sites

Year	Lowest 20% of Days Mean dV	Lowest 20% of Days Median dV	Highest 20% of Days Mean dV	Highest 20% of Days Median dV	Average of all Days Mean dV	Average of all Days Median dV
2000	3.46	3.45	11.88	11.21	7.39	7.03
2001	3.46	3.62	10.67	10.90	7.02	7.07
2002	3.47	3.73	12.25	11.95	7.47	7.34
2003	3.36	3.22	12.67	12.25	7.44	6.80
2004	3.27	3.72	10.35	10.40	6.70	6.68
2005	2.60	2.59	11.66	11.93	6.85	6.85
2006	3.11	2.89	10.73	10.88	6.77	6.77
2007	2.95	3.09	11.18	11.20	6.92	7.09
2008	2.48	2.60	10.88	11.07	6.59	6.65
2009	2.63	2.86	11.01	10.91	6.40	6.55
2010	2.31	2.27	9.89	9.68	5.93	5.92
11-Year Trend Change	**-1.18**	**-1.22**	**-1.40**	**-1.08**	**-1.22**	**-0.82**
Relative Improvement	**33%**	**33%**	**12%**	**9%**	**16%**	**11%**

Source: CSU 2013c

Notes:

Aggregated data for 10 sites: BAND1, CANY1, CAPI1, GRCA2, GRSA1, MEVE1, PEFO1, SAPE1, WEMI1, WHPE1

Missing data substituted by interpolation (11 of 110 sets)

Change and improvement calculated on linear trend basis

A.4 Emissions Monetization of the Social Cost of Carbon

A.4.5 Introduction

The Social Cost of Carbon (SCC) is a monetization of the effects associated with an incremental increase in carbon emissions. It is intended to quantify climate change-induced effects to net agricultural productivity, human health, property damage from increased flood risk, the value of ecosystem services, and other factors.

In Federal rulemaking proceedings, Executive Order 12866 requires that agencies “assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs.” In the context of including the SCC in cost-benefit analysis for rulemaking, a 12-member Interagency Working Group (IWG)[1] was formed to assess the calculation of SCC. The IWG released its initial Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis in February 2010, which was subsequently updated in May 2013.

[1] Council of Economic Advisers; Council on Environmental Quality; Department of Agriculture; Department of Commerce; Department of Energy; Department of Transportation; Environmental Protection Agency; National Economic Council; Office of Energy and Climate Change; Office of Management and Budget; Office of Science and Technology Policy; and Department of the Treasury.

According to the IWG (2010): "[i]t is important to recognize that a number of key uncertainties remain, and that current SCC estimates should be treated as provisional and revisable since they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. The National Academy of Science (2009) points out that there is tension between the goal of producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of existing efforts to model these effects."

In particular, "[t]he choice of a discount rate, especially over long periods of time, raises highly contested and exceedingly difficult questions of science, economics, philosophy, and law. Although it is well understood that the discount rate has a large influence on the current value of future damages, there is no consensus about what rates to use in this context" (IWG 2010).

Draft Guidance on climate change analysis was published by the Council on Environmental Quality (CEQ) in December 2014, and indicates that emissions monetization is not required in every project-level National Environmental Policy Act (NEPA) analysis:

"Monetizing costs and benefits is appropriate in some, but not all cases and is not a new requirement. A monetary cost-benefit analysis need not and should not be used in weighing the merits and drawbacks of the alternatives when important qualitative considerations are being considered. If a cost-benefit analysis is relevant to the choice among different alternatives being considered, it must be incorporated by reference or appended to the statement as an aid in evaluating the environmental consequences. When an agency determines it is appropriate to monetize costs and benefits, then, although developed specifically for regulatory impact analyses, the Federal SCC, which multiple Federal agencies have developed and used to assess the costs and benefits of alternatives in rulemakings, offers a harmonized, interagency metric that can provide decision makers and the public with some context for meaningful NEPA review. When using the Federal SCC, the agency should disclose the fact that these estimates vary over time, are associated with different discount rates and risks, and are intended to be updated as scientific and economic understanding improves."

Office of Surface Mining Reclamation and Enforcement (OSMRE) has included emissions monetization of SCC in the Final Environmental Impact Statement (EIS) according to the IWG methods to provide further context and enhance the discussion of climate change impacts in the NEPA analysis. Providing an SCC dollar amount did not change the findings or the level of significance determined in the Draft EIS for climate change effects, which relied on a comprehensive qualitative analysis of SCC.

The SCC is calculated for the each of the Action Alternatives. The uncertainty in the results is expressed by using the range of discount rates presented in IWG (2013). The emissions are based on operating Units 4 and 5 of Four Corners Power Plant (FCPP) until 2041, and associated coal mining at the Navajo Mine. The SCC is also calculated for the No Action Alternative (shutting down FCPP and providing available replacement generation from other existing power plants in Arizona Public Service Company's [APS] portfolio and assumed new natural gas combined cycle facilities). Similarly, the four minority share co-owners of Units 4 and 5 would also need to replace lost base load generation with extra output from existing generating resources and possibly construct new combined cycle plants, either individually or collectively. The difference between the Action Alternatives and the No Action Alternative represents a rough estimate of the marginal increase of SCC resulting from the Project, compared to No Action. The calculated cost of carbon under the No Action Alternative is approximately half that of the Action Alternatives.

A.4.6 Modeling Approach: IWG Method

The IWG selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from three different integrated assessment models (Integrated Assessment Models [IAMs], discussed below), at net present value (NPV) discount rates of 2.5, 3, and 5 percent. The fourth value, which represents the 95th percentile SCC estimate across all three models at a 3 percent discount rate, was included to represent higher-than-expected impacts from temperature change further out in the “tails” of the SCC probability distributions as an upper–bound on the results (IWG 2013).

The NPV of future carbon emissions is calculated by multiplying annual emissions by the appropriate discounted SCC factor for that year and summing across all affected years. The central value is the average SCC across the three IAMs at the 3 percent discount rate (IWG 2010). The 3 percent discount rate is consistent with 1) guidelines contained in Office of Management and Budget (OMB) Circular A-4 (OMB 2003); and 2) the most recent U.S. Bureau of Labor Statistics (BLS) long-term (30-year) inflation rate data of 2.8 percent (BLS 2014). In addition to the 3 percent discount rate recommended for use by the IWG (2013), this study also quantifies the SCC of future carbon emissions for the 2.5 percent, 5 percent, and the 95th percentile at 3 percent discount rates in order to provide a range of SCC results representing the range in this uncertain variable.

Integrated Assessment Models

The IWG used three IAMs to estimate SCC: DICE, PAGE, and FUND. These models are frequently cited in peer-reviewed literature and used in the Intergovernmental Panel on Climate Change (IPCC) assessments. Each of these models translates emissions into changes in atmospheric greenhouse gas (GHG) concentrations, atmospheric concentrations into changes in temperature, and changes in temperature into economic damages. Therefore, each model was given equal weight by the IWG in developing the published SCC values (IWG 2010).

A common key input parameter to the DICE, PAGE, and FUND models is equilibrium climate sensitivity (ECS). ECS is defined as the long-term increase in the annual global-average surface temperature from a doubling of atmospheric carbon dioxide (CO_2) concentration compared to pre-industrial levels, from about 280 to 550 parts per million by volume (ppmv), mainly due to combustion of fossil fuels. Based on IPCC assessments of several independent lines of evidence, the IWG calibrated the three models for and ECS of 3 degrees Celsius (°C), which represents the middle of a range of 2°C to 4.5°C (IWG 2010). Therefore, this analysis uses the recommended value by IWG (2013) in order to be consistent with other calculations of SCC by federal agencies relying on this guidance.

Values of Other GHGs

While CO_2 is the most prevalent GHG emitted into the atmosphere, five other U.S. Environmental Protection Agency (EPA)-listed GHGs also contribute to climate change: methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride (EPA 2014b). The climate impact of these gases is commonly discussed in terms of their 100-year global warming potential (GWP). GWP measures the ability of different gases to trap heat in the atmosphere (i.e., radiative forcing per unit of mass) over a particular timeframe relative to CO_2. However, because these gases differ in both radiative forcing and atmospheric lifetimes, their relative damages are not constant over time. Due to various effects of non-CO_2 gas properties and mechanisms, transforming other GHGs into CO_2e using GWPs, and then multiplying the carbon-equivalents by the SCC would not result in accurate estimates of the social costs of non-CO_2 gases (IWG 2010). Also, since CO_2 comprises over 99 percent of carbon dioxide equivalent (CO_2e) from fossil fuel combustion, there is no significant difference between the two values with respect to practicable mass emission estimation precision for fossil fuel combustion sources (EPA 2014b).

With respect to estimated fugitive methane emissions from coal mining, the Navajo Mine could emit about 0.069 million metric tonne (MMT) of methane over the 25-year project life (OSMRE 2012), or about 1.45 MMT as CO_2e (GWP = 21). During the same period, FCPP Units 4 and 5 would emit about 258 MMT CO_2e. Thus, coal seam methane CO_2e would comprise less than 1 percent of coal combustion CO_2e, which is within practicable mass emission estimation precision and therefore a relatively small source of uncertainty for estimating SCC for the Action Alternatives (EPA 2014b).

Discount / Inflation Rates

Of central importance to the SCC is determination of the NPV discount rate. The IWG reviewed relevant economics literature and concluded that the consumption rate of interest of 3 percent was the most correct to use in evaluating the benefits and costs of a marginal change in carbon emissions (IWG 2010). The consumption rate of interest also is appropriate when the impacts of a regulation are measured in consumption-equivalent units, as was done in the three IAMs used for estimating the SCC. However, the IWG noted disagreement in the literature on the appropriate market interest rate to use in the context and uncertainty about how interest rates can change over time. Therefore, the IWG chose three discount rates to span a range of discount rates: 2.5, 3, and 5 percent per year. Based on the literature reviews, the IWG determined that these three rates reflect reasonable judgments under both descriptive and prescriptive approaches (IWG 2010).

The IWC concluded that the central value, 3 percent, is consistent with estimates provided in the economics literature and OMB's Circular A-4 guidance for the consumption rate of interest, roughly corresponds to the after-tax riskless interest rate (IWG 2010). The 3 percent discount rate is also consistent with BLS long-term (30-year) inflation rate data of 2.8 percent (BLS 2014). The upper value of 5 percent was included to represent the possibility that climate damages are positively correlated with market returns. The lower value, 2.5 percent, was included to incorporate the concern that interest rates are highly uncertain over time. The 95^{th} percentile estimate across all three models at a 3 percent discount rate was included to represent an upper-boundary condition (IWG 2010, 2013).

As modeled using DICE, PAGE, and FUND, average SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. Table A-20 and Figure A-1 illustrate how the growth rate for the four SCC estimates varies over time for the period between 2010 and 2050 (IWG 2013).

Table A-20 Annual SCC Values 2010-2050 (2007$/MT CO_2e)

Year	NPV Discount Rate 5%	NPV Discount Rate 3%	NPV Discount Rate 2.5%	3% 95th
2010	11	33	52	90
2011	11	34	54	94
2012	11	35	55	98
2013	11	36	56	102
2014	11	37	57	106
2015	12	38	58	109
2016	12	39	60	113
2017	12	40	61	117
2018	12	41	62	121
2019	12	42	63	125
2020	12	43	65	129
2021	13	44	66	132
2022	13	45	67	135
2023	13	46	68	138
2024	14	47	69	141
2025	14	48	70	144
2026	15	49	71	147
2027	15	49	72	150
2028	15	50	73	153
2029	16	51	74	156

Year	NPV Discount Rate 5%	NPV Discount Rate 3%	NPV Discount Rate 2.5%	3% 95th
2030	16	52	76	159
2031	17	53	77	163
2032	17	54	78	166
2033	18	55	79	169
2034	18	56	80	172
2035	19	57	81	176
2036	19	58	82	179
2037	20	59	84	182
2038	20	60	85	185
2039	21	61	86	188
2040	21	62	87	192
2041	22	63	88	195
2042	22	64	89	198
2043	23	65	90	200
2044	23	65	91	203
2045	24	66	92	206
2046	24	67	94	209
2047	25	68	95	212
2048	25	69	96	215
2049	26	70	97	218
2050	27	71	98	221

Source: IWG 2013.

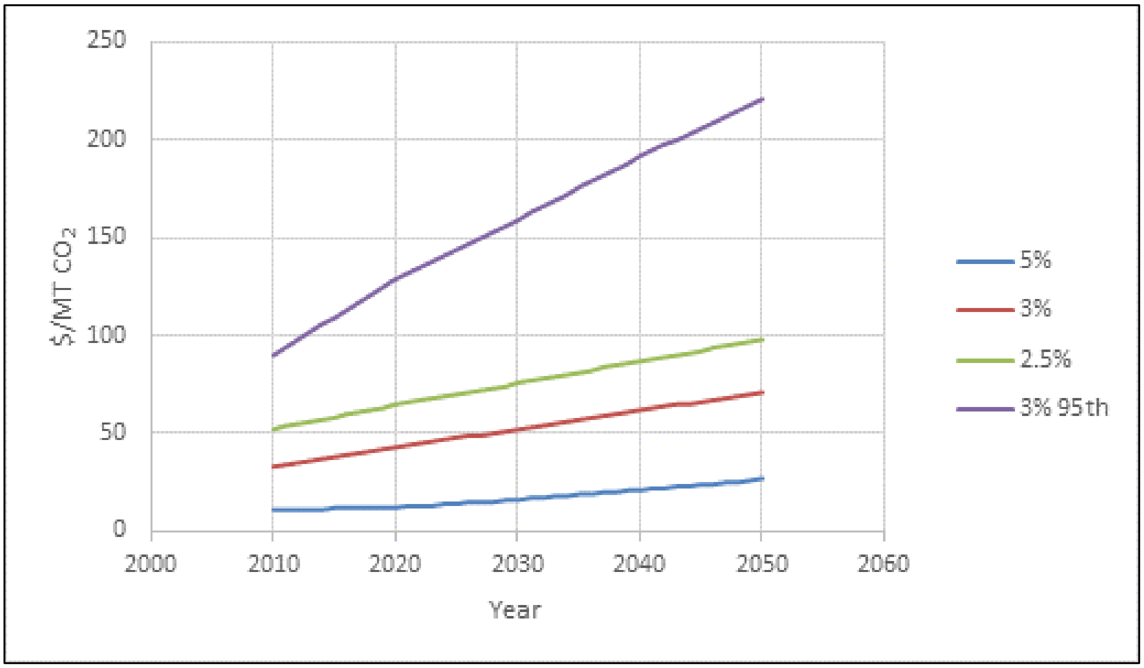

Figure A-1 Annual SCC Values 2010-2050 (2007$/MT CO_2e)

A.4.7 Modeling Results

If one of the Action Alternatives is approved, the SCC analysis assumes that FCPP Units 4 and 5 would operate at maximum historic baseline (92 percent capacity factor) levels for the duration of the 25 year period 2017 to 2041. Under this upper-bound scenario, Units 4 and 5 would potentially emit about 10.34 MMT of CO_2e annually. The SCC of the makeup generation that would be required under the No Action alternative assumes that if the FCPP power plant lease is not renewed and the Navajo Mine Surface Mining Control and Reclamation Act (SMCRA) permits are not approved, then the FCPP and the Navajo Mine would close. In that event, APS, which owns 63 percent of Units 4 and 5, would need to 1) replace the lost base load generation capability with marginally increased output from its nine other partially- and wholly-owned generating resources,[2] and 2) construct new natural gas combined cycle (NGCC) generating facilities similar to Redhawk generating station to make up the difference between FCPP output and the marginal combined outputs of the other nine plants. Similarly, the other 37 percent co-owners of Units 4 and 5 (i.e., Public Service Company of New Mexico [PNM], Salt River Project, Tucson Electric Power, and El Paso Electric [EPE]) would also need to replace lost base load generation with extra output from existing generating resources and possibly construct new NGCC plants, either individually or collectively. The assumptions represent a most probable value for the SCC of the No Action. No Action SCC may be less with a greater contribution from renewable resources, and may be greater with a greater proportion of other coal-fired generating resources. For assessment purposes, these two factors of makeup generation are addressed as follows:

- Lost FCPP generation is based on a 92 percent generation capacity factor determined from 2000-2011 Part 75 operating data;
- Available existing portfolio generation are the differences of 95th and 50th percentiles of 2004-2013 Part 75 operating data (baselines of partially- and wholly-owned generating resources); and
- Make-up generation (i.e., lost FCPP generation minus available existing portfolio generation) is NGCC new construction based on Part 75 operating data for the APS Redhawk Generating Station.

Table A-21 summarizes the 10 existing APS baseline generation resources (portfolio) by plant name. FCPP Units 4 and 5 comprise about 25 percent of APS base load generation capability while emitting about 38 percent of utility-wide CO_2e. The other two APS coal-fired plants, Cholla and Navajo, collectively generate 27 percent of base load and emit 48 percent of utility-wide CO_2e. However, Units 4 and 5 presently emit CO_2e at the rate of 838 kilograms per megawatt hour (kg/MW-hr), which is less than Cholla (981 kg/MW-hr) or Navajo (956 kg/MW-hr). Table A-22 summarizes the No Action baseline replacement generation scenario described above, which would reduce overall CO_2e emissions by about 50 percent on a utility-wide basis (APS 2014; EPA 2014a, 2014b).

Using the IWG-recommended 3 percent NPV discount rate SCC values shown in Table A-20 and the baseline generation values shown in Table A-22, the 25-year estimated SCC in 2007 dollars is determined in Table A-23 for (1) continued operation of Units 4 and 5 (FCPP Generation) if any of the Action Alternatives are approved; and (2) shut down of Units 4 and 5 (Replacement Generation) if the No Action alternative is selected. Similarly, Table A-24 determines the 25-year estimated SCC in 2014 dollars, reflecting a 7-year composite inflation of 14.5 percent. (IWG 2013, BLS 2014)

Attachment 1 contains supplemental tables summarizing SCC results for the 5 percent (Table 1), 2.5 percent (Table 2), and 95th percentile 3 percent (Table 3) NPV discount rates defined by the IWG in 2007 dollars. For 2014 dollars, Attachment A also contains tables summarizing SCC results for the 5 percent (Table 4), 2.5 percent (Table 5), and 95th percentile 3 percent (Table 6) NPV discount rates. The results of these analyses are used to determine the potential range of SCC values based on the range in selected discount rates.

2 Palo Verde Nuclear Generating Station; Cholla Power Plant; Ocotillo Power Plant; APS West Phoenix Power Plant; APS Saguaro Power Plant; Yucca Power Plant; Navajo Generating Station; Redhawk Generating Facility; and Sundance Power Plant.

As shown in Table A-23, summed across 25 years, the estimated SCC for continued operation of FCPP Units 4 and 5 would be about $13.3 billion in 2007 dollars while the estimated SCC for replacement generation would be about $6.4 billion in 2007 dollars, about 50 percent less. Adjusted for inflation in Table A-24, the estimated SCC for continued operation of FCPP Units 4 and 5 would be about $15.2 billion in 2014 dollars while the estimated SCC for replacement generation would be about $7.4 billion in 2014 dollars, also about 50 percent less (IWG 2013, BLS 2014). The difference between the SCC for the Action Alternatives and the SCC for No Action, $7.8 billion in 2014 dollars, is the net SCC for the 25 years of continued operations of FCPP Units 4 and 5.

Tables A-25 and Table A-26 below summarize the SCC results shown in Table A-23 and Table A-24, along with results from Attachment A tables listed above for the 2.5 percent, 5 percent, and 95th percentile 3 percent discount rates in 2007 and 2014 dollars, respectively. The range in these values provides an indication of the degree of uncertainty in SCC based on the range of discount rates recommended by the IWG.

As recommended by the IWG, the 3 percent NPV discount rate represents the central value for this analysis and yields an amortized SCC (in 2014 dollars) of $59/MT CO_2e over the 25-year project life. Similarly, the 2.5 percent discount rate yields an amortized SCC of $85/MT CO_2e, and the 5 percent discount rate yields an amortized SCC of $19/MT CO_2e. The upper-boundary 95th percentile 3 percent discount rate yields a high amortized SCC of $179/MT CO_2e. Since the BLS long-term (30-year) inflation rate is 2.8 percent (BLS 2014) the amortized SCC would apparently be in the range of $59 to $85 per metric tonne CO_2e.

Finally, Table A-27 and Table A-28 compare the calculated SCC for the entire 25 year period for each EIS alternative in billions of dollars. The results are presented in both 2007 dollars (Table A-27) and 2014 dollars (Table A-28). The central value recommended by the IWG, based on a 3 percent NPV, is provided in bold, and the values for the range in discount rates are presented to represent a range in values.

As shown in Table A-28, for a 3 percent discount rate in 2014 dollars, the difference between the Action Alternatives ($15.2 billion) and the No Action Alternative ($7.4 billion) represents a rough estimate of the marginal increase of SCC resulting from the Project ($7.8 billion), compared to No Action. The calculated cost of carbon under the No Action Alternative is approximately half that of the Action Alternatives.

Table A-21 Summary of APS Baseline Generation Resources by Plant Name

Plant Name	ORISPL[1] Code	Reported Units	Fuel Type	APS Share	CO_2e Rate[2] kg/MW-hr	APS Generation[2] MW-hr/yr	APS Generation[2] percent	CO_2e Emissions[2] MT/yr	CO_2e Emissions[2] percent
Four Corners Steam Electric Station	2442	2	Coal	63%	838	7,038,700	24.7%	5,899,800	37.9%
Palo Verde Nuclear Generating Station	na	3	Nuclear	29.1%	0	8,511,750	29.8%	0	0.0%
Cholla Power Plant	113	3	Coal	100%	981	5,024,590	17.6%	4,927,590	31.6%
Ocotillo Power Plant	116	2	PNG	100%	646	113,950	0.4%	73,660	0.5%
APS West Phoenix Power Plant	117	3	PNG	100%	418	1,442,650	5.1%	603,350	3.9%
APS Saguaro Power Plant	118	3	PNG	100%	660	68,770	0.2%	45,410	0.3%
Yucca Power Plant	120	2	PNG	100%	617	92,470	0.3%	57,010	0.4%
Navajo Generating Station	4941	3	Coal	14%	956	2,655,520	9.3%	2,539,250	16.3%
Redhawk Generating Facility	55455	4	PNG	100%	391	3,470,960	12.2%	1,356,130	8.7%
Sundance Power Plant	55522	10	PNG	100%	583	130,270	0.5%	75,900	0.5%
				Totals	**546**	**28,549,630**	**100%**	**15,578,100**	**100%**

Sources: EPA 2014a, 2014b; APS 2014.

Notes:

[1] Office of Regulatory Information Systems Plant Location (power plants)

[2] 50th percentiles of 2004-2013 Part 75 data (median baselines)

Coal and nuclear units are steam turbine

CC = Combustion & steam turbines (combined cycle)

CT = Combustion turbine (simple cycle)

PNG = Pipeline Natural Gas

Table A-22 Summary of CO_2e Emissions of No Action Baseline Replacement Generation

Operating Parameter Estimates	Generation MW-hr/yr	CO_2e Emissions MT/yr	CO_2e Emissions kg/MW-hr
a) Aggregate FCPP Units 4 & 5 Baseline Generation[1]	12,410,900	10,339,000	833
b) Existing APS Portfolio Make-up Generation Available[2]	3,741,600	1,627,100	435
c) Baseline Generation Deficit[3]	(8,669,300)	(8,711,900)	–
d) New Aggregate Make-up Generation Required[4]	8,669,300	3,391,400	391
e) Overall Net Change for Generation Parity[5]	0	(5,320,500)	–
f) Revised Aggregate Replacement Baseline Generation[6]	12,410,900	5,018,500	404
g) Percent Reduction in Carbon Emissions[7]		**51%**	**51%**

Sources: EPA2014a, 2014b; APS 2014.

Notes:

[1] Per DEIS 92% generation (MW-hr/yr) capacity factor for Units 4 & 5 based on 2000-2011 Part 75 data

[2] Differences of 95th and 50th percentiles of 2004-2013 Part 75 data (baselines)

[3] Existing portfolio make-up generation minus Units 4 & 5 generation (c = b - a)

[4] Assumes Natural Gas Combined Cycle (NGCC) new construction

[5] Negative MT/yr CO_2e are avoided emissions (e = c + d)

[6] Sum of existing make-up generation and new make-up generation (f = b + d)

[7] Reduction from FCPP baseline generation to revised portfolio baseline generation (g = 1 - f/a)

Table A-23 Estimated Social Cost of Carbon - Future Baseline GHG Emissions (2007$)

Year	FCPP Generation[1] MW-hr	FCPP Generation Emissions MT CO_2e	Replacement Generation Emissions MT CO_2e	Average SCC[2] $/MT	FCPP Generation SCC $million	Replacement Generation SCC $million
2012	–	–	–	35	–	–
2013	–	–	–	36	–	–
2014	–	–	–	37	–	–
2015	–	–	–	38	–	–
2016	–	–	–	39	–	–
2017	12,410,900	10,339,000	5,018,500	40	414	201
2018	12,410,900	10,339,000	5,018,500	41	424	206
2019	12,410,900	10,339,000	5,018,500	42	434	211
2020	12,410,900	10,339,000	5,018,500	43	445	216
2021	12,410,900	10,339,000	5,018,500	44	455	221
2022	12,410,900	10,339,000	5,018,500	45	465	226
2023	12,410,900	10,339,000	5,018,500	46	476	231
2024	12,410,900	10,339,000	5,018,500	47	486	236
2025	12,410,900	10,339,000	5,018,500	48	496	241
2026	12,410,900	10,339,000	5,018,500	49	507	246
2027	12,410,900	10,339,000	5,018,500	49	507	246
2028	12,410,900	10,339,000	5,018,500	50	517	251
2029	12,410,900	10,339,000	5,018,500	51	527	256
2030	12,410,900	10,339,000	5,018,500	52	538	261
2031	12,410,900	10,339,000	5,018,500	53	548	266
2032	12,410,900	10,339,000	5,018,500	54	558	271
2033	12,410,900	10,339,000	5,018,500	55	569	276
2034	12,410,900	10,339,000	5,018,500	56	579	281
2035	12,410,900	10,339,000	5,018,500	57	589	286
2036	12,410,900	10,339,000	5,018,500	58	600	291
2037	12,410,900	10,339,000	5,018,500	59	610	296
2038	12,410,900	10,339,000	5,018,500	60	620	301
2039	12,410,900	10,339,000	5,018,500	61	631	306
2040	12,410,900	10,339,000	5,018,500	62	641	311
2041	12,410,900	10,339,000	5,018,500	63	651	316
	25-Year Cumulative (MMT)[3]	**258**	**125**	**–**	**13,286**	**6,449**

Sources: EPA 2014a, 2014b; APS 2014; IWG 2013; BLS 2014.

Notes:

[1] Per DEIS 92% generation (MW-hr/yr) capacity factor for Units 4 & 5 based on 2000-2011 Part 75 data

[2] Average SCC for 3% NPV discount rate in unadjusted 2007$ (IWG 2013)

Average annual rate of inflation (30 years; 1984-2014) = 2.8% (BLS 2014) supports 3% discount rate (IWG 2013)

[3] 25-year cumulative is for 2017-2041 (inclusive) in million metric tonnes (MMT) CO_2e

Table A-24 Estimated Social Cost of Carbon - Future Baseline GHG Emissions (2014$)

Year	FCPP Generation[1] MW-hr	FCPP Generation Emissions MT CO_2e	Replacement Generation Emissions MT CO_2e	Average SCC[2] $/MT	FCPP Generation SCC $million	Replacement Generation SCC $million
2012	–	–	–	40	–	–
2013	–	–	–	41	–	–
2014	–	–	–	42	–	–
2015	–	–	–	44	–	–
2016	–	–	–	45	–	–
2017	12,410,900	10,339,000	5,018,500	46	476	231
2018	12,410,900	10,339,000	5,018,500	47	486	236
2019	12,410,900	10,339,000	5,018,500	48	496	241
2020	12,410,900	10,339,000	5,018,500	49	507	246
2021	12,410,900	10,339,000	5,018,500	50	517	251
2022	12,410,900	10,339,000	5,018,500	52	538	261
2023	12,410,900	10,339,000	5,018,500	53	548	266
2024	12,410,900	10,339,000	5,018,500	54	558	271
2025	12,410,900	10,339,000	5,018,500	55	569	276
2026	12,410,900	10,339,000	5,018,500	56	579	281
2027	12,410,900	10,339,000	5,018,500	56	579	281
2028	12,410,900	10,339,000	5,018,500	57	589	286
2029	12,410,900	10,339,000	5,018,500	58	600	291
2030	12,410,900	10,339,000	5,018,500	60	620	301
2031	12,410,900	10,339,000	5,018,500	61	631	306
2032	12,410,900	10,339,000	5,018,500	62	641	311
2033	12,410,900	10,339,000	5,018,500	63	651	316
2034	12,410,900	10,339,000	5,018,500	64	662	321
2035	12,410,900	10,339,000	5,018,500	65	672	326
2036	12,410,900	10,339,000	5,018,500	66	682	331
2037	12,410,900	10,339,000	5,018,500	68	703	341
2038	12,410,900	10,339,000	5,018,500	69	713	346
2039	12,410,900	10,339,000	5,018,500	70	724	351
2040	12,410,900	10,339,000	5,018,500	71	734	356
2041	12,410,900	10,339,000	5,018,500	72	744	361
	25-Year Cumulative (MMT)[3]	**258**	**125**	**–**	**15,219**	**7,387**

Sources: EPA 2014a, 2014b; APS 2014; IWG 2013; BLS 2014.

Notes:

[1] Per DEIS 92% generation (MW-hr/yr) capacity factor for Units 4 & 5 based on 2000-2011 Part 75 data
[2] Average SCC for 3% NPV discount rate adjusted from 2007$ to 2014$ (IWG 2013, BLS 2014)
Average annual rate of inflation (30 years; 1984-2014) = 2.8% (BLS 2014) supports 3% discount rate (IWG 2013)
[3] 25-year cumulative is for 2017-2041 (inclusive) in million metric tonnes (MMT) CO_2e

Table A-25 Cumulative Social Cost of Carbon - Discount Rate Comparison (2007$)

Discount Rate	FCPP Generation[1,2] MMT CO_2e	FCPP Generation[1,2] $million	FCPP Generation[1,2] $/MT	Replacement Generation MMT CO_2e	Replacement Generation $million	Replacement Generation $/MT
2.5%	258	19,272	75	125	9,354	75
3%	258	13,286	51	125	6,449	51
5%	258	4,177	16	125	2,027	16
95th 3%	258	40,467	157	125	19,642	157

Sources: EPA 2014a, 2014b; APS 2014; IWG 2013; BLS 2014.

Notes:

[1] Per DEIS 92% generation (MW-hr/yr) capacity factor for Units 4 & 5 based on 2000-2011 Part 75 data
[2] 25-year cumulative is for 2017-2041 (inclusive)

Table A-26 Cumulative Social Cost of Carbon - Discount Rate Comparison (2014$)

Discount Rate	FCPP Generation[1,2] MMT CO_2e	FCPP Generation[1,2] $million	FCPP Generation[1,2] $/MT	Replacement Generation MMT CO_2e	Replacement Generation $million	Replacement Generation $/MT
2.5%	258	22,063	85	125	10,709	85
3%	258	15,219	59	125	7,387	59
5%	258	4,787	19	125	2,324	19
95th 3%	258	46,350	179	125	22,498	179

Sources: EPA 2014a, 2014b; APS 2014; IWG 2013; BLS 2014.

Notes:

[1] Per DEIS 92% generation (MW-hr/yr) capacity factor for Units 4 & 5 based on 2000-2011 Part 75 data
[2] 25-year cumulative is for 2017-2041 (inclusive)

Table A-27 Cumulative Social Cost of Carbon – Discount Rate Comparison (2007$)

Alternative	Cumulative Cost (Billion $) at each Discount Rate 5%	Cumulative Cost (Billion $) at each Discount Rate 3%	Cumulative Cost (Billion $) at each Discount Rate 2.5%	Cumulative Cost (Billion $) at each Discount Rate 95th 3%
A: Proposed Action	4.2	**13.3**	19.3	40.5
B: Navajo Mine Expansion Project	4.2	**13.3**	19.3	40.5
C: Alternative Pinabete Mine Plan	4.2	**13.3**	19.3	40.5
D: Alternative Ash Disposal Configuration	4.2	**13.3**	19.3	40.5
E: No Action	2.0	**6.4**	9.4	19.6

Sources: EPA 2014a, 2014b; APS 2014; IWG 2013; BLS 2014.

Table A-28 Cumulative Social Cost of Carbon – Discount Rate Comparison (2014$)

Alternative	Cumulative Cost (Billion $) at each Discount Rate 5%	Cumulative Cost (Billion $) at each Discount Rate 3%	Cumulative Cost (Billion $) at each Discount Rate 2.5%	Cumulative Cost (Billion $) at each Discount Rate 95th 3%
A: Proposed Action	4.8	**15.2**	22.1	46.3
B: Navajo Mine Expansion Project	4.8	**15.2**	22.1	46.3
C: Alternative Pinabete Mine Plan	4.8	**15.2**	22.1	46.3
D: Alternative Ash Disposal Configuration	4.8	**15.2**	22.1	46.3
E: No Action	2.3	**7.4**	10.7	22.5

Sources: EPA 2014a, 2014b; APS 2014; IWG 2013; BLS 2014.

A.4.8 References

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ATTACHMENT 1
SCC Monetization for Range of Discount Rates

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Table 1 Estimated Social Cost of Carbon 5% Discount Rate - Future Baseline GHG Emissions (2007$)

Year	FCPP Generation[1] MW-hr	FCPP Generation Emissions MT CO_2e	Replacement Generation Emissions MT CO_2e	Average SCC[2] $/MT	FCPP Generation SCC $million	Replacement Generation SCC $million
2012	–	–	–	11	–	–
2013	–	–	–	11	–	–
2014	–	–	–	11	–	–
2015	–	–	–	12	–	–
2016	–	–	–	12	–	–
2017	12,410,900	10,339,000	5,018,500	12	124	60
2018	12,410,900	10,339,000	5,018,500	12	124	60
2019	12,410,900	10,339,000	5,018,500	12	124	60
2020	12,410,900	10,339,000	5,018,500	12	124	60
2021	12,410,900	10,339,000	5,018,500	13	134	65
2022	12,410,900	10,339,000	5,018,500	13	134	65
2023	12,410,900	10,339,000	5,018,500	13	134	65
2024	12,410,900	10,339,000	5,018,500	14	145	70
2025	12,410,900	10,339,000	5,018,500	14	145	70
2026	12,410,900	10,339,000	5,018,500	15	155	75
2027	12,410,900	10,339,000	5,018,500	15	155	75
2028	12,410,900	10,339,000	5,018,500	15	155	75
2029	12,410,900	10,339,000	5,018,500	16	165	80
2030	12,410,900	10,339,000	5,018,500	16	165	80
2031	12,410,900	10,339,000	5,018,500	17	176	85
2032	12,410,900	10,339,000	5,018,500	17	176	85
2033	12,410,900	10,339,000	5,018,500	18	186	90
2034	12,410,900	10,339,000	5,018,500	18	186	90
2035	12,410,900	10,339,000	5,018,500	19	196	95
2036	12,410,900	10,339,000	5,018,500	19	196	95
2037	12,410,900	10,339,000	5,018,500	20	207	100
2038	12,410,900	10,339,000	5,018,500	20	207	100
2039	12,410,900	10,339,000	5,018,500	21	217	105
2040	12,410,900	10,339,000	5,018,500	21	217	105
2041	12,410,900	10,339,000	5,018,500	22	227	110
	25-Year Cumulative (MMT)[3]	**258**	**125**	**–**	**4,177**	**2,027**

Sources: EPA 2014a, 2014b; APS 2014; IWG 2013; BLS 2014.

Notes:

[1] Per Draft EIS 92% generation (MW-hr/yr) capacity factor for Units 4 & 5 based on 2000-2011 Part 75 data.
[2] Average SCC for 5% NPV discount rate in unadjusted 2007$ (IWG 2013).
[3] 25-year cumulative is for 2017-2041 (inclusive) in million metric tonnes (MMT) CO_2e.

Table 2 Estimated Social Cost of Carbon 2.5% Discount Rate - Future Baseline GHG Emissions (2007$)

Year	FCPP Generation[1] MW-hr	FCPP Generation Emissions MT CO_2e	Replacement Generation Emissions MT CO_2e	Average SCC[2] $/MT	FCPP Generation SCC $million	Replacement Generation SCC $million
2012	–	–	–	55	–	–
2013	–	–	–	56	–	–
2014	–	–	–	57	–	–
2015	–	–	–	58	–	–
2016	–	–	–	60	–	–
2017	12,410,900	10,339,000	5,018,500	61	631	306
2018	12,410,900	10,339,000	5,018,500	62	641	311
2019	12,410,900	10,339,000	5,018,500	63	651	316
2020	12,410,900	10,339,000	5,018,500	65	672	326
2021	12,410,900	10,339,000	5,018,500	66	682	331
2022	12,410,900	10,339,000	5,018,500	67	693	336
2023	12,410,900	10,339,000	5,018,500	68	703	341
2024	12,410,900	10,339,000	5,018,500	69	713	346
2025	12,410,900	10,339,000	5,018,500	70	724	351
2026	12,410,900	10,339,000	5,018,500	71	734	356
2027	12,410,900	10,339,000	5,018,500	72	744	361
2028	12,410,900	10,339,000	5,018,500	73	755	366
2029	12,410,900	10,339,000	5,018,500	74	765	371
2030	12,410,900	10,339,000	5,018,500	76	786	381
2031	12,410,900	10,339,000	5,018,500	77	796	386
2032	12,410,900	10,339,000	5,018,500	78	806	391
2033	12,410,900	10,339,000	5,018,500	79	817	396
2034	12,410,900	10,339,000	5,018,500	80	827	401
2035	12,410,900	10,339,000	5,018,500	81	837	406
2036	12,410,900	10,339,000	5,018,500	82	848	412
2037	12,410,900	10,339,000	5,018,500	84	868	422
2038	12,410,900	10,339,000	5,018,500	85	879	427
2039	12,410,900	10,339,000	5,018,500	86	889	432
2040	12,410,900	10,339,000	5,018,500	87	899	437
2041	12,410,900	10,339,000	5,018,500	88	910	442
	25-Year Cumulative (MMT)[3]	**258**	**125**	**--**	**19,272**	**9,354**

Sources: EPA 2014a, 2014b; APS 2014; IWG 2013; BLS 2014.

Notes:

[1] Per Draft EIS 92% generation (MW-hr/yr) capacity factor for Units 4 & 5 based on 2000-2011 Part 75 data.
[2] Average SCC for 2.5% NPV discount rate in unadjusted 2007$ (IWG 2013).
[3] 25-year cumulative is for 2017-2041 (inclusive) in million metric tonnes (MMT) CO_2e.

Table 3 Estimated Social Cost of Carbon 3% 95th Percentile - Future Baseline GHG Emissions (2007$)

Year	FCPP Generation[1] MW-hr	FCPP Generation Emissions MT CO_2e	Replacement Generation Emissions MT CO_2e	Average SCC[2] $/MT	FCPP Generation SCC $million	Replacement Generation SCC $million
2012	–	–	–	98	–	–
2013	–	–	–	102	–	–
2014	–	–	–	106	–	–
2015	–	–	–	109	–	–
2016	–	–	–	113	–	–
2017	12,410,900	10,339,000	5,018,500	117	1,210	587
2018	12,410,900	10,339,000	5,018,500	121	1,251	607
2019	12,410,900	10,339,000	5,018,500	125	1,292	627
2020	12,410,900	10,339,000	5,018,500	129	1,334	647
2021	12,410,900	10,339,000	5,018,500	132	1,365	662
2022	12,410,900	10,339,000	5,018,500	135	1,396	677
2023	12,410,900	10,339,000	5,018,500	138	1,427	693
2024	12,410,900	10,339,000	5,018,500	141	1,458	708
2025	12,410,900	10,339,000	5,018,500	144	1,489	723
2026	12,410,900	10,339,000	5,018,500	147	1,520	738
2027	12,410,900	10,339,000	5,018,500	150	1,551	753
2028	12,410,900	10,339,000	5,018,500	153	1,582	768
2029	12,410,900	10,339,000	5,018,500	156	1,613	783
2030	12,410,900	10,339,000	5,018,500	159	1,644	798
2031	12,410,900	10,339,000	5,018,500	163	1,685	818
2032	12,410,900	10,339,000	5,018,500	166	1,716	833
2033	12,410,900	10,339,000	5,018,500	169	1,747	848
2034	12,410,900	10,339,000	5,018,500	172	1,778	863
2035	12,410,900	10,339,000	5,018,500	176	1,820	883
2036	12,410,900	10,339,000	5,018,500	179	1,851	898
2037	12,410,900	10,339,000	5,018,500	182	1,882	913
2038	12,410,900	10,339,000	5,018,500	185	1,913	928
2039	12,410,900	10,339,000	5,018,500	188	1,944	943
2040	12,410,900	10,339,000	5,018,500	192	1,985	964
2041	12,410,900	10,339,000	5,018,500	195	2,016	979
	25-Year Cumulative (MMT)[3]	**258**	**125**	**–**	**40,467**	**19,642**

Sources: EPA 2014a, 2014b; APS 2014; IWG 2013; BLS 2014.

Notes:

[1] Per Draft EIS 92% generation (MW-hr/yr) capacity factor for Units 4 & 5 based on 2000-2011 Part 75 data.
[2] Average SCC for 95th percentile 3% NPV discount rate in unadjusted 2007$ (IWG 2013).
[3] 25-year cumulative is for 2017-2041 (inclusive) in million metric tonnes (MMT) CO_2e.

Table 4 Estimated Social Cost of Carbon 5% Discount Rate - Future Baseline GHG Emissions (2014$)

Year	FCPP Generation[1] MW-hr	FCPP Generation Emissions MT CO_2e	Replacement Generation Emissions MT CO_2e	Average SCC[2] $/MT	FCPP Generation SCC $million	Replacement Generation SCC $million
2012	—	—	—	13	—	—
2013	—	—	—	13	—	—
2014	—	—	—	13	—	—
2015	—	—	—	14	—	—
2016	—	—	—	14	—	—
2017	12,410,900	10,339,000	5,018,500	14	145	70
2018	12,410,900	10,339,000	5,018,500	14	145	70
2019	12,410,900	10,339,000	5,018,500	14	145	70
2020	12,410,900	10,339,000	5,018,500	14	145	70
2021	12,410,900	10,339,000	5,018,500	15	155	75
2022	12,410,900	10,339,000	5,018,500	15	155	75
2023	12,410,900	10,339,000	5,018,500	15	155	75
2024	12,410,900	10,339,000	5,018,500	16	165	80
2025	12,410,900	10,339,000	5,018,500	16	165	80
2026	12,410,900	10,339,000	5,018,500	17	176	85
2027	12,410,900	10,339,000	5,018,500	17	176	85
2028	12,410,900	10,339,000	5,018,500	17	176	85
2029	12,410,900	10,339,000	5,018,500	18	186	90
2030	12,410,900	10,339,000	5,018,500	18	186	90
2031	12,410,900	10,339,000	5,018,500	19	196	95
2032	12,410,900	10,339,000	5,018,500	19	196	95
2033	12,410,900	10,339,000	5,018,500	21	217	105
2034	12,410,900	10,339,000	5,018,500	21	217	105
2035	12,410,900	10,339,000	5,018,500	22	227	110
2036	12,410,900	10,339,000	5,018,500	22	227	110
2037	12,410,900	10,339,000	5,018,500	23	238	115
2038	12,410,900	10,339,000	5,018,500	23	238	115
2039	12,410,900	10,339,000	5,018,500	24	248	120
2040	12,410,900	10,339,000	5,018,500	24	248	120
2041	12,410,900	10,339,000	5,018,500	25	258	125
	25-Year Cumulative (MMT)[3]	**258**	**125**	**—**	**4,787**	**2,324**

Sources: EPA 2014a, 2014b; APS 2014; IWG 2013; BLS 2014.

Notes:

[1] Per Draft EIS 92% generation (MW-hr/yr) capacity factor for Units 4 & 5 based on 2000-2011 Part 75 data.
[2] Average SCC for 5% NPV discount rate adjusted from 2007$ to 2014$ (IWG 2013, BLS 2014).
[3] 25-year cumulative is for 2017-2041 (inclusive) in million metric tonnes (MMT) CO_2e.

Table 5 Estimated Social Cost of Carbon 2.5% Discount Rate - Future Baseline GHG Emissions (2014$)

Year	FCPP Generation[1] MW-hr	FCPP Generation Emissions MT CO_2e	Replacement Generation Emissions MT CO_2e	Average SCC[2] $/MT	FCPP Generation SCC $million	Replacement Generation SCC $million
2012	–	–	–	63	–	–
2013	–	–	–	64	–	–
2014	–	–	–	65	–	–
2015	–	–	–	66	–	–
2016	–	–	–	69	–	–
2017	12,410,900	10,339,000	5,018,500	70	724	351
2018	12,410,900	10,339,000	5,018,500	71	734	356
2019	12,410,900	10,339,000	5,018,500	72	744	361
2020	12,410,900	10,339,000	5,018,500	74	765	371
2021	12,410,900	10,339,000	5,018,500	76	786	381
2022	12,410,900	10,339,000	5,018,500	77	796	386
2023	12,410,900	10,339,000	5,018,500	78	806	391
2024	12,410,900	10,339,000	5,018,500	79	817	396
2025	12,410,900	10,339,000	5,018,500	80	827	401
2026	12,410,900	10,339,000	5,018,500	81	837	406
2027	12,410,900	10,339,000	5,018,500	82	848	412
2028	12,410,900	10,339,000	5,018,500	84	868	422
2029	12,410,900	10,339,000	5,018,500	85	879	427
2030	12,410,900	10,339,000	5,018,500	87	899	437
2031	12,410,900	10,339,000	5,018,500	88	910	442
2032	12,410,900	10,339,000	5,018,500	89	920	447
2033	12,410,900	10,339,000	5,018,500	90	931	452
2034	12,410,900	10,339,000	5,018,500	92	951	462
2035	12,410,900	10,339,000	5,018,500	93	962	467
2036	12,410,900	10,339,000	5,018,500	94	972	472
2037	12,410,900	10,339,000	5,018,500	96	993	482
2038	12,410,900	10,339,000	5,018,500	97	1,003	487
2039	12,410,900	10,339,000	5,018,500	98	1,013	492
2040	12,410,900	10,339,000	5,018,500	100	1,034	502
2041	12,410,900	10,339,000	5,018,500	101	1,044	507
	25-Year Cumulative (MMT)[3]	**258**	**125**	**–**	**22,063**	**10,709**

Sources: EPA 2014a, 2014b; APS 2014; IWG 2013; BLS 2014.

Notes:

[1] Per Draft EIS 92% generation (MW-hr/yr) capacity factor for Units 4 & 5 based on 2000-2011 Part 75 data.
[2] Average SCC for 2.5% NPV discount rate adjusted from 2007$ to 2014$ (IWG 2013, BLS 2014).
[3] 25-year cumulative is for 2017-2041 (inclusive) in million metric tonnes (MMT) CO_2e.

Table 6 Estimated Social Cost of Carbon 3% 95th Percentile - Future Baseline GHG Emissions (2014$)

Year	FCPP Generation[1] MW-hr	FCPP Generation Emissions MT CO_2e	Replacement Generation Emissions MT CO_2e	Average SCC[2] $/MT	FCPP Generation SCC $million	Replacement Generation SCC $million
2012	—	—	—	112	—	—
2013	—	—	—	117	—	—
2014	—	—	—	121	—	—
2015	—	—	—	125	—	—
2016	—	—	—	129	—	—
2017	12,410,900	10,339,000	5,018,500	134	1,385	672
2018	12,410,900	10,339,000	5,018,500	139	1,437	698
2019	12,410,900	10,339,000	5,018,500	143	1,478	718
2020	12,410,900	10,339,000	5,018,500	148	1,530	743
2021	12,410,900	10,339,000	5,018,500	151	1,561	758
2022	12,410,900	10,339,000	5,018,500	155	1,603	778
2023	12,410,900	10,339,000	5,018,500	158	1,634	793
2024	12,410,900	10,339,000	5,018,500	161	1,665	808
2025	12,410,900	10,339,000	5,018,500	165	1,706	828
2026	12,410,900	10,339,000	5,018,500	168	1,737	843
2027	12,410,900	10,339,000	5,018,500	172	1,778	863
2028	12,410,900	10,339,000	5,018,500	175	1,809	878
2029	12,410,900	10,339,000	5,018,500	179	1,851	898
2030	12,410,900	10,339,000	5,018,500	182	1,882	913
2031	12,410,900	10,339,000	5,018,500	187	1,933	938
2032	12,410,900	10,339,000	5,018,500	190	1,964	954
2033	12,410,900	10,339,000	5,018,500	194	2,006	974
2034	12,410,900	10,339,000	5,018,500	197	2,037	989
2035	12,410,900	10,339,000	5,018,500	202	2,088	1,014
2036	12,410,900	10,339,000	5,018,500	205	2,119	1,029
2037	12,410,900	10,339,000	5,018,500	208	2,151	1,044
2038	12,410,900	10,339,000	5,018,500	212	2,192	1,064
2039	12,410,900	10,339,000	5,018,500	215	2,223	1,079
2040	12,410,900	10,339,000	5,018,500	220	2,275	1,104
2041	12,410,900	10,339,000	5,018,500	223	2,306	1,119
	25-Year Cumulative (MMT)[3]	**258**	**125**	**—**	**46,350**	**22,498**

Sources: EPA 2014a, 2014b; APS 2014; IWG 2013; BLS 2014.

Notes:

[1] Per DEIS 92% generation (MW-hr/yr) capacity factor for Units 4 & 5 based on 2000-2011 Part 75 data.
[2] Average SCC for 95th percentile 3% NPV discount rate adjusted from 2007$ to 2014$ (IWG 2013, BLS 2014).
[3] 25-year cumulative is for 2017-2041 (inclusive) in million metric tonnes (MMT) CO_2e. Sources: EPA 2014a, 2014b; APS 2014; IWG 2013; BLS 2014.