

California Environmental Protection Agency



Proposed Regulation for Reducing Sulfur Hexafluoride Emissions from Gas Insulated Switchgear

Staff Report: Initial Statement of Reasons



Release Date: January 7, 2010



Gas Insulated Switchgear (GIS)

Typical 245 kV gas insulated substation (GIS) using SF₆ gas as internal insulation and interrupting medium.



Gas Insulated Switchgear (GIS)

Typical 245 kV dead tank circuit breakers using SF₆ gas as internal insulation and interrupting medium.

**State of California
AIR RESOURCES BOARD**

**STAFF REPORT: INITIAL STATEMENT OF REASONS
FOR PROPOSED RULEMAKING**

**Public Hearing to Consider Proposed Regulation for Reducing
Sulfur Hexafluoride Emissions from Gas Insulated Switchgear**

To be considered by the Air Resources Board on February 25, 2010, at:

California Environmental Protection Agency
Headquarters Building
1001 I Street
Byron Sher Auditorium
Sacramento, California

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**State of California
AIR RESOURCES BOARD**

**Public Hearing to Consider Proposed Regulation for
Reducing Sulfur Hexafluoride Emissions
from Gas Insulated Switchgear**

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EXECUTIVE SUMMARY

A. Introduction

The California Global Warming Solutions Act of 2006 (Act or AB 32) (Assembly Bill 32, Ch. 488, Stats 2006) created a comprehensive multi-year program to reduce greenhouse gas (GHG) emissions in California. The Act requires the Air Resources Board (ARB or Board) to create and implement measures needed to reduce current GHG emissions to 1990 levels by 2020. This proposed measure was submitted by the Climate Action Team as an early action measure and approved by the Board at its June 2007 meeting. In addition, on December 11, 2008, the Board approved a Climate Change Scoping Plan (Scoping Plan) describing California's strategy for meeting the greenhouse gas emissions reductions required by AB 32. One of the emission reduction measures contained within the Scoping Plan proposes to reduce sulfur hexafluoride (SF₆) emissions from electrical sector uses.

This Executive Summary outlines ARB staff's proposal to adopt an SF₆ emission reduction measure for gas insulated switchgear used in electrical power systems. It includes an overview of the proposed emission reduction measure, public outreach efforts undertaken, a summary of staff recommendations, and a discussion of the environmental and economic impacts resulting from the proposal. The Executive Summary precedes the full staff report which also comprises the Initial Statement of Reasons for the Proposed Regulation as required by the Administrative Procedure Act (Government Code 11340, *et seq.*).

B. Overview

All greenhouse gases can be classified by a Global Warming Potential (GWP). This value, established by the Intergovernmental Panel on Climate Change (IPCC), provides comparisons among the different greenhouse gases to trap heat in the atmosphere. GWPs are based on the heat-absorbing ability of each gas relative to that of carbon dioxide (CO₂), as well as the decay rate of each gas (the amount removed from the atmosphere over a given timeframe). GWPs may be used to define the impact greenhouse gases will have on global warming over different time periods—usually 20 years, 100 years, or 500 years.

According to the IPCC, SF₆ is the most potent of the six main greenhouse gases with a GWP of 23,900 times that of CO₂ over 100 years. Although the atmospheric concentration of SF₆ is lower than that of other greenhouse gases, reducing SF₆ emissions is important due to its high GWP and long atmospheric lifetime (3200 years). Proportionally, reducing the emissions from one pound of SF₆ is equivalent to an 11 metric ton reduction of CO₂.

Since the 1980s, SF₆ has been used extensively in electrical power systems as a dielectric medium (insulator) and interrupter (arc quencher) in medium and high voltage gas insulated switchgear or "GIS." GIS is commonly found in electrical substations and in underground vaults located in densely populated urban areas. The term switchgear, used in association with an electrical power system, refers to all electrical power

equipment insulated with SF₆ gas regardless of its location. GIS includes switches, stand-alone gas-insulated equipment, and any combination of electrical disconnects, fuses, electrical transmission lines, transformers and/or circuit breakers used to isolate gas insulated electrical equipment. Switchgear is used both to de-energize equipment to allow work to be done safely and to clear electrical faults. Nearly 80 percent of California's SF₆ emissions result from leakage and handling losses from GIS.

Worldwide, only the European Commission, the Executive Branch of the European Union (EU), currently regulates SF₆ use in GIS. The *EU Regulation on Certain Fluorinated Greenhouse Gases* (Regulation EC No. 842/2006) became effective in 2006. The regulations require SF₆ gas in high voltage switchgear to be recovered by trained and certificated personnel for recycling, reclamation, or destruction purposes. All EU member states were required to adopt the regulations with final implementation of all phases occurring in July 2009.

Nationally, in 1999, the U.S. Environmental Protection Agency (U.S. EPA) created a voluntary SF₆ emission reduction program which has been effective in gaining substantial emission reductions from its participants. However, because this is a voluntary program, only five of the dozens of California's utilities and power producers participate in U.S. EPA's voluntary program.

In 2008, the U.S. Department of Defense (DOD) added SF₆ to its list of "Emerging Contaminants Action" list. DOD plans to curtail uses and releases of SF₆ in its procurement chain which will limit the ability of DOD contractors to sell products to the DOD that contain unnecessary amounts of SF₆.

Although a potent greenhouse gas, SF₆ also has properties that allow the optimized operation of electrical switchgear and electricity networks throughout California. Despite international research efforts, no equivalent alternative has been identified. However, currently available low-cost mitigation options are not being consistently applied by electrical switchgear owners. Consequently, the imposition of an SF₆ emission reduction measure is warranted.

C. Summary of the Proposed SF₆ Emission Reduction Measure

The proposed regulation would require GIS owners to reduce SF₆ emissions from electrical equipment used mostly for the transmission and distribution of electricity throughout the State. GIS owners encompass approximately 75 private and public entities including eight investor owned utilities, four large corporations (refineries employing on-site distributed electrical generation), 50 publically-owned utilities and rural electric cooperatives, one State agency (Department of Water Resources), two federal agencies (Western Area Power Association and U.S. Department of Defense), and two national laboratories.

The proposed SF₆ emission reduction measure would require GIS owners to reduce their SF₆ emission rate by one percent per year over a ten year period, from 2011 to 2020. This time period coincides with the timelines established by the Global Warming Solutions Act for greenhouse gas reduction measures.

The initial maximum annual emission rate would be set at ten percent of a GIS owner's nameplate capacity non-hermetically sealed GIS. The annual emission rate would decrease one percent per year until 2020. Beginning January 1, 2020, the maximum annual emission rate would be at one percent.

The measure would also require GIS owners to: (1) annually report their SF₆ emissions; (2) emission rate; (3) provide a complete inventory of all gas insulated switchgear and their SF₆ capacities; (4) produce a SF₆ gas container inventory; and (5) keep all information current for ARB enforcement staff inspection and verification.

D. Regulatory Development Public Process

In developing any regulation, the public and affected industries play an important role in shaping the regulatory proposals. ARB staff has made the following efforts to ensure an open process and provide ample opportunity for input by all parties.

During the past year, ARB staff has held three technical working group meetings and a public workshop; and toured three utility substations, one medical center linear accelerator, and two particle accelerators. Staff has additionally participated at the national level by presenting and discussing California's proposal at two U.S. EPA SF₆ Volunteer Program Conferences. ARB staff has maintained a website to facilitate the dissemination of up-to-date information on the progress of the modifications of the SF₆ emission reduction measure. The website is located at <http://www.arb.ca.gov/cc/sf6elec/sf6elec.htm>.

In addition, ARB staff established an e-mail list serve to notify affected industries and other interested parties of the technical workgroup meetings, agendas, and information to be discussed at the meetings. Nearly 900 individuals from federal, state, and local government; environmental groups; and industry subscribe to the list serve.

Staff also participated in numerous individual meetings and conference calls with affected industry, the U.S. EPA, and other stakeholders to discuss and resolve issues specific to the proposed emission reduction measure.

Staff revised the proposed SF₆ emission reduction measure in consideration of the comments received during the public process. Staff has made and will continue to make the effort needed to consider all comments and recommendations received.

E. Environmental and Economic Impacts of the Proposed Regulation

Environmental Impact

Based on available data, staff estimates current annual SF₆ emissions from GIS to be 40,000 metric tons CO₂-equivalent (MTCO₂e). The proposed SF₆ emission reduction measure is estimated to decrease greenhouse gas emissions by an average of 25,300 MTCO₂e annually, and 253,000 MTCO₂e cumulatively over a ten year regulatory period. Without the proposed regulation, staff estimates annual SF₆ emissions in 2020 would be 33,000 MTCO₂e. The proposed

regulation would reduce this projection by 70 percent or 23,000 MTCO₂e in 2020. Staff estimates that as a result of the proposed regulation, maximum annual SF₆ emissions from GIS in 2020 and beyond would be 10,000 MTCO₂e.

Because the proposed regulation reduces only greenhouse gas emissions by improving SF₆ management practices, it is not expected to result in any significant adverse air quality, wastewater, or hazardous waste impacts.

Economic Impacts

Staff estimates the projected total cost of the regulation over the ten year regulatory period would range from \$4,500,000 to \$7,000,000. The average cost per metric ton of CO₂e emissions reduced, including recordkeeping and reporting costs, would range from \$18/MTCO₂e to \$28/MTCO₂e. Unit costs of emission reductions for the proposed SF₆ GIS regulation vary greatly among emission reduction methods—from -\$1/MTCO₂e for SF₆ recycling to \$55/MTCO₂e for GIS repair and replacement. ARB staff assumed that less expensive methods are employed first, and that the unit cost of SF₆ emission reductions steadily increases over the regulatory period. The high end of the estimate is extremely conservative based on final emission reductions resulting exclusively from equipment replacement, which is the most costly emission control technique. During the final years of the regulatory period, staff believes a combination of less costly emission reduction methods will continue to be used in addition to undertaking equipment replacement, maintaining reduction costs nearer to \$18/MTCO₂e.

The costs and savings occurring in the early years of the proposed regulation would likely be absorbed by the regulated entities. Costs which cannot be absorbed may be passed to consumers as increased electricity costs. If the total cost of the measure were passed to consumers, it would increase electricity rates by approximately \$0.000016 to \$0.000025 per kilowatt-hour. This increase equates to a 0.012 percent to 0.018 percent monthly increase, or one to one and one-half cents per month for an average residential electricity bill.

Recordkeeping and reporting requirements would be required by this proposed regulation. Costs to meet these requirements will vary among regulated entities based on the quantity of their GIS equipment and the physical size of their service territory and will be higher during the first year of the regulatory period. Staff assumed that per-utility recordkeeping and reporting costs for the first year would range between approximately \$500 and \$1,900. Annual recordkeeping and reporting costs for succeeding years would range between \$240 and \$960 per entity.

F. Recommendation

The staff recommends that the Board adopt the proposed regulation to reduce SF₆ from GIS.

I. INTRODUCTION

This Initial Statement of Reasons (Staff Report) presents an evaluation of the need to reduce sulfur hexafluoride (SF₆) emissions from gas insulated switchgear (GIS). The term switchgear, used in association with electric power systems, refers to the combination of electrical disconnects, fuses and/or circuit breakers used to isolate electrical equipment. Switchgear is used both to de-energize equipment to allow work to be done and to clear electrical faults.

This evaluation summarizes the proposed regulation and presents its potential emission reductions and estimated costs for compliance. The alternative proposals considered by staff are also discussed. A copy of the proposed regulation is provided in Appendix A.

A. Overview

This report provides:

- The authority of the Air Resources Board (ARB or Board) to adopt the proposed SF₆ emission reduction measure;
- A discussion of current SF₆ emission reduction measures, voluntary reduction programs, and international reduction efforts;
- A summary of the proposed SF₆ emission reduction measure for gas insulated switchgear;
- The environmental and economic impacts of the proposed regulation;
- The proposed regulation; and
- Other supplemental information.

B. Enabling Legislation

In June 2005, Governor Arnold Schwarzenegger signed Executive Order S-3-05, which established targets for reducing greenhouse gas (GHG) emissions in California. The Executive Order requires GHG emissions to be reduced to 2000 levels by 2010, to 1990 levels by 2020, and finally to 80 percent below 1990 levels by 2050. In 2006, the Governor signed Assembly Bill 32, the California Global Warming Solutions Act (AB 32 or Act) (Stats. 2006, ch. 488), which established the 2020 GHG emission reduction goal in State law (HSC § 38500 et seq.) and made the ARB responsible for monitoring and reducing GHG emissions.

AB 32 required the Board, by January 1, 2009, to design and adopt an overall plan to reduce GHG emissions to 1990 levels by 2020. On December 11, 2008, the Board approved a Climate Change Scoping Plan (Scoping Plan) describing California's strategy for meeting the greenhouse gas emissions reductions required by AB 32.

This proposed measure was submitted by the Climate Action Team as an early action measure and approved by the Board at its June 2007 meeting. The Board approved

Scoping Plan identified the reduction of sulfur hexafluoride (SF₆) emissions from electrical sector uses as an emission reduction measure to help achieve the State's GHG emission goals.

The Act requires the Board to create and implement measures needed to reduce current GHG emissions to 1990 levels by 2020. The Board has until January 1, 2011, to adopt the necessary regulations to implement the Scoping Plan. Full implementation of regulations adopted pursuant to AB 32 must begin no later than January 1, 2012. The emission reduction target must be fully achieved by January 1, 2020.

C. Background

Sulfur hexafluoride (SF₆) is a potent greenhouse gas with an atmospheric lifetime of 3,200 years and a one-hundred year global warming potential (GWP) of 23,900 times that of carbon dioxide (CO₂). In the last five years, atmospheric concentrations have been growing at a rate of five percent per year. The growth rate could be the result of increasing emissions in any or all emission sectors. However, given the long atmospheric lifetime of SF₆, even declining emissions will result in an increasing atmospheric concentration. Without intervention, it is anticipated that the growth rate will continue at a similar rate for the next several years.

Since the 1980s, SF₆ has been used extensively in electrical power systems as a dielectric medium (insulator) and interrupter (arc quencher) in medium and high voltage gas insulated switchgear or "GIS." GIS is commonly found in electrical substations ground and in underground vaults in densely populated urban areas. The term switchgear, used in association with an electrical power system, refers to all electrical power equipment insulated with SF₆ gas regardless of its location. GIS includes switches, stand-alone gas-insulated equipment, and any combination of electrical disconnects, fuses, electrical transmission lines, transformers and/or circuit breakers used to isolate gas insulated electrical equipment. Switchgear is used both to de-energize equipment to allow work to be done safely and to clear electrical faults. Nearly 80 percent of California's SF₆ emissions result from leakage and handling losses from GIS.

Although a potent greenhouse gas, SF₆ has properties that allow the optimized operation of electrical switchgear and electricity networks throughout California. The advantages of using SF₆ in electrical switchgear are considerable, primarily because the gas is non-flammable, non-corrosive to internal switchgear components, and its thermal properties make it an excellent arc suppressant. Even when SF₆ is momentarily broken down during arcing, due to its "self-healing" properties, the decomposition products re-combine back into its original state. In its pure form, it is non-toxic and does not pose a hazard to human health. Combined, these properties enable placement of high voltage switchgear in compact configurations in small areas, and demand less frequent maintenance than equipment using air or oil for arc extinguishing and insulation.

Despite continued international research efforts, no equivalent alternative has been identified. Worldwide, only the European Commission, the Executive Branch of the European Union (EU) currently regulates SF₆ use in GIS. The *EU Regulation on Certain Fluorinated Greenhouse Gases* (Regulation EC No. 842/2006) became effective in 2006. The regulations require SF₆ gas in high voltage switchgear to be recovered by trained and certificated personnel for recycling, reclamation, or destruction purposes. All EU member states were required adopt the regulations with final implementation of all phases occurring in July 2009.

Nationally, in 1999, the U.S. Environmental Protection Agency (U.S. EPA) created a voluntary SF₆ emission reduction program which has been effective in gaining substantial emission reductions from its participants. However, because this is a voluntary program only five of the dozens of California's utilities and power producers participate in the U.S. EPA's voluntary program. In the absence of regulations, currently available low cost mitigation options are not being consistently utilized by all GIS owners.

In 2008, the United States' Department of Defense (DOD) added SF₆ to its "Emerging Contaminants Action" list. DOD plans to curtail uses and releases of SF₆ in its procurement chain which will limit the ability of DOD contractors to sell products to the DOD that contain unnecessary amounts of SF₆.

SF₆ is used in a several other economic sectors including the semiconductor industry, tracer gas uses, electronics manufacture, magnesium casting and military operations. SF₆ emission reductions from these uses were addressed under separate regulations adopted by the Board.

II. STATUTORY REQUIREMENTS

AB 32 contains standards in Health and Safety Code section 38562 that apply to regulations adopted consistent with the Scoping Plan. Those criteria are summarized here along with staff's assessment as to why the proposed regulatory action complies.

-The State Board shall adopt rules and regulations in an open public process to achieve the maximum technologically feasible and cost effective greenhouse gas emission reduction from sources or categories of sources.

The proposal was developed in consultation with affected parties in an open process through *three* technical working group meetings, several industry-specific consultation meetings, one public workshop, and numerous telephone conferences. Draft regulatory concepts were modified through discussion and feedback during this process to ensure that least-cost methods to achieve reductions were proposed. Section III of this report provides details of staff outreach activities.

-Design the regulations, including distribution of emissions allowance where appropriate, in a manner that is equitable, seeks to minimize costs and maximize the total benefits to California, and encourages early action to reduce greenhouse gas emissions.

The proposed regulation was designed to acknowledge SF₆ emission reductions made through voluntary efforts. By setting a maximum emission rate rather than a percentage reduction mandate, those gas insulated switchgear owners who have voluntarily reduced their emissions will not be unfairly burdened with higher cost emission reduction requirements. All regulated parties will be required to meet the same emission rates.

The proposed regulation does not mandate specific actions to meet the mandatory emission limit. Entities are allowed to choose from least-cost methods which best fit their operational needs.

-Ensure that activities undertaken to comply with the regulations do not disproportionately impact low-income communities.

SF₆ emissions from GIS occur throughout California. Activities to reduce these emissions will occur equally in all communities, regardless of income, and will have no adverse environmental effects.

-Ensure that entities that have voluntarily reduced their greenhouse gas emissions prior to the implementation of this section receive appropriate credit for early voluntary reductions.

Five GIS owners that would be subject to the proposed regulation participate in the U.S. EPA's voluntary SF₆ emission reduction partnership program. Each of these entities has created its own emission reduction program and has substantially reduced its emission rate over time. Because the participants have already invested resources through participation in the volunteer program, their current emission rates fall below the early emission rate requirements of the proposed regulation. By establishing an emission rate requirement rather than imposing performance or prescriptive standards, volunteer program participants' early efforts are acknowledged and nominal costs are anticipated during the first years of the proposed regulation.

-Ensure that activities undertaken pursuant to the regulations complement and do not interfere with, efforts to achieve and maintain federal and state ambient air quality standards and to reduce toxic air contaminant emissions.

GIS owners will be required to reduce SF₆ emissions from electrical equipment used mostly for the transmission and distribution of electricity throughout the State. The methods normally employed to attain these reductions—equipment leak detection and repair, gas recycling, equipment evacuation, refurbishment, and equipment replacement—will have no impact on efforts to achieve and maintain state or federal ambient air quality standards.

-Consider cost-effectiveness of these regulations.

The cost-effectiveness of the regulation would range from \$18 to \$28 per metric ton of emissions (CO₂e) reduced, See Section VI and Appendix D of this report for detailed information regarding cost-effectiveness.

-Consider overall societal benefits, including reductions in other air pollutants, diversification of energy sources, and other benefits to the economy, environment, and public health.

The proposed regulation will allow the lowest-cost emission reduction methods of SF₆ from gas insulated switchgear to be utilized. The proposed regulation may serve as a model for future federal regulations further reducing GHG emissions from this high global warming potential gas.

Increased GIS equipment maintenance has the potential to enhance electrical system reliability.

-Minimize the administrative burden of implementing and complying with these regulations.

The administrative burden of complying with the proposed regulation has been minimized to the extent possible by ensuring that the proposed regulation's reporting requirements are consistent with those contained in ARB's mandatory

reporting regulations (17 CCR Sections 95100, *et seq.*). The proposed SF₆ emission reduction measure also requires the development and maintenance of a gas insulated switchgear and container inventory. Staff believes that the GIS owners currently develop these or similar inventories in order to determine and submit their required SF₆ emission inventory information to ARB.

The proposed regulation mandates GIS owners to progressively reduce their SF₆ emission rate over a ten-year period. The annual emission rate must be calculated and reported to ARB. GIS equipment and gas container inventories must also be annually reported. In order to minimize duplication and avoid the submission of multiple reports, ARB's on-line reporting tool, used to collect greenhouse gas emissions information under its mandatory greenhouse gas reporting regulations, would be modified to accept SF₆ emission rate, GIS equipment, and SF₆ container information.

The proposed regulation includes recordkeeping requirements. These requirements are consistent with those established by ARB's mandatory reporting regulations and should not create an excessive administrative burden.

-Minimize leakage

Leakage occurs when State policy causes activities and related emissions to move outside of California. The proposed regulation affects California electrical power equipment which must remain near the load it serves. Moving this equipment out of the state would be infeasible, inefficient, and cost-prohibitive. Consequently, the proposed regulation would not cause any leakage problems.

-Consider the significance of the contribution of each source or category of sources to statewide emissions of greenhouse gases.

Sulfur hexafluoride has the highest GWP currently identified by the Intergovernmental Panel on Climate Change (IPCC) at 23,900 times that of CO₂ and a very long atmospheric lifetime of 3,200 years. In the last five years, atmospheric concentrations have been growing at a rate of five percent per year. Given the long lifetime and potent GWP, all SF₆ emission reductions are important to consider. The projected reductions that will be achieved through implementation of the proposed regulation are equivalent to reducing 253,000 metric tons CO₂-equivalent (MTCO_{2e}).

-The greenhouse gas emission reductions achieved are real, permanent, quantifiable, verifiable, and enforceable by the State board.

Real Reductions. Staff believes that the emission reductions for GIS operations would be real because they were based on actual current emissions as reported in data submitted within surveys and pursuant to ARB's mandatory emission reporting regulations by the affected industries. All entities subject to the

regulation (with the exception of a couple entities) would be required to reduce emissions to comply with the proposed 2020 emission rate. The GHG emissions, reductions, and emission rates would be based on a mass balance approach derived from the U.S. EPA's voluntary SF₆ emission reduction program, and would be based on GWP values defined by the IPCC Second Assessment Report. The GHG reductions would be verifiable through annual reporting and recordkeeping requirements included in the proposed regulation.

Permanency. The proposed regulations would require GIS owners to attain a one percent emission rate by 2020. The proposed regulation does not allow for emission rates to exceed this amount.

Quantification and Verification. The proposed regulations would require GIS owners to maintain detailed inventories of SF₆ gas both within equipment and gas containers. Specific measuring procedures would be used. Scales used to measure replacement SF₆ would be required to be accurate to within one percent. Quantification methods are specified in the regulation to account for all SF₆ emitted annually. ARB's SF₆ emission reduction regulations governing non-electric sector and non-semiconductor uses are scheduled to become effective in 2010. These regulations will require SF₆ distributors to maintain documentation related to California-specific sales and purchases. This documentation will be available to ARB upon request and could be used to verify the accuracy of the GIS owner's records.

Enforceability. The regulation, as proposed, contains requirements which support enforcement efforts, including report submissions with data that can be verified by on-site inspections and third party information. Once the proposed regulation is approved by the Office of Administrative Law, the proposed emission rate limits will become State law.

-The reduction is in addition to any greenhouse gas emission reduction otherwise required by law or regulation, and any other greenhouse gas emission reduction that otherwise would occur.

Sulfur hexafluoride emission reductions from GIS are not included in any other federal or State regulation.

-If applicable, the greenhouse gas emission reduction occurs over the same time period and is equivalent in amount to any direct emission reduction required pursuant to this division.

This requirement does not apply to the proposed regulation because it achieves its emission reductions as direct emissions.

-The State board shall rely upon the best economic and scientific information and its assessment of existing and projected technological capabilities when adopting the regulations required by the law.

ARB staff used the best available economic and scientific information available to develop the proposed regulation. Staff surveyed all potential regulated entities and conducted a literature review for other available economic and scientific information. Staff relied upon data obtained through development of ARB's mandatory reporting regulations, the U.S. EPA, and industry organizations including the Electric Power Research Institute, and the International Council on Large Electric Systems (CIGRE).

III. PROPOSED REGULATION DEVELOPMENT

Following is a general overview of the proposed regulation, the steps taken to develop the proposal, and a discussion of the alternatives to the proposal which were considered by staff.

A. Public Outreach

ARB staff has made extensive efforts to have an open process and provide ample opportunity for input by all parties. Industries affected by this proposed regulation played an important role in shaping this regulatory proposal.

During the past year, ARB staff has held three technical working group meetings and a public workshop; and toured three utility substations, one medical center linear accelerator, and two particle accelerators. Staff has additionally participated at the national level by presenting and discussing California's proposal at two U.S. EPA SF₆ Volunteer Program Conferences. ARB staff has maintained a website to facilitate the dissemination of up-to-date information on the progress of the modifications of the SF₆ emission reduction measure. The website is located at <http://www.arb.ca.gov/cc/sf6elec/sf6elec.htm>.

In addition, ARB staff established an e-mail list serve to notify affected industries and other interested parties of the technical workgroup meetings, agendas, and information to be discussed at the meetings. Over 900 individuals from federal, State, and local government; environmental groups; and industry subscribe to the list serve.

Staff also participated in numerous individual meetings and conference calls with affected industry, the U.S. EPA, and other stakeholders to discuss and resolve issues specific to the proposed emission reduction measure.

Staff revised the proposed SF₆ emission reduction measure in consideration of the comments received during the public process. Staff has made and will continue to make the effort needed to consider all comments and recommendations received.

(See Public Outreach Table at Appendix C for more detail on public outreach activities.)

B. Regulation Development

ARB staff first identified GIS owners and other stakeholders from industry, trade organizations, and government. Staff then developed a survey to determine equipment inventories, current emissions, and supply costs. Recipients of the survey included electrical utilities, universities, national laboratories, and industries using distributed generation technologies. Appendix B provides a copy of the survey and an aggregate of the results.

In addition to the survey, ARB obtained information on emissions and mitigation options from the U.S. EPA based on its volunteer emissions reduction partnership program for electric power systems. The partnership program was established in 1999. Although established as volunteer program, utilities which agreed to membership in the program were required to:

- Estimate initial annual SF₆ emissions;
- Annually inventory emissions of SF₆ using an emissions inventory protocol;
- Establish a strategy for replacing older, more leak-prone pieces of equipment;
- Implement SF₆ recycling;
- Ensure that only knowledgeable personnel handle SF₆; and
- Submit annual progress reports.

U.S. EPA estimates that the partnership's SF₆ emission rate has dropped from 17 percent in 1999 to 6.5 percent in 2006. U.S. EPA data and technical reports were included in the analysis for this proposal. Additionally, five California utilities (Kings River Conservation District, Southern California Edison (SCE), Pacific Gas and Electric Corporation (PG&E), Pacific Corp, and the City of Palo Alto) participate in the U.S. EPA volunteer partnership program. ARB staff toured substations of both PG&E and SCE and discussed their current SF₆ emission reduction programs. Knowledge gained through these discussions helped to inform the development of the proposed regulation.

A technical working group was established during the regulation development process and served an invaluable role by providing input on emission reduction opportunities and implementation costs. Based on information received through ARB's survey, U.S. EPA, and the technical working group, staff developed specific proposals and alternatives and presented them to the working group and the public. Staff made modifications to the original proposal after consideration and evaluation of comments.

C. Alternatives Considered

Government Code section 11346.2 requires ARB to consider and evaluate reasonable alternatives to the proposed regulation and provide reasons for rejecting those alternatives. Staff identified three alternative approaches to the current proposal: "No Action," "Establishing an SF₆ Emission Reduction Measure for GIS and Particle Accelerators," and "Establishing Performance and Equipment Standards."

1. Alternative One – No Action

A "No Action" alternative would be to forego adopting the proposed regulation. The "No Action" alternative would have no cost to business but would allow emissions to continue at current levels or increase.

2. Alternative 2 – Establishing an SF₆ Emission Reduction Measure for GIS and Particle Accelerators

Because both GIS and particle accelerators use SF₆ as an insulator and arc quencher, an SF₆ emission reduction measure was proposed within the Scoping Plan which included both applications. During the regulatory development process, ARB staff toured several particle accelerators including those used for cancer radiation treatment and physics research, which represent the majority of the State's particle accelerator inventory. Particle accelerators are also used within scanning equipment by U.S. Customs and the military.

Staff found that particle accelerators used and emitted very small amounts of SF₆. For example, at one medical center's radiation treatment facility, a five-pound container of SF₆ was still in use after a five-year period. Staff determined that imposing reduction standards beyond those already achieved by these particle accelerators would be costly and burdensome for these applications.

On-site substations which power particle accelerators at national laboratories would still be subject to the proposed regulations.

3. Alternative Three – Establishing Performance and Equipment Standards

Staff evaluated the option of establishing performance standards and mandating the replacement of medium voltage (<69 kilovolt (kV)) switchgear. Staff also evaluated requiring establishing standards for new equipment. However, by choosing instead to set a less-prescriptive, maximum allowable emissions rate to meet the GHG emission reduction goal, affected entities would be motivated to purchase the lowest emitting GIS equipment.

Performance standards for training, emission notification equipment, and 24-hour repair requirements were considered. Technical working group members commented that this alternative was infeasible and provided information to substantiate this position.

One utility would have been required to substitute non-SF₆ equipment for nearly 2,000 circuit breakers. The cost of replacing each breaker exceeded \$50,000—totaling approximately \$100,000,000. Although this substitution would have resulted in reducing 48,000 pounds of SF₆ (520,000 MTCO₂e) from this utility, the reductions were cost-prohibitive relative to the benefits derived. The development of these standards would be time and resource intensive and the resulting regulations would be burdensome to implement and enforce.

D. Alternative Means of Compliance

The proposed regulation allows regulated entities to choose the least-cost means of compliance to reduce their emission rate. Least-cost gas management techniques currently employed by participants in the U.S. EPA's voluntary SF₆ emission reduction program and within the European Union regulations consist of technical training programs, SF₆ leak detection and repair, gas recycling, equipment evacuation, and equipment refurbishment or replacement. The following summary illustrates these established gas management techniques.

Leak Detection and Repair (LDAR). SF₆ leak detection is achieved using various techniques, including “sniffing” for gas with SF₆ gas sensors and using laser-based remote sensing technology. LDAR-based repairs address small leaks on specific components, such as a bushing or flange gasket.



Handheld Sniffer

(LACO Technologies,
http://lacotech.com/product_pages/GasCheck_SF6_Leak_Detector_672214792.html)



Infrared Camera

(FLIR Thermography - Infrared Cameras and Thermal Imagers)

<http://www.flir.com/thermography/americas/us/>)

SF₆ Recycling. Recycling gas cart systems are available which can withdraw, purify, and return SF₆ to gas-insulated equipment. Recycling equipment is capable of capturing nearly 100 percent of SF₆. However, normal industry practice limits recovery to approximately 80 percent of the gas held in high-voltage equipment because of the additional time required to recover it fully. Because it would take as much time to recover the final 20 percent of the gas as it takes to recover the first 80 percent (by mass), the costs of this level of evacuation are much higher and are addressed as a separate SF₆ emission reduction option.



SF₆ gas evacuation, storage and cleaning systems

(Dilo Company, SF₆ Gas Recycling Equipment and Services, <http://dilo.com/index2.html>)

Evacuation of Equipment. Evacuation includes costs associated with attaining a higher level of SF₆ recovery from closed-pressure equipment (i.e., drawing evacuation pressure from 50 millibar [mbar] down to 20 mbar). The lower the residual pressure in a container, the less SF₆ is left in the container to escape once the container is opened.

Equipment Refurbishment. Equipment refurbishment encompasses comprehensive repairs for large leakage losses. Refurbishment consists of disassembling, rebuilding and possibly upgrading equipment using remachined, cleaned, and/or new components. Generally, equipment refurbishment represents a less expensive option than equipment replacement. Costs to refurbish a 362 kilovolt (kV) circuit breaker are estimated to be \$100,000.

Equipment Replacement. Equipment replacement is the most expensive option and is undertaken when equipment parts are no longer available or when refurbishment will not correct leakage problems. Costs for replacing a large breaker (362 kV) can range from \$300,000 to \$400,000.

IV. PROPOSED REGULATION SUMMARY

The following provides a summary and explanation for each section of the proposed regulation. The full text of the proposed regulation is found in Appendix A.

§ 95350. Purpose, and Applicability.

Purpose. The proposed regulation is to reduce greenhouse gas emissions in California.

Sources of SF₆ Emissions Addressed by the Proposed Regulation. The proposed regulation would reduce SF₆ emissions from gas insulated switchgear (GIS) found in electrical power systems. GIS is commonly found in electrical substations and in underground vaults located in densely populated urban areas. The term switchgear, used in association with an electrical power system, refers to all electrical power equipment insulated with SF₆ gas regardless of its location. GIS includes switches, stand-alone gas-insulated equipment, and any combination of electrical disconnects, fuses, electrical transmission lines, transformers and/or circuit breakers used to isolate gas insulated electrical equipment. Switchgear is used both to de-energize equipment to allow work to be done safely and to clear electrical faults. Nearly 80 percent of California's SF₆ emissions result from leakage and handling losses from GIS.

Affected Industries. The proposed regulation would affect approximately 75 private and public entities including eight investor owned utilities, four large corporations (refineries employing on-site distributed electrical generation), 50 publically-owned utilities and rural electric cooperatives, one State agency (Department of Water Resources), two federal agencies (Western Area Power Association and U.S. Department of Defense), and two national laboratories.

§ 95351. Definitions. The proposed regulation defines terms related to GIS which could have more than one meaning to regulated parties.

§ 95352. Maximum Annual SF₆ Emission Rate. The proposed regulation would establish maximum annual SF₆ emission rates for GIS owners. The emission rate requirements begin in 2011 at ten percent of the GIS owners' total equipment capacity averaged over the year. The rate steadily would decline by one percent per year over a ten year period. Beginning in 2020, the maximum allowable annual emission rate would be one percent. The proposed regulation does not mandate specific actions to meet the mandatory emission limit. Entities are allowed to choose from least-cost methods which best fit their operational needs. Examples of currently available emission reduction methods are detailed in Section III. D, Pages 11 and 12 of this report.

§ 95353. Emergency Event Exemption. Beginning in 2020, the SF₆ emission rate would be set at one percent. Emissions resulting from a defined "emergency event" could be exempted from the emission rate calculation for that year, if those emissions

cause the one percent rate to be exceeded. GIS owners would be required to demonstrate to the Executive Officer that the emergency event causing the emission rate to be exceeded could not have been prevented by any available means.

§ 95354. *SF₆ Inventory Measurement Procedures.* This proposed regulation section would address the accuracy of procedures, measurements, and scales used to calculate SF₆ emissions. These procedures are consistent with proposed federal SF₆ emission reporting regulations.

§ 95355. *Recordkeeping.* Regulated parties would be required to develop and maintain records related to GIS equipment and SF₆ purchases and retain these records for a minimum of three years. Upon request by the Executive Officer, regulated parties would need to provide these records to ARB.

§ 95356. *Annual Reporting Requirements.* The proposed regulation would require GIS owners to submit an annual report which includes their GIS equipment and SF₆ container inventories, their annual SF₆ emissions, and overall emission rate.

The majority of GIS owners are currently required to report annual SF₆ emissions to ARB under its mandatory greenhouse gas reporting requirements for entities which generate electricity (title 17, California Code of Regulations, Sections 95100, *et seq.*). These reporting requirements would be extended to a limited number of entities not currently covered by the mandatory greenhouse gas reporting regulations (*e.g.*, entities which own gas insulated switchgear but do not generate electricity).

§ 95357. *Treatment of Confidential Information.* This section informs GIS owners under what circumstances information required to be submitted to ARB would be considered confidential.

§ 95358. *Enforcement.* This section states the circumstances for which penalties may be assessed for violations of the regulation.

§ 95359. *Severability.* The proposed regulation states that if any part of the regulation is held to be invalid, the remainder of the regulation shall continue to be effective.

V. ENVIRONMENTAL IMPACTS

The goal of this regulation is to reduce GHG emissions from GIS. An additional consideration is the impact that the proposed regulation may have on the environment. This section describes the potential impacts that the proposed regulation may have on air quality, water treatment, and hazardous waste disposal. Based upon available information, staff has determined that no significant adverse environmental impacts should occur as a result of adopting the proposed regulation.

A. Legal Requirements Applicable to the Analysis

The California Environmental Quality Act (CEQA) and ARB policy require an analysis to determine the potential environmental impacts of proposed regulations. ARB's program for adopting regulations has been certified by the Secretary of Resources, pursuant to Public Resources Code section 21080.5. Consequently, the CEQA environmental analysis requirements may be included in the Initial Statement of Reasons (ISOR) for the proposed regulation. In the ISOR, the ARB must include a functionally equivalent document, rather than adhering to the format described in CEQA of an Initial Study, a Negative Declaration, and an Environmental Impact Report. In addition, staff will respond to all significant environmental issues raised by the public during the 45-day public review period or at the Board hearing in the Final Statement of Reasons for the proposed regulation.

Public Resources Code section 21159 requires that the environmental impact analysis conducted by ARB include the following:

- An analysis of reasonably foreseeable environmental impacts of the methods of compliance;
- An analysis of reasonably foreseeable feasible mitigation measures; and
- An analysis of reasonably foreseeable alternative means of compliance with the proposed regulation.

B. Summary of Project Environmental Impacts, Occupational Safety Concerns, and Mitigation Options

The proposed regulations would reduce 253,000 MTCO₂ over the ten year regulatory period. Parties affected by the proposed regulation would be required to have no more than a ten percent SF₆ emission rate for their GIS equipment and to continue to reduce this annual emission rate by one percent per year beginning in 2011. Specific methods to attain these reductions are not set out in the proposed regulation. Rather, affected entities would determine which methods they would employ to meet the requirements. Currently, least-cost gas management techniques employed by participants in the U.S. EPA's voluntary SF₆ emission reduction program and within the European Union consist of technician training, SF₆ leak detection and repair, gas recycling, equipment evacuation, and equipment refurbishment or replacement. (See Section III. D,

Pages 11 and 12 for examples of these emission reduction methods.) These emission reduction techniques would have no adverse effect on criteria or toxic air pollutants. Because SF₆ is chemically inert, contains no chlorine or bromine atoms, it has no impact on stratospheric ozone depletion. SF₆ is not a criteria pollutant, a precursor compound, or a toxic air pollutant.

While SF₆ is inert during normal use, when electrical discharges occur within SF₆-filled equipment, toxic byproducts may be produced which pose a health threat to workers who come into contact with them. Employee exposure limits have been set by the National Institute for Occupational Safety and Health (NIOSH) and the United States' Occupational Safety and Health Administration (OSHA). Guidelines have been published by U.S. EPA, the International Council on Large Electric Systems (CIGRE), NIOSH and others regarding the handling, detection, and safety of SF₆ gas and its byproducts. These guidelines indicate that employee exposure should be minimized by wearing protective equipment when handling and disposing SF₆ byproducts and by meeting the exposure concentration standards.

Staff has concluded that no significant adverse environmental or employee health impacts should occur from adoption of, and compliance with, the proposed regulation. An additional benefit of this emission reduction measure is a possible reduction in employee exposure to SF₆ toxic byproducts. Because the proposed regulation reduces only greenhouse gas emissions by improving SF₆ management practices, it is not expected to result in any significant adverse air quality, wastewater, or hazardous waste impacts. Consequently, no mitigation measures are needed.

C. Other Potential Environmental Impacts

Staff does not expect any adverse environmental impacts in other sectors (including waste disposal and water quality) or increased energy use as a result of implementing the proposed regulation.

D. Environmental Justice and Community Health

State law defines environmental justice as the fair treatment of all people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies. ARB is committed to evaluating community impacts of proposed of proposed regulation, including environmental justice concerns.

The proposed regulation will reduce statewide greenhouse gases without increasing other pollutants. All Californians should benefit equally from the reduction in these greenhouse gas emissions.

VI. ECONOMIC IMPACTS

A. Legal Requirements

Section 11346.3 of the Government Code requires State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt any administrative regulation. The assessment must include a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination or creation; and the ability of California businesses to compete with businesses in other states. (See Appendix D for SF₆ emission detail, cost information, and calculation tables.)

Also, State agencies are required to estimate the cost or savings to any State or local agency and school district in accordance with instructions adopted by the Department of Finance. The estimate shall include any nondiscretionary cost or savings to local agencies and the cost or savings in federal funding to the State.

B. Potential Impact on California Businesses

Affected Businesses

Any business which owns gas insulated switchgear in California can be affected by the proposed regulation. Approximately 75 entities could be impacted by this regulation. Of these 75 entities, 11 are private businesses and 64 are public entities (59 municipal utilities (local government entities), one state government entity, and four federal government entities).

Potential Impact on Small Businesses

Of the approximately 75 affected businesses and government agencies, only the Mountain Utilities can be categorized as a small business¹. Because this business maintains limited GIS equipment and is currently subject to State mandatory emissions reporting regulations, the impact of the proposed regulation should be minimal.

Potential Impact on Business Creation, Elimination, or Expansion

The costs of the proposed measure are not expected to have a significant impact on the profitability of affected businesses in California. The proposal may have a limited, positive impact on job creation. It not expected to have any impact on business creation, elimination, or expansion in California.

Potential Impact on Business Competitiveness

The proposed measure affects equipment and services located only within the State and will have no impact on the ability of California businesses to compete nationally and internationally.

¹ Mountain Utilities, LLC, is a private company with estimated annual sales totaling \$750,000 and employs a staff of approximately 10 people.

Potential Impact on California Consumers

The proposed regulation is not expected to have an adverse impact on California consumers. Costs which cannot be absorbed by the regulated entities may be passed to consumers as increased electricity costs. If the total cost of the measure were passed to consumers, it would increase electricity rates by approximately \$0.000016 to \$0.000025 per kilowatt-hour. This increase equates to a 0.012 percent to 0.018 percent monthly increase, or one to one and one-half cents per month for an average residential electricity bill.

Potential Impact on California Employment

The proposed measure is not expected to have an adverse impact on California employment and payroll. The proposal may require larger GIS owners to increase jobs to meet the requirements of the proposed regulation.

Analysis of Potential Impacts to California State or Local Agencies

The proposed regulation will affect publically-owned and municipal utilities, and one State agency—the Department of Water Resources (DWR). These local agencies and DWR are currently subject to ARB's mandatory emission reporting regulations. The proposed regulation will expand on the recordkeeping and reporting requirements already required by the mandatory reporting regulations. The additional requirements are minimal and will have a limited impact on DWR and local agencies. SF₆ emission reduction activities will incur a cost savings during the initial years of the ten year regulatory period and will continue to be minimal until the final three years of this period. During these initial years, any additional costs to state and local agencies may be offset by savings from reductions in SF₆ usage, absorbed within current operating costs or, if needed, passed on to electricity consumers.

Based on current data, the total cost of the proposed regulation over its ten year regulatory period is estimated to range from \$4,500,000 to \$7,000,000. Survey data received from affected entities which supports staff's economic analysis reflects that between 18 and 21 percent of the cost will be borne by the publically-owned utilities. This results in a total cost range to local entities of \$940,000 to \$1,300,000 during the ten year regulatory period.

Survey respondents represent approximately 95 percent of the load in the State. For the remainder of the utilities that did not report, staff extrapolated the data from the utilities that did report. This yields an average annual cost of \$1,600 to \$2,100 per year per publicly-owned utility over the ten year regulatory period.

Average annual costs for the one affected state government agency (Department of Water Resources) are estimated to be \$1,700 to \$2,500 per year.

Because ARB's compliance cost estimation method relies on unverified, self-reported emission and nameplate data, and emission rates for some regulated entities are based on U.S. EPA national data, state and local costs contain some

uncertainty. Staff requests and will respond to all additional cost information raised by the public during the 45-day public review period or at the Board hearing in the Final Statement of Reasons for the proposed regulation.

C. Analysis of Cost-Effectiveness

ARB evaluates the costs to comply with the proposed regulation by considering the potential impacts on business, the cost-effectiveness of the proposed regulation, and the estimated cost impacts to consumers. The term “cost-effectiveness” within this analysis is defined as the dollar cost per metric ton of CO₂e emissions reduced.

Based on our analysis, staff estimates the overall cost-effectiveness of the proposed regulation ranges from \$18 to \$28 per metric ton of CO₂e reduced. This cost corresponds to an estimated range of \$450,000 to \$700,000 per year over the ten year life of the regulation, or a total cost range of \$4,500,000 to \$7,000,000. These amounts include the cost of emission reduction opportunities, reporting and recordkeeping.

D. SF₆ Emission Rate Reduction Cost Estimation Methodology

This section outlines ARB’s method for estimating the compliance cost of the proposed regulation to reduce SF₆ emissions from gas-insulated switchgear (GIS). The proposed regulation requires GIS owners to achieve an initial emission (leak) rate of ten percent beginning January 1, 2011, and to achieve progressively lower emission rates in subsequent years (one percent per year) concluding with a one percent emission rate beginning January 1, 2020.

This cost estimation method has two main elements:

1. An estimate of the amount of emission reductions needed to comply with the proposed regulation; and
2. An estimate of the unit cost of emission reductions.

Values generated for required reductions and unit cost are multiplied together to estimate compliance cost.

SF₆ emission reduction requirements are quantified as metric tons of CO₂-equivalent emissions reduced. The unit costs of emission reduction are expressed in terms of 2008 dollars per metric ton of CO₂ equivalent reduction and are presented for a discount rate of ten percent and a regulated entity tax rate of 40 percent.

Estimating the Quantity of Emission Reductions Needed

To estimate the quantity of emission reductions required, values are needed for:

- SF₆ nameplate capacity,
- Initial SF₆ leak rate, and

- Targeted leak rate(s) for the compliance period.

To estimate the cost of compliance for a given regulatory period, it is necessary to establish an initial (pre-regulatory) leak rate (**LR**) for regulated entities. **LR** can be calculated by dividing annual SF₆ emissions (**E**) by the “nameplate capacity” of non-hermetically sealed GIS owned by the regulated entity (**NP**).

$$LR \text{ (percent)} = E \text{ (lbs)} / NP \text{ (lbs)}$$

This equation also permits us to use any two known variables to calculate the value of any unknown third variable.

Of the two values needed to calculate baseline leak rates for regulated entities, only one—SF₆ emissions—is widely available. Self-reported data on the annual (2008) SF₆ emissions of regulated entities are available through the mandatory AB 32 GHG reporting program administered by ARB’s Emissions Inventory Branch. Of the 75 entities believed to be subject to the proposed SF₆ regulation, only 20 reported SF₆ emissions through ARB’s mandatory reporting program. However, within these 20 entities are those which are responsible for serving approximately 95% of the State’s electrical load. Although SF₆ usage is not directly correlated to electrical generation, for purposes of this analysis, staff assumes that the affected entities which generate the most electricity will also own the majority of gas insulated switchgear and the greatest volume of SF₆.

In addition, only a few regulated entities self-reported SF₆ nameplate capacity in response to an ARB survey. Accurate, complete GIS nameplate capacity data and therefore emission rates will not become available until 2012, when the proposed SF₆ GIS regulation would establish a verified GIS inventory for regulated entities.

In those cases where regulated entities self-reported both SF₆ emissions and SF₆ nameplate capacity, ARB staff applied those self-reported data to calculate initial leak rates and estimate compliance requirements.

Where regulated entities did not self-report SF₆ nameplate capacity in response to the ARB survey, nameplate capacity is estimated on the basis of other information. Non-reporting entities represent approximately five percent of electricity sales in the State. Staff estimated the unreported GIS capacity to be proportional to the reported capacity based on electricity sales. For the non-reported capacity, the initial leak rate is based on the experience of electric utilities participating in U.S. EPA’s voluntary SF₆ reduction program between 1999 and 2008. According to statistics published by the U.S. EPA partnership, the average initial leak rate of its participants was 15.2 percent. Nameplate capacity for regulated California entities is estimated by combining their reported emissions data with the U.S. EPA leak rate.

Using values developed for each regulated entity's SF₆ emissions, initial leak rate, and nameplate capacity, ARB staff estimated the amount of emission reductions needed to comply with the proposed standards. In any given year, emission reductions needed to meet the proposed standard can be calculated using the formula:

- $\Delta E = \Delta LR * NP$
- ΔE is the amount in pounds by which SF₆ gas emissions (or their CO₂ equivalent) must be reduced (changed) to achieve compliance in a given period;
- ΔLR is the percentage reduction (change) in leak rate required to achieve compliance in a given period;
- NP is the nameplate capacity in pounds of the regulated entity's GIS switchgear.

This calculation yields the number of pounds of SF₆ emissions that must be reduced in a given period to achieve compliance. To convert that amount into metric tons of equivalent CO₂ emission reductions needed, we multiply by 23,900 (the GWP of SF₆), and then divide by 2204 (the number of pounds in a metric ton).

The estimated lifespan of regulated (non-hermetically sealed) GIS equipment is approximately 40 years. However, for the ten year period of the proposed regulation, staff assumed a ten percent replacement rate of GIS inventory due to attrition based on survey responses. Given the reduced size, maintenance requirements, and emissions profile of new GIS, we assume that it replaces obsolescent GIS with higher nameplate capacities and emission rates. Although current GIS nameplate capacity is projected to gradually diminish over the ten year period of the proposed regulation due to normal turnover, new GIS installations are not anticipated to occur due to the minor anticipated load growth. ARB staff assumed a 2.0 percent annual reduction to nameplate capacity over the regulatory period due to the turnover of old high capacity GIS with newer low volume GIS.

Estimating the Unit Cost of Emission Reduction

The second main element of the cost estimation methodology—the cost to reduce one metric ton of CO₂-equivalent SF₆ emissions—is multiplied by the amount of required emission reductions to yield estimated compliance cost.

Estimated unit costs to reduce SF₆ emissions from GIS are taken from U.S. EPA's June 2006 report, "Global Mitigation of Non-CO₂ Greenhouse Gases." The report includes 2010 and 2020 unit cost estimates for all major SF₆ emission reduction methods applicable to the United States, including:

- SF₆ Recycling,
- Leak Detection and Repair, and

- Equipment Refurbishment.

In developing its unit cost estimates for these three SF₆ emission reduction methods, the report's authors projected that by 2010, 80 percent of available reductions would already have been achieved. The study estimates that 50 to 60 percent of remaining SF₆ emissions in the electricity sector can be reduced through these methods at the estimated costs. To be conservative, ARB staff assumed that these techniques could only be utilized to achieve the first 66 percent of reductions from the national average, or until an emission rate of five percent was achieved. After that point, it was assumed that the more expensive techniques would be progressively used to achieve further reductions. (See Section III. D., Pages 11 and 12 of this report for detailed descriptions of these emission reduction techniques.)

In addition, the report presents estimated unit costs for more expensive SF₆ reduction methods that may be employed in countries with more advanced SF₆ emission reduction regimes. These include equipment evacuation, repair, and replacement.

Each of the U.S. EPA study's emission reduction unit cost estimates is comprised of a range of values, expressed in 2000\$/MTCO₂e and presented for a discount rate of ten percent and a tax rate of 40 percent. ARB staff converted these values to 2008\$ by adjusting for inflation.

To estimate unit costs of reduction for the proposed SF₆ GIS regulation, ARB staff assumed that less expensive methods are employed first and that the unit cost of SF₆ emission reductions steadily increases over the regulatory period. To approximate the gradual increase of marginal abatement costs, annual values were evenly scaled from the lowest estimated 2010 unit cost (-\$1/MTCO₂e for SF₆ recycling) to the highest estimated 2020 unit cost (\$33/MTCO₂e for equipment evacuation for the low end of the range to \$55/MTCO₂e for GIS repair and replacement for the high end of ranges) over the regulatory period. ARB's cost estimation methodology integrates the full range of abatement options and their associated unit cost estimates as projected by the U.S. EPA study.

Presentation of Results

ARB staff's compliance cost analysis, based on the estimation methodology described above, indicates that the proposed SF₆ emission reduction regulation would reduce a total of 253,000 metric tons of CO₂-equivalent SF₆ emissions at a total cost of \$4.5 to \$7 million (2008 dollars). Emission reductions for rule compliance would occur over a period of ten years but the vast majority of projected reductions would not be required until 2019, due to the largest utilities voluntary emission reductions. (See Appendix D for detailed SF₆ emission detail, cost information and calculation tables.)

Because this compliance cost estimation method relies on unverified, self-reported emission and nameplate data, and because emission rates for some regulated entities are based on U.S. EPA national data, the results should not be regarded as evidence of GHG emission reductions achieved by individual regulated entities. The results of this cost-estimation method are primarily intended for use in aggregated form.

VII. IMPLEMENTATION AND ENFORCEMENT

GIS owners would be required to demonstrate compliance with the emission rate standards contained within the proposed regulation. Compliance would be demonstrated primarily through recordkeeping and reporting requirements. GIS owners would be required to develop and maintain records related to SF₆ containing equipment (GIS equipment and gas container inventories) and SF₆ purchases. These records must be maintained for three years and provide them to ARB upon request of the Executive Officer.

GIS owners would also be required to submit annual reports detailing their GIS equipment and SF₆ container inventories, their annual SF₆ emissions, and overall emission rate. Most GIS owners would be required to submit these reports electronically via ARB's greenhouse gas reporting tool. The majority of GIS owners are currently required to report annual SF₆ emissions to ARB under its mandatory greenhouse gas reporting requirements for entities which generate electricity (title 17, California Code of Regulations, sections 95100, *et seq.*). GIS owners not subject to mandatory reporting would be allowed to select their method of reporting.

Enforcement activities would be pursued to assure that all gas insulated switchgear owners are in compliance with the proposed regulation. This would include inspection of the above mentioned records provided by GIS owners and cross-verified by inspection of SF₆ distributor records. ARB enforcement staff may also inspect facilities, gas containers, and GIS equipment to ensure consistency with the owner's reports and inventories.

Penalties may be assessed for noncompliance with the reporting and allowable emission rate requirements. Penalties may be assessed for any violation of this subarticle pursuant to Health and Safety Code section 38580. Each day during any portion of which a violation occurs is a separate offense. Any exceedance of the maximum allowable SF₆ emission rate for a calendar year shall constitute a single, separate violation of this subarticle for each day of the calendar year. Enforcement actions can also include developing a court case, testifying in court, and responding to legal action.

Staff expects enforcement to be primarily conducted through the recordkeeping and reporting requirements. As most reporting will be done via electronic submittals using an existing ARB reporting tool, staff expects ARB to absorb the cost of enforcing the proposed regulation utilizing existing resources.

VIII. REFERENCES

1. ARB, 2009. *California Greenhouse Gas Emissions Inventory Data – 2000 to 2006*, <http://www.arb.ca.gov/cc/inventory/data/data.htm>
2. ARB, 2008. *Clearinghouse of Technological Options for Reducing Anthropogenic Non-CO2 GHG Emissions from All Sectors* (Pages 61-62, 77-79), <http://www.arb.ca.gov/cc/non-co2-clearinghouse/non-co2-clearinghouse.htm>
3. ARB, 2008. *Climate Change Scoping Plan: A Framework for Change*. (Pages 61, C186-C187), <http://www.arb.ca.gov/cc/scopingplan/document/scopingplandocument.htm>
4. ARB, 2009. *Initial Statement of Reasons for Proposed Regulation for Reduction of Sulfur Hexafluoride from Non-Semiconductor and Non-Utility Applications*, http://www.arb.ca.gov/cc/inventory/pubs/reports/appendix_a2_Inventory_IPCC_All_1990.pdf
5. ARB, 2009. *Initial Statement of Reasons for Proposed Regulation to Reduce Greenhouse Gas Emissions from California Semiconductor Operations*, <http://www.arb.ca.gov/regact/2009/semi2009/semi2009.htm>
6. California Department of Water Resources, 2007. *Management of the California State Water Project*. Bulletin 132-06, Ch. 10, Power Resources, <http://www.water.ca.gov/swpao/docs/bulletin/06/Bulletin132-06.pdf>
7. California Energy Conservation and Development Commission (CA Energy Commission), 2005. *US Per Capita Electricity Use by State in 2005*, http://energyalmanac.ca.gov/electricity/us_per_capita_electricity_2005.html
8. Electrical Review (The), 2009. *Switchgear – Environment First with SF6*. Accessed November 2009, from [http://www.electricalreview.co.uk/features/118462/Switchgear - Environment first with SF6.html](http://www.electricalreview.co.uk/features/118462/Switchgear_-_Environment_first_with_SF6.html)
9. Electric Power Research Institute, 2005, Technical Updates: *Effective SF₆ Training, Development of an On-Line SF₆ Reference; 2003, SF₆ and the Environment, Guidelines for Electric Utility Substations; 2005, Sulfur Hexfluoride Leak Detection Techniques, Selection Guidelines and Latest Passive Infrared Research*
10. European Fluorocarbon Technical Committee, 2006. *F-Gas Regulation*. Accessed November 2009, from http://www.fluorocarbons.org/en/debate/regulatory_developments/f_gas_regulation.html

11. European Parliament and of the Council, 2006. *Regulation (EC) No 842/2006 on Certain Fluorinated Greenhouse Gases*. Accessed September 2009, from http://ec.europa.eu/environment/climat/fluor/actions_en.htm
12. Gorin, T., and Pisor, K, 2007. *California Energy Commission Staff Paper: California's Residential Electricity Consumption, Prices, and Bills, 1980-2005*, <http://www.energy.ca.gov/2007publications/CEC-200-2007-018/CEC-200-2007-018.PDF>
13. ICF Consulting, 2002. *Byproducts of Sulfur Hexafluoride (SF₆) Use in the Electric Power Industry*, http://www.epa.gov/electricpower-sf6/documents/sf6_byproducts.pdf
14. IPCC, 2007. *Climate Change 2007: The Physical Science Basis, IPCC Working Group 1 Fourth Assessment Report*, http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_TS.pdf
15. McKenna Long & Aldridge LLP, 2009, *Climate Changes Insights*, <http://www.climatechangeinsights.com/2008/09/articles/air-water/the-addition-of-sf6-to-dods-emerging-contaminants-action-list>
16. National Institute of Standards and Technology, 2001. NIST Policy on Traceability. Accessed December 2009, from http://ts.nist.gov/Traceability/Policy/nist_traceability_policy-external.cfm
17. O'Connell, P., Heil, F., Henriot, J., Mauthe, G., Morrison, H., Niemeyer, L., Pittroff, M., Probst, R., Taillebois, J. P., for the International Council on Large Electric Systems (CIGRE WG 23.02) *SF₆ in the Electric Industry, Status 2000*
18. PEW Center on Global Climate Change, 2009. *High Global Warming Potential Gas Abatement*. Accessed November 2009, from <http://www.pewclimate.org/node/7042>
19. Reilly, J.M., Jacoby, H.D., and Prinn, R.G., 2003. *Multi-Gas Contributors to Global Climate Change: Climate Impacts and Mitigation Costs of Non-CO₂ Gases*. Massachusetts Institute of Technology, http://www.pewclimate.org/global-warming-in-depth/all_reports/multi_gas_contributors
20. U.S. Department of Labor Bureau of Labor Statistics, 2008. *National Compensation Survey-Wages*, <http://www.bls.gov/ncs/ocs/compub.htm>
21. U.S. Energy Information Administration, 2009. *Average Retail Price of Electricity to Ultimate Customers by End-Use Sector by State*, http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_b.html

22. U.S. Environmental Protection Agency, 2009. *SF₆ Emission Reduction Partnership for Electric Power Systems*. Accessed January 2010, from <http://www.epa.gov/electricpower-sf6/basic.html>
<http://www.epa.gov/electricpower-sf6/accomplishments.html>
<http://www.epa.gov/electricpower-sf6/partners/index.html>
<http://www.epa.gov/electricpower-sf6/workshops/conf06/awards.html>
http://www.epa.gov/electricpower-sf6/documents/pge_casestudy.pdf
23. U.S. Environmental Protection Agency, 2006. *Global Mitigation of Non-CO₂ Greenhouse Gases*,
<http://www.epa.gov/climatechange/economics/downloads/GlobalMitigationFullReport.pdf>
24. U.S. Environmental Protection Agency, 2009. *Final Mandatory Reporting of Greenhouse Gases Rule*,
<http://www.epa.gov/climatechange/emissions/ghgrulemaking.html>
25. U.S. Office of the Federal Register, 2009. *National Archives and Records Administration Federal Register*, Volume 74, No. 68,
http://www.access.gpo.gov/su_docs/fedreg/a090410c.html