EVALUATION OF THE AIR QUALITY CO-BENEFITS OF LOCAL GREENHOUSE GAS REDUCTION MEASURES: A CASE STUDY OF SAN FRANCISCO

PREPARED FOR:

U.S. Environmental Protection Agency Region 9

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Evaluation of the Air Quality Co-Benefits of Local Greenhouse Gas Reduction Measures: A Case Study of San Francisco

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Acronyms and Abbreviations

AB	Assembly Bill
BAAQMD	Bay Area Air Quality Management District
Bay Area	San Francisco Bay Area
CalEEMod	California Emission Estimator Model
CAMx	Comprehensive Air Quality Model with Extensions
CAP	Climate Action Plan
CAPCOA’s	California Air Pollution Control Officers Association’s
CAPPA	Climate and Air Pollution Planning Assistant
CCAP	Center for Clean Air Policy
CH_4	methane
City	City and County of San Francisco
CMAQ	EPA Community Multi-Scale Air Quality System
CMAS	Community Modeling and Analysis System
CAMx	Comprehensive Air Quality Model with Extensions
COBRA	Co-Benefits Risk Assessment
CO_2	carbon dioxide
CO_2e	CO_2 equivalent
CTCC	Tree Carbon Calculator
CUFR	Center for Urban Forest Research
EBMUD	East Bay Municipal Utility District
EPA	U.S. Environmental Protection Agency
EV	electric vehicle
GHG	greenhouse gas
GWP	global warming potential
HFCs	hydrofluorocarbons
ICF	ICF International
ICLEI	Local Governments for Sustainability
IPCC	Intergovernmental Panel on Climate Change
MOVES	EPA Motor Vehicle Emission Simulator
MPEM	Multi-Pollutant Evaluation Method
$MTCO_2e$	metric tons of CO_2e

N_2O	nitrous oxide
ng/m^3	nanograms per cubic meter
NH_3	ammonia
NO_x	oxides of nitrogen
PFCs	perfluorocarbons
PM	particulate matter
PM2.5	particulate matter less than or equal to 2.5 microns in diameter
PM10	particulate matter less than or equal to 10 microns in diameter
ppm	parts per million
ppt	parts per trillion
RECO	Residential Energy Conservation Ordinance
ROGs	reactive organic gases
SF CAP	San Francisco Climate Action Plan
SF_6	sulfur hexafluoride
SFBAAB	San Francisco Bay Area Air Basin
SFE	San Francisco Department of the Environment
SIP	state implementation plan
SO_2	sulfur dioxide
SPUR	San Francisco Planning and Urban Research Association
TDM	travel demand management
UCD ITS	University of California, Davis, Institute of Transportation Studies
VMT	vehicle miles traveled
WARM	EPA Waste Reduction Model

Executive Summary

Climate change and its effects on health have emerged as important issues at the global, national, state, and local levels. To mitigate the impacts of climate change, many cities and counties in the United States are evaluating potential measures to reduce greenhouse gas (GHG) emissions related to activities in their jurisdictions. Most of these jurisdictions are quantifying the effectiveness of these measures in reducing GHG emissions, and many are looking at the costs of implementing them. Very few, however, are quantifying the co-benefits of GHG reductions, such as health benefits resulting from reduced emissions and concentrations of criteria pollutants.

To demonstrate the utility of existing tools and guidance in addressing this gap, U.S. Environmental Protection Agency (EPA) Region 9 initiated this study of the air quality benefits from the GHG mitigation measures that are being considered as part of an update to the City of San Francisco's *Climate Action Plan* (SF CAP). To ensure that this study is an effective case study and provides useful results for local decision-makers, EPA established a partnership of local agencies and stakeholders to provide input and feedback on the study's process and results. A main objective of this study is to evaluate the feasibility of quantifying local-regional air quality co-benefits of local GHG reduction measures (i.e., proof of concept) and provide and a framework for evaluating co-benefits that can be used by local and regional decision-makers to allow for the optimization of GHG mitigation, air quality benefits, and other co-benefits. A second objective is to provide decision-support to local climate change and air quality planners by identifying the regional air quality benefits that could result from implementation of local and regional GHG reduction measures.

ICF International (ICF) used standard methods, models, and tools to estimate reductions in criteria pollutant precursor emissions from each SF CAP measure. In collaboration with the Bay Area Air Quality Management District (BAAQMD), ICF used the BAAQMD's Multi-Pollutant Evaluation Method (MPEM) to estimate the health benefits of regional air quality changes resulting from each SF CAP measure, including criteria pollutant concentration reductions and the economic impact from the model's predicted exposure reductions. The criteria pollutant analysis in this study focuses on ozone and fine particles (particulate matter less than or equal to 2.5 micrometers in diameter, or PM2.5).

The results of this analysis indicate that the SF CAP measures are anticipated to reduce criteria pollutant precursor emissions in the San Francisco Bay Area and are anticipated to reduce ambient (of the surrounding area or environment) concentrations of PM2.5. Because of the dynamics of ozone formation in the San Francisco Bay Area, the SF CAP would result in a slight increase in ozone concentrations. However, these ozone increases are small compared to the total ozone concentrations in the San Francisco Bay Area. Although the predicted changes in criteria pollutants are small on a regional scale (PM2.5 decrease of 12.64 nanograms per cubic meter [ng/m^3] and ozone increase of 3.627 parts per trillion [ppt], presuming that all measures are implemented simultaneously), the results of this study indicate that the SF CAP measures would result in significant economic benefits (approximately $114 million) from the improved health outcomes anticipated to result from the SF CAP measure reductions in both GHG emissions and PM2.5 concentrations.

It is important to note that while the individual influence on regional air quality of the single actions of the City of San Francisco from the GHG reduction measures may be relatively small, the combined regional effect of the implementation of similar GHG reduction measures by municipalities across the San Francisco Bay Area would have a much larger effect. For comparison, the City of San

Francisco's population in 2010 was just over 805,000, compared to the total 2010 population of the nine-county Bay Area region of 7.2 million. As of 2011, at least 33 of 106 local municipalities in the Bay Area had adopted climate action plans. These municipalities include: Santa Clara County, Sonoma County, Napa County, and the cities of Berkeley, Hayward, Oakland, Palo Alto, Redwood City, San Francisco, San Mateo, San Rafael, Santa Rosa, Union City, and many others. Further, many other cities and counties are presently working on developing their own climate action plans such that in a few years the majority of the Bay Area jurisdictions will have GHG reduction measures adopted into their local planning documents. Even if only half of the Bay Area region's municipalities were to ultimately adopt similar GHG reduction measures as that of San Francisco, this collective action could represent an increased improvement for regional air quality of approximately 450% greater than that of City of San Francisco's GHG reduction measures.

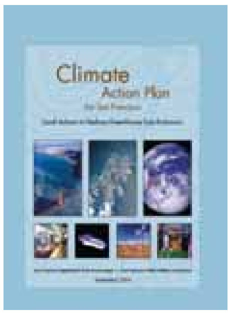
This study's overall air quality outcomes are specific to the San Francisco Bay Area and dependent on the SF CAP measure assumptions and the particular photochemistry and geography of the region (as modeled with MPEM). For example, the SF CAP renewable energy measure includes an ambitious goal of 100% renewable energy by 2030. Other cities and counties may have different GHG measure goals and may choose a different goal for renewable energy. Should this assumption be modified, the magnitude of the air quality impact and benefit associated with this measure would vary. The GHG and criteria pollutant precursor emissions outcomes may be roughly approximated in other jurisdictions by scaling the assumptions in the measures, as appropriate, to estimate the relative emissions impact of a particular measure in another locale. However, for ozone analyses, the specific photochemistry and geography of different locales will affect the outcome for air quality benefits given that ozone formation varies based on local chemistry.

Other types of benefits, ranging from aesthetic improvements to climate adaptation benefits, are also considered for each SF CAP measure in this study. This assessment provides a broad perspective on each measure's overall societal benefits that may be useful for decision-making and implementation purposes. Specifically, measures may result in a broad range of societal benefits despite their relatively modest air quality improvements. Further, although this study predicts considerable air quality monetary benefits associated with the SF CAP measures due to reductions in health costs from the pollutant exposure changes, this study does not account for measure implementation costs. Where net savings (such as from energy cost savings) can be realized from implementation of a particular measure, these monetary benefits would augment the measure's air quality monetary benefit. Where measure implementation involves net costs, then those costs could partially or completely offset the air quality benefits. A measure's overall economic benefit should be considered as the combined result of measurable costs and benefits, and weighted based on a combination of quantitative and qualitative benefit considerations.

This report presents numerous metrics throughout the document including: tons pollutant reduced, changes in ambient air pollutant concentration, $MTCO_2e$ (i.e., GHG reductions), dollars saved from avoided health costs from air pollutant exposure, monetary benefits of GHG reductions, air quality benefits per ton CO_2e reduced, a qualitative cost evaluation of GHG reduction measures, and a qualitative assessment of potential societal benefits (e.g., aesthetic improvements) for each GHG reduction measure. The various metrics have been presented to provide a menu of metrics that a municipality might want to consider in its climate change policy decision-making process. EPA is not endorsing certain metrics over others: the utility of a specific metric will depend upon the priorities and current decisions for each municipality. Further, EPA is not suggesting that all of the analyses conducted for this project would need to be conducted for a co-benefits analysis by a municipality.

Rather, this project seeks to present a range of various tools and metrics that could be used by a municipality that sought to consider co-benefits such as those for air quality of their GHG reduction policies.

Chapter 1
Study Description



Chapter 1
Study Description

Chapter 1 describes the overall purpose and approach of this project. This chapter specifically outlines the steps for this particular project but can be used as a template for how any municipality might conduct a co-benefits evaluation of their GHG reduction measures.

Background

Worldwide, climate change and its effects on health are critical issues. These issues are also top priorities for the U.S. Environmental Protection Agency (EPA). EPA initiatives and studies have begun to address the effects of climate change on health; to identify mitigation and adaptation options and their potential co-benefits or adverse health effects, as well as environmental justice issues; and to develop the means to protect the health of children and other vulnerable populations. Although climate change is a long-term, global threat, measures to reduce greenhouse gas (GHG) emissions can provide near-term and local air quality benefits.

The concept of considering GHG reduction strategies in the context of potential co-benefits is gaining attention. Reduction of GHG emissions, through the development of renewable energy, energy efficiency, reduction of transportation emissions, and other initiatives can also reduce emissions or concentrations of criteria air pollutants, which can lead to improvements in air quality and public health. Improvements in public health and investments in clean energy would likely stimulate economic activity and support jobs. In February 2010, EPA published a report titled *Assessing the Multiple Benefits of Clean Energy: A Resource for States* to help state and local policymakers identify and quantify the benefits of clean energy to support the development and implementation of cost-effective clean energy initiatives.

The measures evaluated in this study include actions under consideration by the City of San Francisco to reduce local GHG emissions. GHG and criteria pollutant precursor emissions reductions associated with the implementation of City measures are assumed to occur primarily in San Francisco, although some may occur at power plants or at other locations outside of San Francisco. Associated changes in criteria pollutant concentrations are evaluated on a region-wide basis in the Bay Area Air Quality Management District's (BAAQMD) Multi-Pollutant Evaluation Method (MPEM) (Bay Area Air Quality Management District 2010a), such that criteria pollutant concentration changes resulting from these measures are presumed to occur throughout the entire San Francisco Bay Area. Air quality benefits will vary by location. For example, particulate matter emission reductions could disproportionately benefit receptor populations in close proximity to the emissions source whereas ozone precursor emission reductions will result in more general benefits throughout the Bay Area.

Purpose

EPA Region 9 has undertaken a case study of GHG gas mitigation measures for the City of San Francisco, using an analytical framework and specific tools developed by a local air pollution control agency for the San Francisco Bay Area, to demonstrate how a local government might undertake a multi-pollutant approach to GHG mitigation.[1] The GHG mitigation measures evaluated in this case study were provided to ICF by the City of San Francisco. These measures may be included as part of a future update to the 2004 SF CAP (San Francisco Department of the Environment and San Francisco Public Utilities Commission 2004). These measures are currently under development and will likely be incorporated into the updated SF CAP, unless substantial changes to the measures result from the forthcoming public review of the SF CAP update. This case study identifies local GHG measures that provide the greatest regional health benefits with respect to air quality. This study also provides a framework for evaluating other measure co-benefits that can be used by local and regional decision makers to make informed decisions about optimizing GHG mitigation, air quality benefits, and other societal benefits. Throughout this report, the terms *criteria pollutant* and *air pollutant* are often used interchangeably.

Participants and Collaborators

To initiate the case study, EPA Region 9 established a partnership with local agencies and stakeholders, including the San Francisco Planning and Urban Research Association (SPUR), BAAQMD, and San Francisco Department of the Environment (SFE). EPA Region 9 also requested the participation of US EPA Headquarters and Elmwood Consulting as Technical Advisors. Table 1-1 contains a list of the individual participants and their roles in the study. ICF International (ICF) was chosen to provide contract support for this case study, including estimation of quantitative results, coordination of participants, and production of the final report/presentation.

Table 1-1. Participants in Case Study

Name	Organization	Role
Meredith Kurpius	EPA Region 9	Coordinator/collaborator
Laura Tam	SPUR	Collaborator
David Burch	BAAQMD	Collaborator
David Fairley	BAAQMD	Collaborator
Calla Ostrander	SFE	Collaborator
Tim Johnson	US EPA	Technical advisor
Nick Hutson	US EPA	Technical advisor
Chris Stoneman	US EPA	Technical advisor
Denise Mulholland	US EPA	Technical advisor
Bruce Riordan	Elmwood Consulting	Technical advisor

[1] Of note, the EPA has its own methods for quantifying the benefits of air quality improvements that it utilizes for federal rule-making and air quality evaluation. Local methods from Bay Area Air Quality Management District (BAAQMD) were used for this study as the purpose of this study is to show how one local jurisdiction conducted such an evaluation using its own local tools and resources. The purpose of this study is not to evaluate different methods for benefit evaluation of air quality but to provide a proof of concept on the approach to evaluating air quality cobenefits of GHG reduction measures utilizing local resources.

Climate Planning in San Francisco

The City and County of San Francisco (City) was selected for this case study because it has been proactive in taking action to address climate change and has evaluated numerous options for reducing GHG emissions, across all sectors of GHG emissions. Under the SF CAP, the City has committed to reduce GHG emissions to 20% below 1990 levels by 2012. Other local entities have also participated in the City's climate planning efforts, as described below:

- The City developed the SF CAP in 2004 and is currently updating numerous policies aimed at curbing GHG emissions. The 2004 SF CAP can be found at http://www.sfenvironment.org/downloads/library/climateactionplan.pdf
- In May 2009, SPUR released a report entitled *Critical Cooling: Analyzing San Francisco's Options to Reduce Greenhouse Gas Emissions* (San Francisco Planning and Urban Research Association 2009) that discusses the cost-effectiveness of 42 options to reduce global warming, focusing on local policy. The 42 options were generated from the original SF CAP and input provided at local stakeholder meetings. SPUR prioritized its recommendations based on the options' potential impacts and cost-effectiveness. SPUR considered private savings, public revenue, private cost, reductions in energy demand, equity issues, improvements in mobility, and carbon dioxide (CO_2) emissions from construction. However, SPUR did not consider air quality impacts.
- BAAQMD recently developed MPEM to simultaneously evaluate air quality and GHG benefits. Using this tool, BAAQMD has been exploring the GHG impacts of air quality control programs. Conversely, the tool could be used to determine the air quality impacts of local GHG mitigation policies.
- SFE is presently updating the SF CAP measures, including quantifying the GHG reductions associated with each measure.

Steps and Outcomes

The major quantitative analysis components of this case study included estimating criteria pollutant direct and precursor emissions—oxides of nitrogen (NO_x), sulfur dioxide (SO_2), reactive organic gases (ROGs), and direct particulate matter (PM) less than or equal to 2.5 microns in diameter (PM2.5)—and GHG emission reductions associated with each SF CAP measure, and then using MPEM to generate air quality health benefits (or costs) associated with those policies. Table 1-2 illustrates the case study process and outcomes.

Table 1-2. Case Study Process and Outcomes

Step	Participants (Lead)	Activities	Outcome or Deliverable
1—Identify GHG reduction measures to evaluate and prioritize	All (EPA/ICF)	Hold meetings with stakeholders and collaborators, and assess project resources	Prioritized list of GHG reduction measures
2—Quantify emission reductions from selected GHG reduction measures	EPA and BAAQMD (ICF)	Establish inputs needed for MPEM and evaluate criteria pollutant precursor emission reductions	Database of criteria pollutant precursor emission reductions for each measure
3—Determine societal benefits that result from criteria pollutant emission reduction	EPA, BAAQMD, and SFE (ICF)	Run MPEM for each measure and evaluate outputs	Database of criteria pollutant emission reductions and benefits for each measure
4—Assess measures for other societal benefits	EPA (ICF)	Develop qualitative criteria to assess measures for other societal benefits	Assessment of each measure's potential societal benefit
5—Conduct outreach and prepare report	All (ICF)	Convene meeting to solicit input from stakeholders on results of analysis and prepare final report	Communicate case study results to stakeholders

Technical Tools for Local GHG and Air Quality Analyses

Local jurisdictions, regional planning entities, and air quality agencies (at all levels of government) can use a number of tools (or models) to analyze GHG and air quality benefits from local actions, several of which are listed and described in Table 1-3. Although this list is not exhaustive, these tools and resources are well-documented and based on standard protocols or methodologies. In addition, some rely on California-specific emission factors and other parameters.

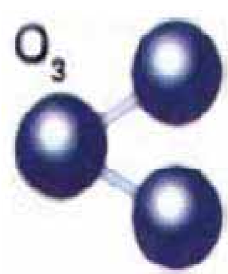
This list includes tools capable of calculating GHG and criteria pollutant direct/precursor emissions, as well as those capable of evaluating criteria pollutant concentrations, through the use of photochemical modeling. Photochemical modeling, specific to a particular air basin or region, is required to accurately evaluate criteria pollutant concentrations and the effectiveness of regulatory control strategies for precursor emissions. Although there are many tools and software programs for photochemical modeling of air pollutant concentrations, only MPEM, which is specific to the San Francisco Bay Area (Bay Area), currently combines this capability with the ability to calculate GHG emission reductions and the economic benefits of both GHG emission reductions and criteria pollutant emission reductions. Extensive technical documentation for MPEM is available from the BAAQMD and on the web at: http://www.baaqmd.gov/Divisions/Planning-and-Research/Plans/Clean-Air-Plans/Resources-and-Technical-Docs.aspx.

Table 1-3. Tools and Resources for Local GHG and Air Quality Analyses

Tool Name	Description
BAAQMD MPEM	Microsoft Excel–based tool for estimating changes in ambient (of the surrounding area or environment) concentrations, population exposures, and health outcomes for a variety of criteria pollutants, including air toxics. Also determines monetary value of total health benefits from criteria pollutant and GHG reductions. Requires criteria pollutant precursor emission reductions as inputs. Further information: http://www.baaqmd.gov/Divisions/Planning-and-Research/Plans/Clean-Air-Plans/Resources-and-Technical-Docs.aspx
California Emission Estimator Model (CalEEMod)	Software program developed in coordination with air districts throughout California that can be used to evaluate potential emissions (GHGs and criteria pollutants) associated with both construction and operational use of land use projects. Further information: http://www.caleemod.com/
Center for Clean Air Policy (CCAP) *Transportation Emissions Guidebook*	Web-based tool that can calculate the impacts (vehicle miles traveled [VMT] and reductions in criteria pollutant precursor and GHG emissions) of transportation-related measures, including land use, transit, and travel demand management (TDM) measures, in addition to vehicle technology and fuel measures. Further information: http://www.ccap.org/safe/guidebook/guide_complete.html
Center for Urban Forest Research (CUFR) Tree Carbon Calculator (CTCC)	Microsoft Excel spreadsheet that can be used to estimate the amount of biomass and carbon stored in a tree and amount of carbon sequestered annually. Provides information on the effects of tree shade on residential heating and cooling energy use. Further information: http://www.fs.fed.us/ccrc/topics/urban-forests/ctcc/
Co-Benefits Risk Assessment (COBRA) Screening Model	A stand-alone Windows application that can be used to help state and local governments estimate the air quality (PM), human health, and related economic co–benefits of clean energy policies or other actions that potentially reduce air pollution. Further information: http://www.epa.gov/statelocalclimate/resources/cobra.html
Comprehensive Air Quality Model with Extensions (CAMx)	Simulates air quality over many geographic scales. Treats a wide variety of inert and chemically active pollutants, including ozone, PM, inorganic and organic particles, and mercury and other toxics. Also has a plume-in-grid and source apportionment capability. Further information: http://www.camx.com/
EPA Community Multi-Scale Air Quality System (CMAQ)	Used by EPA and supported by Community Modeling and Analysis System (CMAS). Includes capabilities for conducting urban- to regional-scale simulations of multiple air quality issues, including ozone, fine particles, toxics, acid deposition, and visibility degradation. Further information: http://www.epa.gov/AMD/CMAQ/
EPA Motor Vehicle Emission Simulator (MOVES)	Estimates emissions for mobile sources covering a broad range of pollutants and CO2. Allows multiple-scale analysis. Currently estimates emissions from cars, trucks, and motorcycles. Further information: http://www.epa.gov/otaq/models/moves/index.htm
EPA NONROAD Model	Estimates air pollution inventories by professional mobile source modelers, such as state air quality officials and consultants, for nonroad engines, equipment, and vehicles. NONROAD2008 update includes new nonroad emission standards promulgated in 2008 related to small gasoline engines and pleasure craft. Further information: http://www.epa.gov/otaq/nonrdmdl.htm
EPA Waste Reduction Model (WARM)	Online or Microsoft Excel–based tool that can provide GHG reductions associated several different waste management practices, including reduction, recycling, combustion, composting, and landfilling. Further information: http://www.epa.gov/climatechange/wycd/waste/calculators/Warm_home.htm l

Tool Name	Description
ICLEI—Local Governments for Sustainability (ICLEI) Climate and Air Pollution Planning Assistant (CAPPA)	Microsoft Excel spreadsheet that can calculate reductions in GHG and criteria pollutant precursor emissions from more than 110 distinct strategies, from energy efficiency to solid waste. Also estimates economic benefits (annual cost savings and simple payback) of the measures. Further information: http://www.icleiusa.org/tools/cappa/climate-and-air-pollution-planning-assistant-cappa

Chapter 2
Environmental Setting



Chapter 2
Environmental Setting

Chapter 2 provides background on the San Francisco Bay Area region to give context for this study. This chapter also describes the basic emission and chemical characteristics of ozone, particulate matter, and GHGs in the San Francisco Bay Area. Finally, this chapter presents an overview of air planning efforts by the local air quality management district.

San Francisco Bay Area Characteristics

The San Francisco Bay Area (Bay Area) is a metropolitan region that surrounds the San Francisco and San Pablo estuaries. It includes Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma Counties. The Bay Area is home to approximately 7.15 million people and contains numerous cities, nine counties, international airports, and park and open space areas connected by a network of roads, railroads, bridges, and tunnels. Figure 2-1 shows a map of the Bay Area, in relation to the surrounding area, and Table 2-1 presents average temperatures and precipitation for several representative cities in the region.

Table 2-1. Average Temperature and Precipitation in Representative Bay Area Cities

City	Annual Average Temperature (°F)	Annual Precipitation (inches)
Livermore	61	15
Oakland	59	24
San Francisco	57	21
San Jose	60	15
San Rafael	59	48

Source: http://www.nws.noaa.gov/climate/local_data.php?wfo=mtr

Air quality in the San Francisco Bay Area Air Basin (SFBAAB) is influenced by the region's topography, its meteorology, and the emission rates of criteria pollutants and their precursors. The SFBAAB is characterized by complex terrain, including coastal mountain ranges, inland valleys, and bays, which result in complex wind flow patterns. The SFBAAB climate is dominated by the strength and location of the semi-permanent, subtropical Pacific high-pressure cell. During summer, the cell is centered over the northeastern Pacific Ocean, resulting in stable meteorological conditions and a steady northwesterly wind flow. In winter, the cell weakens and shifts southward, resulting in wind flow offshore and an increase in storms compared to summer.

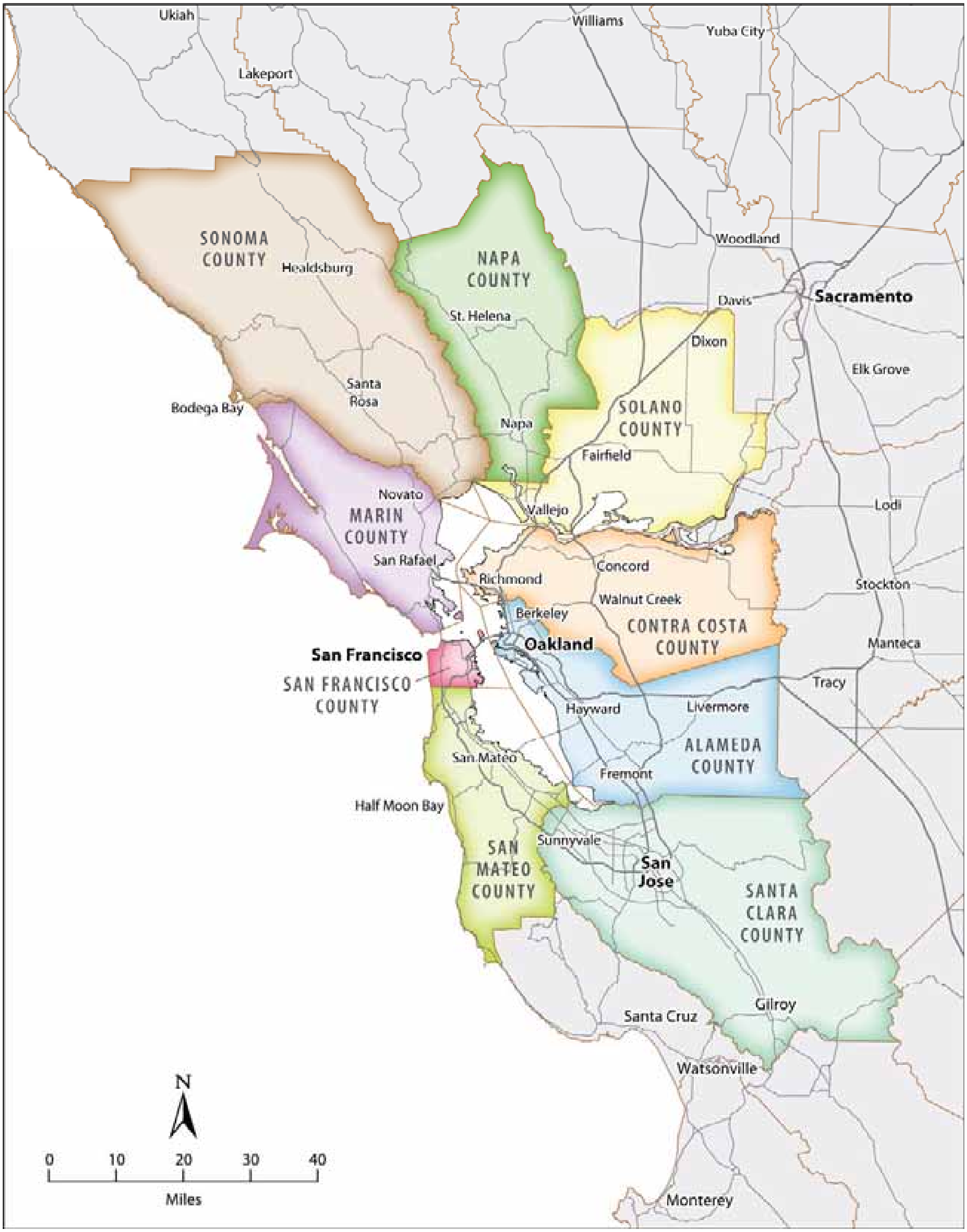


Figure 2-1. Map of San Francisco Bay Area

Sources

This section provides a brief overview of ozone and particulate matter formation in the Bay Area. This provides context for other municipalities and also provides background to help interpret the results from this study. A more comprehensive discussion of Bay Area photochemistry can be found in the *Bay Area 2010 Clean Air Plan* (Bay Area Air Quality Management District 2010b). A short description of GHGs is also included to provide basic background information.

Ozone

Ozone is not emitted directly into the environment, but is formed in the atmosphere by complex chemical reactions between ROGs and NO_x (i.e., ozone precursors) in the presence of sunlight. Short-term exposure to ozone can irritate the eyes and constrict the airways. Besides causing shortness of breath, it can aggravate existing respiratory diseases such as asthma, bronchitis, and emphysema. Chronic exposure to high ozone levels can permanently damage lung tissue. Ozone can also damage plants, trees, and materials such as rubber and fabrics. Health impacts have been determined based on ambient concentrations (ppt); therefore, that is the metric that is used to determine the health valuation for this project.

Ozone formation is greatest on warm, windless, sunny days, and in inland valleys. As air temperatures rise, the rate of ozone photochemistry increases, and the formation of ground-level ozone also increases. This effect can often be augmented by increased rates of emissions through evaporation or anthropogenic (i.e., caused or produced by humans) activities related to the high temperatures (e.g., increased use of air conditioning). The main sources of ROGs and NO_x are combustion processes (including motor vehicle engines); evaporation of solvents, paints, and fuels; and biogenic sources. Automobiles are the largest source of ozone precursors in the SFBAAB. Because ozone is a regional pollutant, efforts to reduce ozone levels focus on reducing ROG and NO_x emissions throughout the entire SFBAAB.

The ratio of ROGs and NO_x influences ozone formation. BAAQMD’s ozone modeling indicates that the Bay Area is “ROG-limited” for ozone formation (Bay Area Air Quality Management District 2010b). As such, control programs that reduce ROG emissions will likely be more productive in reducing ozone concentrations than programs that reduce NO_x emissions. However, the modeling also indicates that considerable reductions in NO_x emissions are needed to achieve the considerable ozone reductions required to attain federal ozone standards.

In its *Multi-Pollutant Evaluation Method Technical Document* (Bay Area Air Quality Management District 2010a), BAAQMD makes the following observations based on photochemical modeling of the Bay Area:

- ROG-only reduction control measures lead to ozone reductions virtually everywhere.
- NO_x-only reduction control measures lead to ozone *reductions* in some areas and substantial ozone *increases* in other areas.

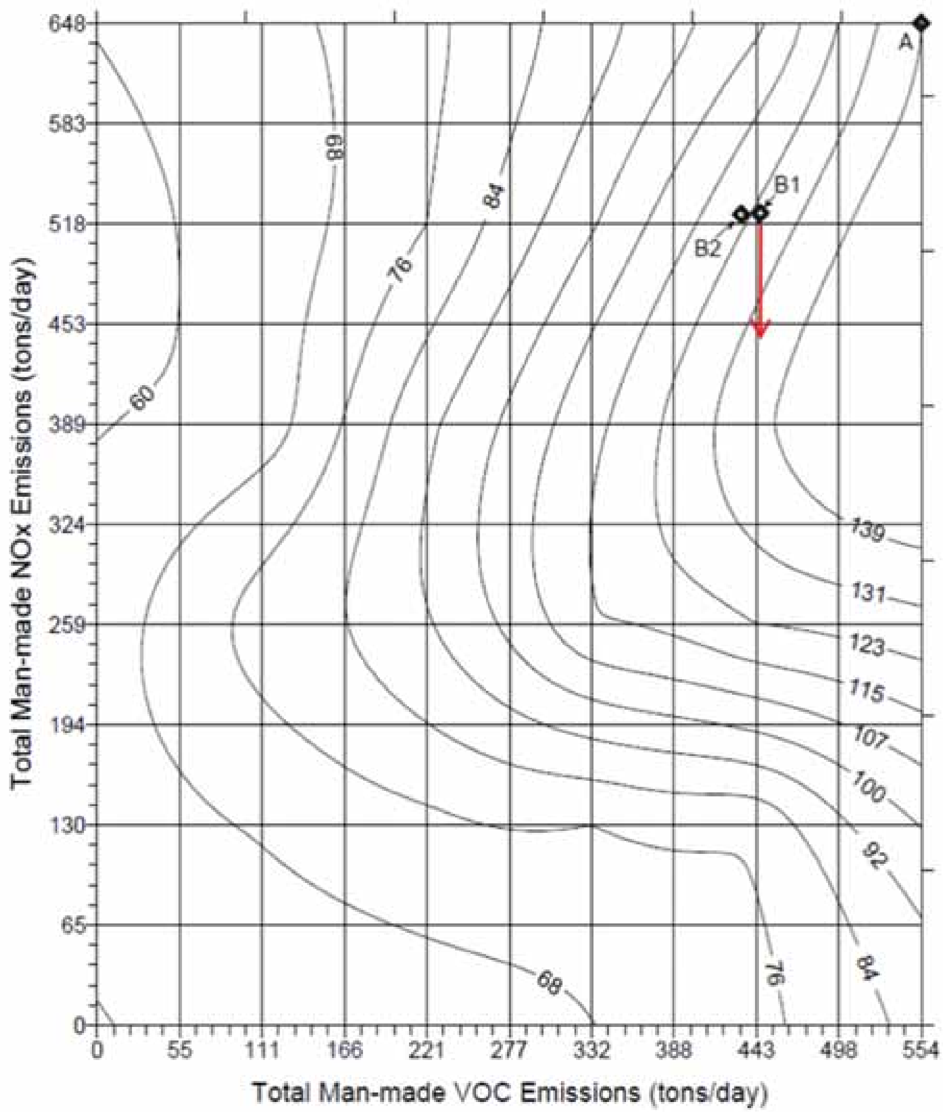
Photochemical modeling can illustrate the relationship between NOx and ROG emission rates and predicted ozone concentrations, relative ambient ozone concentrations. Specifically, photochemical modeling provides ozone isopleths, which are graphical representations of ozone concentrations in an area (or air basin). These isopleths show the relationship between NO_x and ROG emission rates and simulated ambient ozone concentrations. Similar to topographical mapping where lines represent the same elevation, isopleth lines represent NO_x and ROG emission rates that result in the same ozone concentration. Ozone isopleths are highly nonlinear, but are instructive in determining whether a region is NO_x-limited (i.e., whether ozone is best controlled by reducing NO_x emissions) or ROG-limited (i.e., whether ozone is best controlled by reducing ROG emissions), as in the case of the Bay Area.

As an illustration of the ozone regimes described above, Figure 2-2 presents an ozone isopleth for Livermore that was included in the *San Francisco Bay Area 2001 Ozone Attainment Plan* (Bay Area Air Quality Management District 2001). Because of the Bay Area's emission patterns, geography, and air flow, Livermore often has the highest ozone concentrations in the region. In Figure 2-2, the red arrow (at point B1) directed downward depicts an arbitrary decrease in NO_x emissions and the resulting *increase* in ozone concentration (as indicated by the labeled contour lines) in an area of the ozone isopleth that is ROG-limited. This example illustrates how control measures that reduce NO_x emissions in the ROG-limited regime can result in ozone concentration *increases*.

Particulate Matter

PM refers to solid or liquid particles suspended in the atmosphere, including smoke, dust, aerosols, and metallic oxides. Coarse PM (PM10) is particles with an aerodynamic diameter of 10 micrometers or less. Fine PM (PM2.5) is a subgroup of finer particles with an aerodynamic diameter of 2.5 micrometers or less (sometimes referred to as *fine PM*). PM is emitted directly (i.e., direct or primary PM, resulting from fossil fuel combustion and wood burning) and also forms in the atmosphere through reactions among different pollutants (i.e., indirect or secondary PM). Ammonium nitrate and ammonium sulfate are secondary PM. ROGs, NO_x, ammonia (NH_3), and sulfur dioxide (SO_2) are precursors of secondary PM. Like ozone, PM concentrations can vary daily and seasonally, and throughout different areas of the Bay Area. The PM spatial and seasonal variability can be even greater than that of ozone because of the complexity of PM chemistry, formation, and transport. Secondary PM, however, is typically high in winter because of more stagnant meteorology.

Some PM, such as windblown dust and sea salt, occurs naturally. In the SFBAAB, most PM is caused by combustion. Motor vehicles are responsible for a large portion of the PM in the SFBAAB. Wood burning in fireplaces and stoves is another important source. Extended exposure to PM can cause increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing, for example; decreased lung function; aggravated asthma; development of chronic bronchitis; irregular heartbeat; nonfatal heart attacks; and premature death in people with heart or lung disease. Health impacts have been determined based on ambient concentrations (ng/m^3); therefore, that is the metric that is used to determine the health valuation for this project.



Isopleths of Livermore peak ozone concentrations (parts per billion) based on photochemical model sensitivity simulations. Point B1 represents the projected emissions for Year 2006 considering already adopted measures. Point B2 includes the effect of new control measures included in this Plan. The isopleth labeled 123 ppb represents a design value equivalent to attainment of the national 1-hour standard. The corresponding VOC emissions level is approximately 439 tons/day, given projected NOx emissions.

Figure 2-2. Livermore Ozone Isopleths Based on Modeling for San Francisco Bay Area 2001 Ozone Attainment Plan

Greenhouse Gases

GHGs are gases that trap heat in the atmosphere. GHGs can occur naturally or through human activities. GHGs produced naturally and through human activities include Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Those produced primarily through human activities include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

The Intergovernmental Panel on Climate Change (IPCC) estimates that CO_2 accounts for more than 75% of all anthropogenic (i.e., caused by human activity) GHG emissions. Three-quarters of these CO_2 emissions result from fossil fuel burning, and approximately one-quarter of them result from land use change (Intergovernmental Panel on Climate Change 2007a). Methane, the second-largest contributor of anthropogenic GHG emissions, results from growing rice, raising cattle, combustion, and mining coal (National Oceanic and Atmospheric Administration 2005). Although it is not as abundant as CO_2 or methane, nitrous oxide is also a powerful GHG. Sources include agricultural processes, nylon production, fuel-fired power plants, nitric acid production, and vehicle emissions.

To simplify reporting and analysis of GHG emissions, methods have been developed to define emissions of different GHGs in terms of a single gas. The most commonly accepted method is the global warming potential (GWP) methodology defined by IPCC (1996; 2001). GWP is a measure of a gas's heat-absorbing capacity and lifespan relative to a reference gas, CO_2, which has a GWP of 1 by definition. IPCC defines the GWP of various GHG emissions on a normalized scale in terms of CO_2 equivalent (CO_2e). Table 2-2 lists the GWP of CO_2, methane, and nitrous oxide; their lifetimes; and their atmospheric abundances in parts per million (ppm) or ppt in 2005. For example, methane had an atmospheric abundance (i.e., concentration) of 1.7 ppt in 2005, an average lifetime (i.e., residence time) in the atmosphere of 9-15 years, and a global warming potential of 21 which indicates that methane traps 21 times more heat than CO_2 over a 100-year time horizon.

Table 2-2. Global Warming Potential, Lifetime, and Atmospheric Abundance of Carbon Dioxide, Methane, and Nitrous Oxide

Gas	GWP (100 years)	Lifetime (years)	Atmospheric Abundance (2005)
Carbon dioxide	1	50–200	379 ppm
Methane	21	9–15	1.7 ppt
Nitrous oxide	310	120	0.32 ppt

Source: Intergovernmental Panel on Climate Change 2007a, 2007b

The six GHGs included in this study have lifetimes of years, as compared to hours or days for ozone or PM, and are therefore distributed globally. Local sources and sinks can have small influences on local concentrations but ambient levels of GHGs are typically not driven by local sources/sinks. The benefits for GHG reductions are typically based on emission reductions, rather than ambient concentrations. Therefore, this study relies on local emission reductions ($MTCO_2e$) to determine the benefits and therefore chemistry is not considered.

Bay Area Emissions Inventory

There are many sources of ozone precursors in the Bay Area, including industrial and commercial facilities, motor vehicles, and consumer products (e.g., household cleaners and paints). Ozone precursors produced by human activity are called anthropogenic (defined above), while those produced by natural sources (e.g., plants and animals) are called biogenic. In the Bay Area, emissions of ozone precursors from anthropogenic sources are larger than those from biogenic sources (Bay Area Air Quality Management District 2010b). Motor vehicles and evaporation of solvents, fuels, and other petroleum products are the main sources of ROG emissions in the Bay Area. The main sources of NO_x are motor vehicles and combustion at industrial and other facilities.

As discussed above, PM can be emitted directly and formed indirectly from precursor chemicals, such as ROGs, NO_x, and NH_3. Although direct PM2.5 emissions in the Bay Area are produced by a variety of sources, both human made and natural, a few sources dominate. About half of PM2.5 emissions in the Bay Area are emitted directly from combustion (e.g., burning fossil fuels, wood, or other vegetative matter, or cooking).

The Bay Area's annual average emission inventory for ozone precursors (ROGs and NO_x) and direct PM (both PM10 and PM2.5) is presented in Table 2-3 and Table 2-4 contains a summary of the Bay Area GHG emissions for 2007 for each major source category. Both inventories are presented to provide context for the overall Bay Area and a point of comparison for other local agencies but the information from these inventories was not used as part of the analyses for this project.

Table 2-3. Ozone and Particulate Matter Emissions Precursors for Bay Area, 2008 (tons per day)

Source	ROGs	NO_x	PM10	PM2.5
Stationary				
Fuel combustion	3.2	45.3	5.4	5.4
Waste disposal	36.0	0.6	0.1	0.1
Cleaning and surface coatings	34.9	0.0	0.0	–
Petroleum production and marketing	21.4	0.6	1.0	0.9
Industrial processes	11.1	4.1	9.8	5.8
Total for stationary sources	*106.6*	*50.6*	*16.3*	*12.1*
Areawide				
Solvent evaporation	71.5	–	–	–
Miscellaneous processes	16.5	16.9	175.5	52.9
Total for areawide sources	*87.9*	*16.9*	*175.5*	*52.9*
Mobile				
On-road motor vehicles	112.3	206.7	10.1	7.1
Other mobile sources	70.8	173.8	10.2	9.1
Total for mobile sources	*183.1*	*380.5*	*20.3*	*16.3*
Grand total for SFBAAB	*377.6*	*448.0*	*212.1*	*81.3*
Source: California Air Resources Board 2009a				

The GHG inventory presented in Table 2-4 estimates direct and indirect emissions from sources within the Bay Area for the following gases: CO_2, methane, nitrous oxide, HFCs, PFCs, and sulfur hexafluoride. The largest sources of GHG emissions in the Bay Area are from stationary/commercial sources and transportation. The activity data utilized to develop this GHG emissions inventory is the same as that utilized for the BAAQMD's criteria pollutant and toxic air pollutant[2] emissions inventories. Although this emissions inventory covers the entire Bay Area, the GHG reductions associated with the measures selected for this analysis result from actions developed and implemented by the City. As indicated in an October 2011 press release by the San Francisco

[2] Toxic air pollutants, as defined by the U.S. EPA, are those pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects. For more information, please refer to: http://www.epa.gov/oar/toxicair/newtoxics.html.

Mayor's office, the City's GHG emissions have been estimated as 6.2 million MT CO_2e in 1990 and 5.4 million MT CO2e in 2010 (refer to: http://www.sfmayor.org/index.aspx?page=593).

Table 2-4. GHG Emissions for Bay Area, 2007 (metric tons)

Source Category	CO_2	CH_4	N_2O	PFCs/HFCs	SF_6	CO_2e
Industrial/commercial	28,766,652	80,052	1,181	2,184	0.13	34,862,465
Residential fuel usage	6,622,682	6,369	196	–	–	6,817,118
Electricity/co-generation	15,126,111	1,483	37	–	1.18	15,197,047
Off-road equipment	2,845,974	1,025	171	–	–	2,920,462
Transportation	34,098,941	3,629	2,246	–	–	34,871,276
Agriculture/farming	199,883	25,991	1,163	–	–	1,106,246
Total emissions	*87,660,281*	*118,549*	*4,993*	*2,184*	*1.3*	*95,774,635*

Source: Bay Area Air Quality Management District 2010c

BAAQMD Air Quality Planning

In September 2010, BAAQMD adopted the *Bay Area 2010 Clean Air Plan* (Bay Area Air Quality Management District 2010b), a comprehensive plan to improve San Francisco Bay Area air quality and protect public health. The 2010 Clean Air Plan serves to:

- Update the *Bay Area 2005 Ozone Strategy* (Bay Area Air Quality Management District 2005) in accordance with the requirements of the California Clean Air Act to implement "all feasible measures" to reduce ozone.
- Provide a control strategy to reduce ozone, PM, air toxics, and GHGs in a single, integrated plan.
- Review progress on improving air quality in recent years.
- Establish emission control measures to be adopted or implemented in the 2010–2012 timeframe.

Although BAAQMD has steadily reduced ozone levels in the Bay Area, the region is designated as nonattainment for both the 1- and 8-hour state ozone standards. In addition, emissions of ozone precursors in the Bay Area contribute to air quality problems in neighboring air basins. As such, state law requires the 2010 Clean Air Plan to include all feasible measures to reduce these emissions and reduce their transport to neighboring air basins (Bay Area Air Quality Management District 2010b).

The Bay Area was recently designated as nonattainment for the national 24-hour PM2.5 standard and must prepare a PM2.5 state implementation plan (SIP) pursuant to federal air quality guidelines by December 2012. The 2010 Clean Air Plan is not a SIP and does not respond to federal requirements for PM2.5 or ozone planning. However, in anticipation of future PM2.5 planning requirements, the 2010 Clean Air Plan control strategy aims to reduce PM emissions and concentrations. In addition, EPA is reevaluating national ozone standards and may modify them in the future. The control measures in the 2010 Clean Air Plan will help in the Bay Area's continuing effort to attain the national ozone standards (Bay Area Air Quality Management District 2010b).

Chapter 3
Methods and Analysis

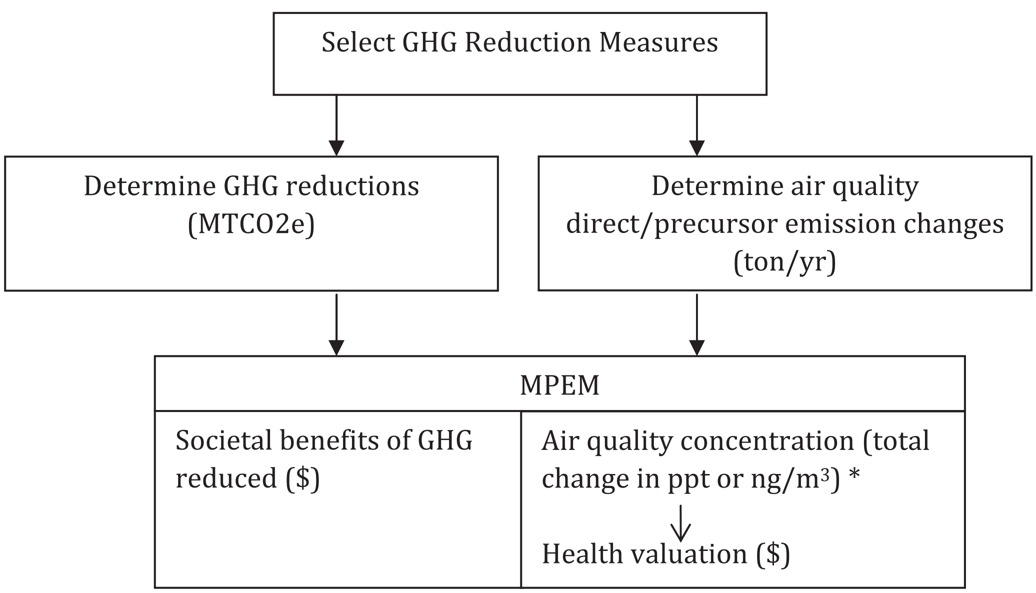
Chapter 3
Methods and Analysis

This chapter lists the GHG reduction measures selected for this project and explains how they were chosen. This chapter then describes the analysis conducted to estimate criteria pollutant direct and precursor emission reductions for each SF CAP measure, as well as a brief overview of the GHG emissions reduction analysis for the SF CAP measures that was conducted under a separate study and used in this study to evaluate the economic benefits of the GHG reductions. This chapter describes the use of MPEM to evaluate the air quality benefits associated with the SF CAP measures. The air quality benefits include criteria pollutant concentration reductions and health effect valuations from the expected exposure reductions. Limitations of the technical tools used in this study are provided at the end of the chapter.

Overall Methodology Scheme

The first step in conducting an analysis of the air quality health co-benefits from GHG reduction measures are is to select GHG reduction measures for the analysis. Once the GHG reduction measures have been selected, the next step is to quantify the GHG reductions (in MT CO_2e) and the direct and precursor air pollutant emission changes (in tons/year). The final steps are to quantify societal benefit of CO_2e reductions and determine air pollution concentration changes and associated health valuation. The overall scheme for the methodology for this study is depicted in Figure 3-1.

Figure 3-1. Schematic of steps in determining monetary benefits for GHGs and air quality from GHG reduction measures



*See Table 3-5 for additional details on air quality health valuation steps in MPEM.

Local Climate Action and Air Quality Measures Selected for Evaluation

ICF provided support to SFE to update its *Climate Action Plan* measures. SFE provided 23 climate action measures to be included in this analysis, based on measures that were originally quantified in SPUR's *Critical Cooling* report. SFE updated the underlying assumptions and program specifics for the SPUR actions, and ICF quantified the GHG reductions associated with this new information for each measure. This analysis may be updated in the future, as new or more accurate information becomes available.

Based on guidance provided by SFE, ICF organized SFE's 23 selected climate action measures into the 13 quantifiable measures ("SF CAP measures") presented in Table 3-1. GHG reductions associated with these measures are also listed in Appendix A. A detailed description of each measure, including the methodology and assumptions for estimating reductions for each measure are provided in Appendix B. The actions are grouped into six categories: community transportation demand management, electric transportation, energy efficiency, renewable energy, zero waste, and land use. GHG reductions associated with each measure are provided as 2020 reductions in metric tons of CO_2e ($MTCO_2e$) (Figure 3-2). Some of the original 23 measures were combined with other measures to provide a more robust accounting of GHG reductions (or where data for specific measures necessary for individual quantification was unavailable). The new SF CAP measures and original SPUR *Critical Cooling* report measures are compared in Table 3-2a. The SPUR *Critical Cooling* report measures that are significantly different from and cannot be matched one to one to the SF CAP measures are listed in Table 3-2b; these measures are not the focus of this study.

Greenhouse Gas Emission Reduction Analysis

As indicated in the previous section, GHG reductions for each measure were developed in a prior effort for the City, completed by ICF. ICF used standard models and tools to evaluate the GHG emissions reductions associated with the SF CAP measures. The detailed methods associated with the GHG emissions reduction analysis are not included in this report.

Table 3-1. SF CAP Measures Considered in Co-Benefits Analysis and Corresponding GHG Emission Reductions in 2020

SF CAP Measure Number and Short Title	Description	2020 GHG Emission Reductions ($MTCO_2e$)
Community Transportation Demand Management (TDM)		
1a—Workplace TDM	Develop and expand TDM programs to reduce the number of single-occupancy trips for work or special events. Increase support for San Francisco employers to comply with the Commuter Benefits Ordinance and expand marketing and outreach to City employees. Develop outreach materials for citywide special events on transit, biking, and ridesharing to reduce congestion. Outreach to San Francisco residents to inform them of workplace commute benefits, programs, and travel alternatives.	53,047
1b—Community TDM	Develop and expand TDM programs to reduce the number of single-occupancy trips to transit hubs, shopping centers, and schools. Develop outreach materials for citywide special events on transit, biking, and ridesharing to reduce congestion. Homeowners' association outreach to San Francisco residents to inform them of commute benefits, programs, and travel alternatives.	226,677
2—Ridesharing	Promote and expand ridesharing programs.	4,431
Electric Transportation		
3—Electric Vehicle Infrastructure	Establish sufficient public and residential electric vehicle (EV) charging to support a 10% EV market (new car sales) by 2015. In new residential construction, require EV charging infrastructure and ensure access to charging for residents of existing multifamily buildings.	42,511
Energy Efficiency		
4—RECO Update	Update the Residential Energy Conservation Ordinance (RECO)	92,226
5a—Residential Loan Program	Create a loan program to finance comprehensive energy efficiency services (residential).	1,910
5b—Commercial Loan Program	Create a loan program to finance comprehensive energy efficiency services (commercial).	22,151
6—Energy Efficiency Legislation Support	Support the implementation of legislation requiring energy benchmarking and energy efficiency audits for commercial buildings.	194,513
7—Energy Efficiency Services	Expand energy efficiency rebates and installation services.	1,511
Renewable Energy		
8—Renewable Energy Goal	100% renewable electricity by 2030.	610,525
Zero Waste		
9—Achieve Zero Waste	Decrease disposal through recycling and composting 9% (about 44,000 tons) annually to achieve zero waste by 2020.	544,533

SF CAP Measure Number and Short Title	Description	2020 GHG Emission Reductions ($MTCO_2e$)
10—Digester Capture	Work with East Bay Municipal Utility District (EBMUD) to capture 120 tons per day of food waste for use in energy-producing digesters.	8,367
Land Use		
11—Land Use Measures	Participate in and develop land use plans in accordance with the region's adopted Sustainable Communities Strategy required by state legislation (Senate Bill 375).	239,052
12—Transit-Oriented New Jobs	Increase the number of jobs accessible by high-capacity transit.	7,598
13—Tree Planting	Plant an additional 10,000 trees.	3,291

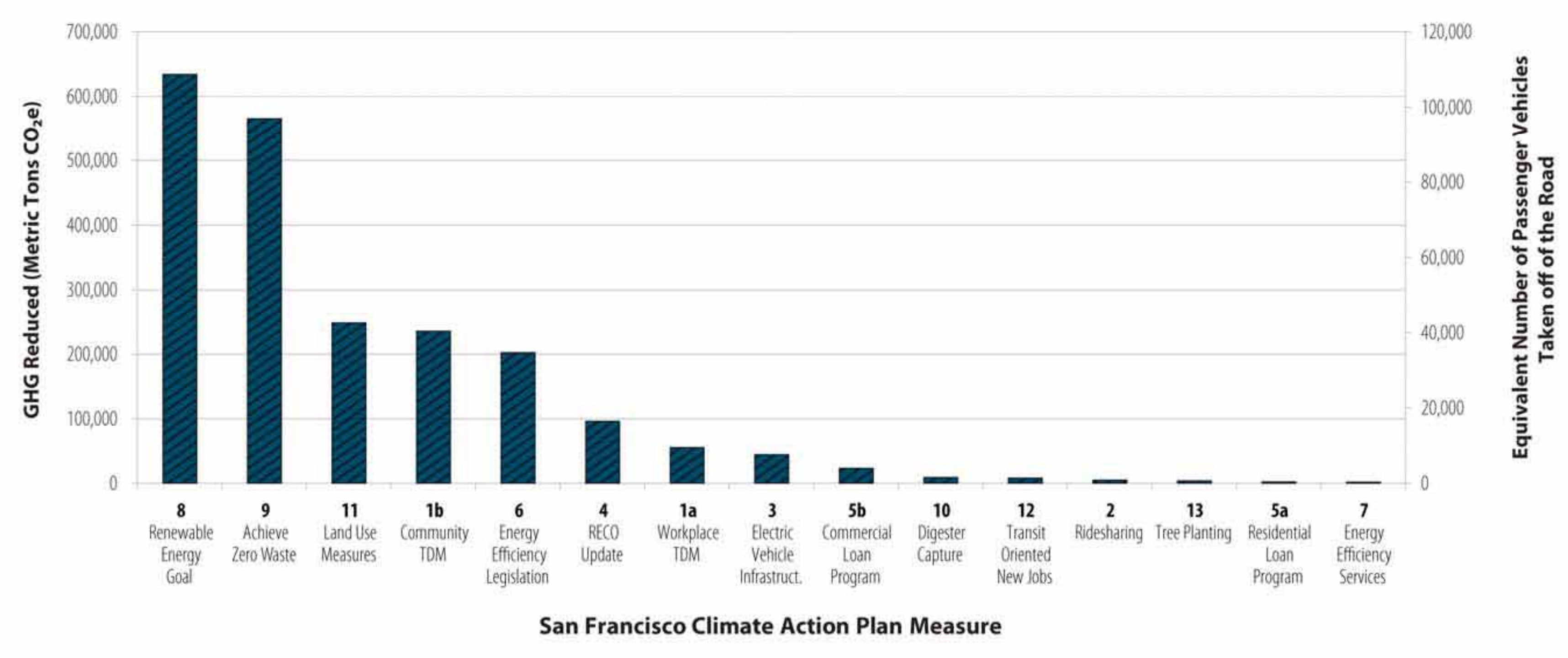


Figure 3-2. GHG reductions in 2020 for SF CAP Measures

Table 3-2a. Comparison of SF CAP Measures and SPUR Critical Cooling Report Measures

SF CAP Measure Number and Short Title	SPUR Measure Short Title
1a—Workplace TDM	Build the Phase 1 bicycle network Build the Phase 2 bicycle network Create bike rental or sharing system Expand commuter benefits for city workers Use prices to manage the supply of curb parking Enforce parking cash-out law
1b—Community TDM	Build the Phase 1 bicycle network Build the Phase 2 bicycle network Create bike rental or sharing system Use prices to manage the supply of curb parking Enforce parking cash-out law Expand use of commuter benefits by residential developers and HOAs Expand use of commuter benefits by universities
2—Ridesharing	Expand HOT lanes in Bay Area** Set aside car-sharing parking spaces on the street (500 spaces)
3—Electric Vehicle Infrastructure	N/A
4—RECO Update	Update the Residential Energy Conservation Ordinance Update the RECO and require home performance testing
5a—Residential Loan Program	Create a loan program to finance comprehensive energy efficiency services Create a "green lease" program
5b—Commercial Loan Program	Create a loan program to finance comprehensive energy efficiency services Create a "green lease" program Reinstate the Commercial Energy Conservation Ordinance
6—Energy Efficiency Legislation Support	Require retrocommissioning in commercial buildings Reinstate the Commercial Energy Conservation Ordinance
7—Energy Efficiency Services	Expand energy efficiency rebates and installation services
8—Renewable Energy Goal	Expand solar PV incentives for municipal or private installations Expand small-scale wind Build smart grid infrastructure
9—Achieve Zero Waste	Further increase recycling and composting
10—Digester Capture	Build green waste digesters to produce energy from compost
11—Land Use Measures	Adopt regional compact land use development Permit more housing in SF 10% over ABAG 2030 allocation
12—Transit-Oriented New Jobs	None
13—Tree Planting	None

Table 3-2b. SPUR Critical Cooling Report Measures Not Matched to SF CAP Measures

Implement the TEP recommendations for Muni
BRT on Geary
BRT on Van Ness
Build the Downtown Transit Center/Caltrain extension**
Build the Central Subway
Caltrain electrification**
Expand ferry service**
Implement congestion pricing
Implement climate fee on gasoline (AB 2744)**
Expand Pay as You Drive Insurance (PAYD)**
Create individualized marketing programs (Travelchoice)
Convert the city fleet to biodiesel
Create GHG standard for taxi fleet
Impose a carbon tax (utility users' tax)
Reduce taxiing under jet power at SFO**
Improve signaling to reduce idling and congestion
Impact on SF from Pavley bill, 2020
State incentives for clean air vehicles (feebates)
Note: These measures are not the focus of this study.

Criteria Pollutant Precursor Emission Reduction Analysis

The methods used to estimate criteria pollutant direct and precursor emission reductions associated with the SF CAP measures is provided in this section. Direct emissions of PM2.5 are defined for the purposes of this study, and are limited to emissions of diesel PM2.5 and other direct PM2.5. Criteria pollutant precursors are defined for the purposes of this study and limited to: 1) ROGs and NO_x for both ozone and PM2.5, and 2) direct PM2.5 and SO_2 for secondary PM2.5. The quantification includes projected reductions in criteria pollutant direct/precursor emissions in the SF CAP forecast year of 2020. Emission reductions for each measure represent the total reductions that would occur in the Bay Area as a result of each measure's implementation. Reductions associated with the measures may also occur outside the Bay Area, but these reductions are not quantified in this analysis.

ICF used standard models and tools to evaluate the criteria pollutant direct and precursor emission reductions associated with the SF CAP measures. Table 3-3 summarizes the methodology used for each measure (or groups of measures) and references the source for the emission factors used in the analysis. The direct and precursor emission changes became the inputs for the MPEM analysis which determined concentration changes.

Air Quality and Greenhouse Gas Benefits Analysis

ICF used MPEM to determine the air quality and GHG benefits of the SF CAP measures, including criteria pollutant concentration reductions and health effect valuations from the expected exposure changes (for both criteria pollutants and GHGs). MPEM was developed by BAAQMD to simultaneously analyze emission control measures for multiple pollutants to assist in air quality control policy development. MPEM produces ambient concentrations and predicts exposure changes and health effects resulting from reductions in GHG and criteria pollutant precursor emissions due to implementation of emissions control measures (Bay Area Air Quality Management District 2010a). MPEM can be used to:

- Estimate how reductions of each pollutant for a given control measure will affect ambient concentrations, population exposures, and health outcomes related to that pollutant.
- Monetize the value of total health benefits for all pollutants that would be reduced by each potential control measure.
- Evaluate and compare the estimated benefit of potential control measures based on the value of each measure in reducing health costs from air pollutants and environmental/social impacts related to GHG reductions.

MPEM considers ozone precursors (ROGs and NO_x), directly emitted PM2.5 (diesel PM2.5 and other direct PM2.5) and PM2.5 precursors (NH_3, NO_x, ROGs, SO_2, and direct sulfate), toxics, and CO_2e. The user specifies the emission reduction (in pounds per day) in the MPEM spreadsheet interface to determine the change in ambient concentration of criteria pollutants and the societal and health care benefits associated with improved air quality.

Table 3-3. Summary of Greenhouse Gas and Criteria Pollutant Precursor Emission Reduction Methodology for SF CAP Measures

SF CAP Measure	Methodology Description	References for Emission Factors Used
1a and 1b—Workplace and Community TDM	VMT reductions associated with several TDM strategies, as calculated by ICF for San Francisco County Transportation Authority.	• EMFAC2007 • California Climate Action Registry 2009
2—Ridesharing	VMT reductions associated with current and future estimates of participants in the City's 511.org ridesharing program.	• EMFAC2007 • California Climate Action Registry 2009
3—Electric Vehicle Infrastructure	Light-duty vehicle gasoline emissions offset by less-carbon-intensive EVs in 2020.	• California Climate Action Registry 2009 • EMFAC2007 • EPA eGRID2007 • University of California, Davis, Institute of Transportation Studies (UCD ITS) 2006
4, 5a, 5b, 6, and 7—RECO Update, Residential Loan Program, Commercial Loan Program, Energy Efficiency Legislation Support, and Energy Efficiency Services	Electricity and natural gas reductions were calculated for each of these measures, based on program parameters and expected participation rates in 2020.	• EPA eGRID2007 and EPA 1995 • UCD ITS 2006 • URBEMIS2007 • California Climate Action Registry 2009
8—Renewable Energy Goal	Projection of renewable energy in 2020, based on 2008 levels and 2030 goal. Emissions calculated based on projected energy usage in 2020.	• EPA eGRID2007 and EPA 1995 • UCD ITS 2006 • URBEMIS2007 • California Climate Action Registry 2009
9—Achieve Zero Waste	Not quantified for criteria pollutant emission reductions.*	–
10—Digester Capture	Energy produced from food waste digested was calculated and assumed to offset nonrenewable energy use in 2020.	• EPA eGRID2007 • UCD ITS 2006
11—Land Use Measures	Data for seven Priority Development Areas (PDAs) were modeled in URBEMIS** to estimate area and mobile source emission reductions associated with the PDAs, and were compared to model simulation of existing land use for these areas.	• URBEMIS2007
12—Transit-Oriented New Jobs	Two scenarios of auto mode shares (i.e., low and high) were compared for existing and 2020 employment levels to determine VMT reduction associated with increased transit ridership in the low auto mode scenario.	• URBEMIS2007

SF CAP Measure	Methodology Description	References for Emission Factors Used
13—Tree Planting	Electricity and natural gas reductions associated with energy savings from tree shading were calculated based on outputs from the U.S. Forest Service's Tree Carbon Calculator tool.	• EPA eGRID2007 • UCD ITS 2006 • URBEMIS2007 • California Climate Action Registry 2009

* Criteria pollutant precursor emissions were not evaluated for this measure due to uncertainty in the implementation of this measure, including the transport method and destination of the diverted waste.

** Although URBEMIS2007 was used for the land use measures analysis, this report also references CalEEMod as a useful tool for criteria pollutant emission analyses in California. Both models quantify emissions from the various phases of construction and operation for land uses identified in the Institute of Transportation Engineers *Trip Generation* (2008), but CalEEMod includes additional features such as a comprehensive set of GHG reduction measures and estimates of CO_2e. CalEEMod was developed recently for the Southern California Air Quality Management District and is available for download at http://www.caleemod.com.

The MPEM health valuation is an estimate of the economic value of pollution reductions in terms of decreased health and social costs. In other words, improvements in air quality result in avoided health effects which can be quantified as a cost-saving. This includes, as possible, the direct costs of illness, such as hospitalization and medications, and the value placed by individuals on avoiding the illness. Table 3-4 lists the health effects considered in MPEM for PM2.5 and ozone. Specific health values were developed based on data available in current literature and research studies as discussed in the BAAQMD MPEM technical documentation located at: http://www.baaqmd.gov/Divisions/Planning-and-Research/Plans/Clean-Air-Plans/Resources-and-Technical-Docs.aspx (Bay Area Air Quality Management District 2010a), including a comprehensive technical study of the MPEM model and uncertainty analysis. In addition, the BAAQMD MPEM technical documentation was peer reviewed by several researchers (Bay Area Air Quality Management District 2010d).

Table 3-4. Health Effects Considered in Multi-Pollutant Evaluation Method

Health Effect	PM2.5	Ozone
Mortality	x	x
Chronic bronchitis onset	x	
Respiratory hospital admissions	x	x
Cardiovascular hospital admissions	x	
Nonfatal heart attacks	x	
Asthma emergency room visits	x	x
Acute bronchitis episodes	x	
Upper respiratory symptom days	x	
Lower respiratory symptom days	x	
Work loss days	x	
Minor restricted activity days	x	x
School absence days		x
Cancer		

MPEM also produces the social benefit or value of reducing GHG emissions, typically “the cost to society of a ton of carbon emissions.” This value attempts to capture the total costs to society of a wide range of climate change impacts, including impacts on public health, the environment, and societal disruption (e.g., after a major weather disaster). BAAQMD performed a literature review and selected the value of $28 per metric ton of GHG reduced (expressed in CO_2e) for the social cost of carbon, as described in Section 5.3 of the *Multi-Pollutant Evaluation Method Technical Document* (Bay Area Air Quality Management District 2010a). For this analysis, the GHG emissions reduction associated with each measure, as developed for the prior City study, were included as an input to MPEM for the purpose of estimating the GHG social benefit/value of reducing the GHG emissions.

Table 3-5 lists the MPEM steps to produce air quality and GHG benefits.

Table 3-5. Steps in Multi-Pollutant Evaluation Method

Step	Description
1—Criteria pollutant precursor emissions	Estimate how much a given control measure would reduce (or increase) emissions of each criteria pollutant. For this study, these estimates were developed by ICF as described above.
2—Criteria pollutant concentrations	Estimate how a change in emissions of each criteria pollutant would affect its ambient concentrations. For ozone, PM, and air toxics, these results are based on sensitivity evaluations of photochemical modeling results.
3—Population exposure	Estimate how a change in ambient criteria pollutant concentrations would affect the exposure of Bay Area residents to each criteria pollutant. *Ambient exposure* is the exposure of the population to a pollutant resulting from the ambient pollutant concentration.
4—Health impacts	Estimate how a reduction in population exposure would affect various health endpoints, projecting changes in the incidence of endpoints such as emergency room visits for asthma, lower respiratory symptoms, and deaths.
5—Health/social benefits (valuation)	Monetize the benefits (i.e., avoided costs) of each control measure by estimating the cost of the health and climate impacts from each pollutant. For each health endpoint, the change in the number of incidents is multiplied by an estimate of the per-incident social cost. For GHGs, the change in tons of emissions is multiplied by the estimated social cost per ton of GHGs, expressed in terms of CO_2e.

Source: Bay Area Air Quality Management District 2010a

Study Limitations

Analyzing the environmental, health, and economic impacts associated with implementing GHG mitigation measures in 2020 is a complex, data-intensive undertaking. Important analyses and modeling assumptions used in this study were evaluated by ICF and EPA. To provide the reader with a perspective on this study's findings, the following provides an overview of several of the limitations of the technical tools and analytical methods used in this study.

For the precursor emissions reduction analysis, for example, predicting emission factors for 2020 includes inherent uncertainty. The future carbon intensity of fuels, electricity, vehicle trips, etc., may be unknown or highly variable. Where literature values or established metrics for future emission factors were not available, future emission factors used in this analysis were estimated based on either historical trends or related forecasts or were assumed to remain constant. Also, the models (EMFAC and URBEMIS) used in the analysis are based on activity data that may be outdated or contain inherent uncertainties associated with the geographical domain of the emission analysis.

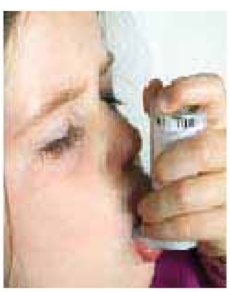
The technical limitations of MPEM are included in the *Multi-Pollutant Evaluation Method Technical Document* (Bay Area Air Quality Management District 2010a). Several important limitations are listed below.

1. MPEM "spreads" emission reductions proportionally across the entire modeling domain such that one cannot specify where in the domain a reduction will occur.
2. Some health effects are not included in MPEM because the link between pollutants and the health effects is not yet clearly established. Even for the health effects that are included, the per-incidence cost estimates may not fully capture all costs associated with a given illness or impact.

3. Estimating the societal cost of one ton of GHG reduced may not fully capture all potential impacts and costs related to climate change and global warming. MPEM is sensitive to the $28-per-ton GHG valuation, and an order-of-magnitude change in this valuation would result in an order-of-magnitude change in model results.
4. MPEM assumes full-time (24/7) "backyard" exposure, although in reality people do not spend all of their time at home and in their yards.
5. MPEM does not consider the benefits of improvements in air quality beyond the boundaries of BAAQMD that would result from reduced transport of Bay Area emissions to neighboring air basins.
6. Environmental benefits such as improving water quality or protecting ecosystems that may result from reducing emissions of criteria pollutants are not addressed.

Chapter 4

Study Findings and Results



Chapter 4
Study Findings and Results

This chapter discusses the major findings and results of this study. It presents criteria pollutant direct and precursor emission reductions and resulting criteria pollutant concentration changes, as well as the MPEM health valuation outcome for both criteria pollutants and GHGs. Numerous metrics (e.g., emissions reductions and air pollutant concentration changes) are provided to give the reader a variety of different ways to consider the data. For example, an air planner considering these results may be more interested in the criteria pollutant reductions while a climate planner may be more interested in the societal valuation of the GHG reductions. The main co-benefit results and findings are presented in the "Monetary Co-benefits" section and specifically in Figures 4-3 and Table 4-6. Further comparison of the monetary co-benefits for each of the SF CAP measures are provided in Figures 4-4 and 4-5 and Table 4-7.

Regional Air Quality Impact

The SF CAP measures will have a beneficial overall impact on GHG and criteria pollutant emissions in the Bay Area. As shown in Table 4-1 and in more detail in Appendix C, almost all of the measures would reduce criteria pollutant direct/precursor emissions. The only exception is *Electric Vehicle Infrastructure*, which would indirectly generate a small amount of SO_2 as a result of increased electricity production. Additionally, *Achieve Zero Waste* was not analyzed for criteria pollutant direct/precursor emission reductions. The criteria pollutant emission reductions for each measure are small compared to total criteria pollutant emissions in the Bay Area, given the hundreds of sources that contribute to these emissions throughout the entire Bay Area. While direct/precursor emissions are useful as an indicator of pollutant levels, ultimately, it is the atmospheric concentration changes (see Table 4-4) that are caused by these direct/precursor emissions that determine the health impacts.

Table 4-1. Reductions of GHG and Criteria Pollutant Precursor Emissions by SF CAP Measure and Percent of Total Bay Area Criteria Pollutant Emissions

		Criteria Pollutant Precursor Emissions Reductions (pounds per day)				Percent of 2005 Bay Area Total Emissions			
Measure	GHG Reductions ($MTCO_2e$ per year)	ROG	NO_x	PM2.5	SO_2	ROG	NO_x	PM2.5	SO_2
1a—Workplace TDM	53,046.63	26.11	72.66	17.79	3.78	0.0033	0.0070	0.0103	0.0028
1b—Community TDM	226,677.17	111.58	310.48	76.00	16.17	0.0142	0.0298	0.0442	0.0119
2—Ridesharing	4,431.14	2.18	6.07	1.49	0.32	0.0003	0.0006	0.0009	0.0002
3—Electric Vehicle Infrastructure	42,511.34	47.96	70.05	28.68	-41.02	0.0061	0.0067	0.0167	-0.0302
4—RECO Update	92,225.86	25.35	397.82	32.43	97.84	0.0032	0.0382	0.0189	0.0719
5a—Residential Loan Program	1,909.59	0.52	8.24	0.67	2.03	0.0001	0.0008	0.0004	0.0015
5b—Commercial Loan Program	22,150.96	5.08	91.09	7.46	35.22	0.0006	0.0087	0.0043	0.0259
6—Energy Efficiency Legislation Support	194,513.13	44.61	799.88	65.52	309.29	0.0057	0.0768	0.0381	0.2274
7—Energy Efficiency Services	1,510.58	0.43	6.60	0.54	1.39	0.0001	0.0006	0.0003	0.0010
8—Renewable Energy Goal	610,524.81	79.07	2,014.60	166.69	1,369.03	0.0101	0.1933	0.0969	1.0066
9—Achieve Zero Waste	544,533.19	–	–	–	–	–	–	–	–
10—Digester Capture	8,366.61	0.29	7.36	0.61	5.00	0.0000	0.0007	0.0004	0.0037
11—Land Use Measures	239,052.29	140.16	1,124.38	44.38	1.21	0.0178	0.1079	0.0258	0.0009
12—Transit-Oriented New Jobs	7,598.40	4.44	12.36	3.03	0.64	0.0006	0.0012	0.0018	0.0005
13—Tree Planting	3,291.11	0.11	2.17	0.18	1.07	0.0000	0.0002	0.0001	0.0008
Total	*2,052,342.79*	*487.91*	*4,923.76*	*445.47*	*1,801.96*	*0.0621*	*0.4725*	*0.2590*	*1.3250*

Tables 4-2 (a-e) show the top five SF CAP measures contributing to annual reductions of GHG and the criteria pollutant direct/precursor emissions (ROG, NO_x, PM2.5, and SO_2). The *Renewable Energy Goal* measure is the top contributor to emissions reductions for GHG, NOx, PM2.5, and SO_2. Other "top" measures for these emissions categories include, but are not limited to, *Energy Efficiency Legislation Support*, *RECO Update*, *Land Use Measures*, and *Community Transportation Demand Management*.

Table 4-2a. Five SF CAP Measures Resulting in the Greatest GHG Reductions

Measure Name	Absolute Reduction ($MTCO_2$, equivalent/yr)	Percent Reduction of Total GHG Reduction
Renewable Energy Goal	610, 525	30%
Achieve Zero Waste	544,533	27%
Land Use	239,052	12%
Community Transportation Demand Management	226,677	11%
Energy Efficiency Legislation Support	194,513	10%
Total of 5 Measures Listed Above	*1,815,300*	*89%*

Table 4-2b. Five SF CAP Measures Resulting in the Greatest ROG Reductions

Measure Name	Absolute Reduction (tons/yr)	Percent Reduction of Total ROG Reduction
Land Use	25.58	29%
Community Transportation Demand Management	20.36	23%
Renewable Energy Goal	14.43	16%
Energy Efficiency Legislation Support	8.75	10%
Electric Vehicle Infrastructure	8.14	9%
Total of 5 Measures Listed Above	*77.27*	*87%*

Table 4-2c. Five SF CAP Measures Resulting in the Greatest NO_x Reductions

Measure Name	Absolute Reduction (tons/yr)	Percent Reduction of Total NO_x Reduction
Renewable Energy Goal	367.7	41%
Land Use	205.20	23%
Energy Efficiency Legislation Support	145.98	16%
RECO Update	72.60	8%
Community Transportation Demand Management	56.66	6%
Total of 5 Measures Listed Above	*848.11*	*95%*

Table 4-2d. Five SF CAP Measures Resulting in the Greatest Direct PM2.5 Reductions

Measure Name	Absolute Reduction (tons/yr)	Percent Reduction of Total Direct PM2.5 Reduction
Renewable Energy Goal	30.42	38%
Community Transportation Demand Management	13.87	17%
Energy Efficiency Legislation Support	11.96	15%
Land Use Measures	8.1	10%
RECO Update	5.92	7%
Total of 5 Measures Listed Above	*70.27*	*87%*

Table 4-2e. Five SF CAP Measures Resulting in the Greatest SO_2 Reductions

Measure Name	Absolute Reduction (tons/yr)	Percent Reduction of Total SO_2 Reduction
Renewable Energy Goal	249.85	76%
Energy Efficiency Legislation Support	56.45	17%
RECO Update	17.86	5%
Commercial Loan Program	6.43	2%
Community Transportation Demand Management	2.95	1%
Total of 5 Measures Listed Above	*333.54*	*101%**

*The total SO_2 percent reduction for the five SF CAP measures listed above is greater than 100% because one SF CAP measure (*Electric Vehicle Infrastructure*) increases SO_2 emissions such that the net SO_2 emissions reduction for all SF CAP measures is less than the total reduction for these five measures.

The criteria pollutant direct/precursor emissions reductions associated with the SF CAP measures can be viewed in the context of reductions from similar measures developed by the State of California for its *Climate Change Scoping Plan: A Framework for Change* (*Scoping Plan*) (California Air Resources Board 2008), which was required by Assembly Bill (AB) 32 (California Global Warming Solutions Act), signed in 2006. As shown in Table 4-3, the emission reductions from the SF CAP measures (as summed by sector) represent a small but measurable fraction of the total reductions from similar state measures included in the *Scoping Plan*. The state measures in Table 4-3 are shown with their criteria pollutant reductions for the state as a whole.

Table 4-3. Criteria Pollutant Precursor Emission Reductions by SF CAP Sector and for Similar State Measures

	Criteria Pollutant Precursor Emissions Reductions (tons per day)			
Sector	ROG	NO_x	PM2.5	SO_2
Transportation				
Community Transportation Demand Management (SF CAP)	0.07	0.19	0.05	0.01
Emission Reductions from State Measure T-1 Regional Transportation-Related GHG Targets (Scoping Plan)	–	8.7	1.4	–
Electric Transportation				
Electric Transportation (SF CAP)	0.02	0.04	0.01	-0.02
Emission Reductions from State Measure T-4 Vehicle Efficiency Measures (Scoping Plan)	–	0.2	0.8	–
Energy Efficiency				
Energy Efficiency (SF CAP)	0.04	0.65	0.05	0.22
Emission Reductions from State Measure E-1 Energy Efficiency (Electricity) (Scoping Plan)	1	7	4	0.6
Renewable Energy				
Renewable Energy (SF CAP)	0.04	1.01	0.08	0.68
Emission Reductions from State Measure E-3 Renewable Portfolio Standard (Scoping Plan)	1.4	9.8	5.6	0.8
Land Use				
Land Use (SF CAP)	0.07	0.57	0.02	0.00
Emission Reductions from State Measure T-1 Regional Transportation-Related GHG Targets (Scoping Plan)	–	8.7	1.4	–

In addition to reducing criteria pollutant precursor emissions, the SF CAP measures will reduce ambient concentrations of total PM2.5, as shown in Table 4-4. The health valuation is based on avoided health effects from incremental improvements in air quality. Total PM2.5 is considered to be the sum of direct carbon PM2.5, ammonium nitrate, and ammonium sulfate, as defined in MPEM and listed in Table 4-4. Total PM2.5 reductions are comprised primarily from reductions in direct carbon PM2.5 (64.7%), with ammonium sulfate and ammonium nitrate contributing 21.9% and 13.4%, respectively (Figure 4-1). Other areas may have different contributions from direct carbon PM2.5, ammonium nitrate, and ammonium sulfate which may influence reduction strategies.

Total PM2.5 concentration reductions in Table 4-4 are expressed in terms of ng/m^3 and reflect reductions (i.e., a negative change in concentration). Note that typical ambient concentrations are expressed in micrograms per cubic meter. Reductions in total PM2.5 concentrations (Table 4-4 and Figure 4-2) result in corresponding reductions in the ambient exposure to PM2.5. These reductions in pollutant exposure are expected to generate monetary savings through improvements in public health, as demonstrated by the values presented for the total PM2.5 health valuation.

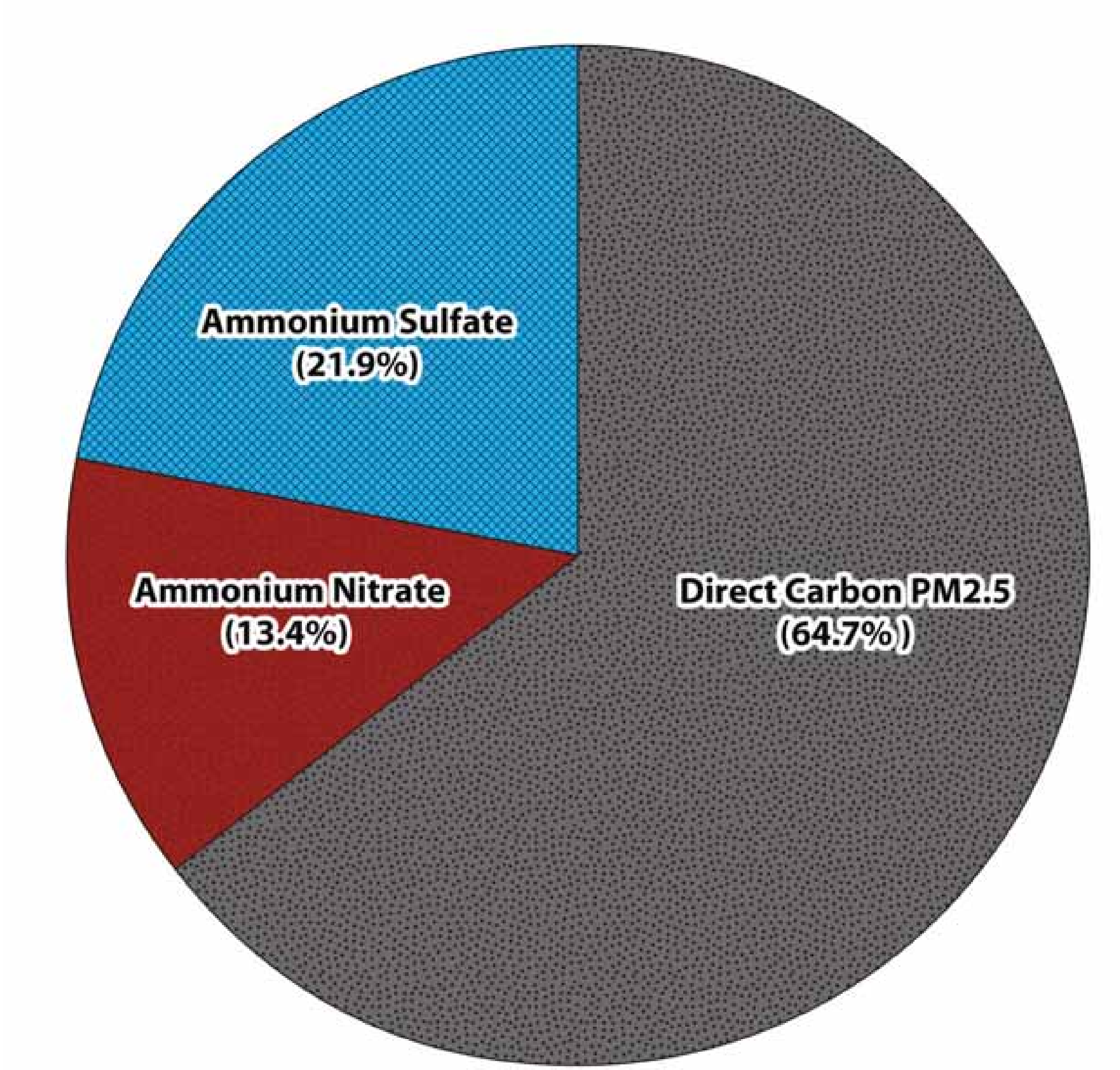


Figure 4-1. Composition of Total PM2.5

Table 4-4. Reductions in PM2.5 Annual Ambient Concentrations by SF CAP Measure

Measure	PM2.5—Direct Carbon (ng/m^3)	Ammonium Nitrate (ng/m^3)	Ammonium Sulfate (ng/m^3)	PM2.5—Total (ng/m^3)	Health Valuation from PM2.5 Exposure Change (dollars saved)
Community Transportation Demand Management					
1a—Workplace TDM	0.505	0.043	0.009	0.557	$1,635,676
1b—Community TDM	2.157	0.184	0.038	2.379	$6,988,054
2—Ridesharing	0.042	0.004	0.001	0.047	$136,991
Electric Transportation					
3—Electric Vehicle Infrastructure	0.814	0.047	-0.098	0.763	$2,242,778
Energy Efficiency					
4—RECO Update	0.920	0.208	0.233	1.361	$4,001,869
5a—Residential Loan Program	0.019	0.004	0.005	0.028	$82,767
5b—Commercial Loan Program	0.212	0.047	0.084	0.343	$1,007,425
6—Energy Efficiency Legislation Support	1.859	0.417	0.736	3.012	$8,847,643
7—Energy Efficiency Services	0.015	0.003	0.003	0.022	$64,949
Renewable Energy					
8—Renewable Energy Goal	4.731	1.042	3.256	9.029	$26,486,107
Zero Waste					
9—Achieve Zero Waste	–	–	–	–	–
10—Digester Capture	0.017	0.004	0.012	0.033	$96,834
Land Use					
11—Land Use Measures	1.260	0.604	0.003	1.867	$5,511,654
12—Transit-Oriented New Jobs	0.086	0.007	0.002	0.095	$278,534
13—Tree Planting	0.005	0.001	0.003	0.009	$25,781
Sum (all measures implemented simultaneously)	*12.64*	*2.62*	*4.29*	*19.54*	*$57,407,061*

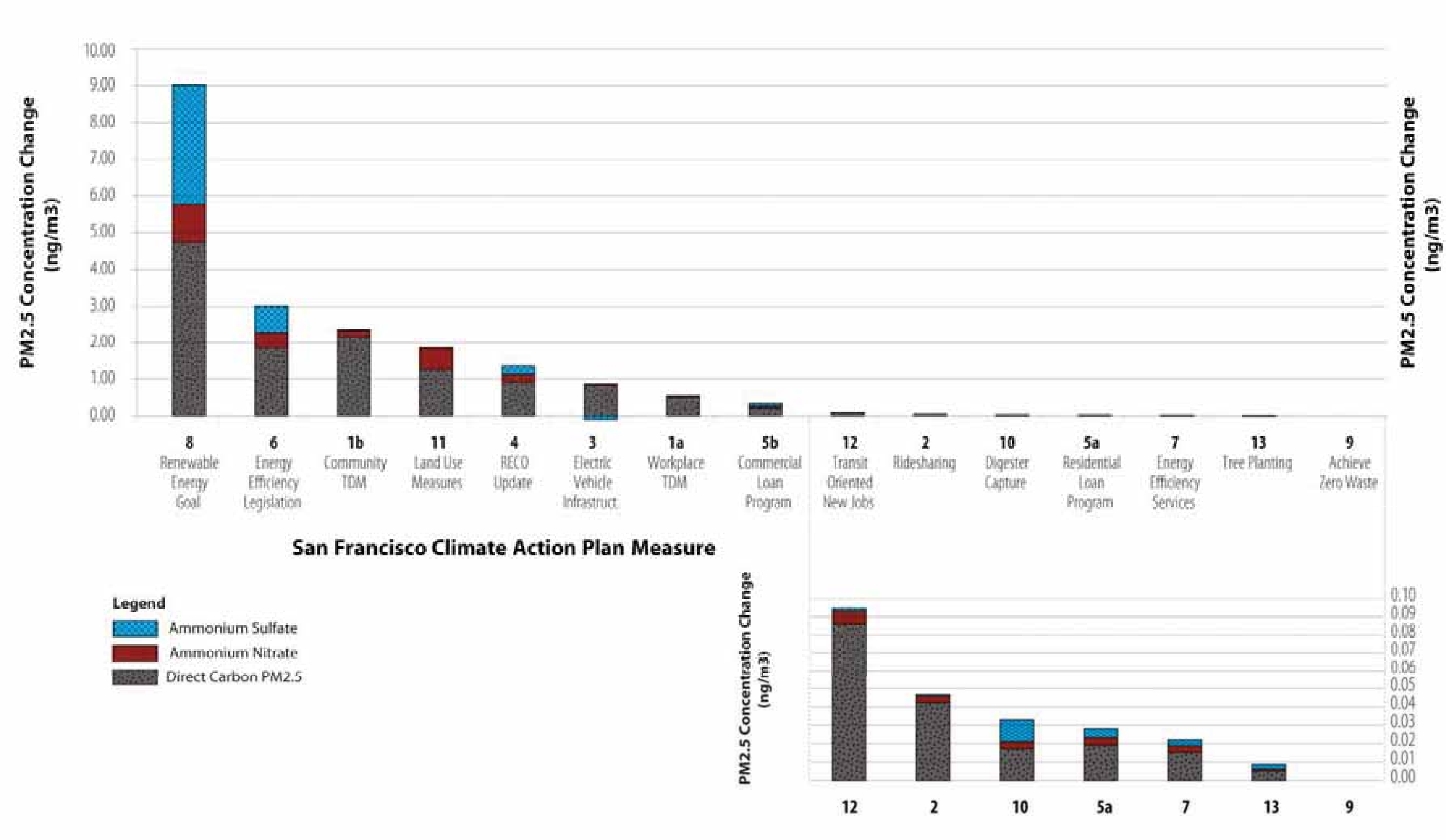


Figure 4-2. Annual Ambient Concentration Reduction in PM2.5 for each SF CAP Measure

Although all of the measures (except *Achieve Zero Waste*, which was not evaluated) will reduce NO_x emissions, the SF CAP would result in a slight increase in ozone concentrations. Table 4-5 lists the SF CAP measures in order of increase in ozone concentration. Note that concentration changes in Table 4-5 are given in units of parts per trillion while typical ambient concentrations are usually listed in parts per billion. As described in Chapter 2, because of the dynamics of ozone formation in the Bay Area, strategies to reduce NO_x levels are effective only under certain chemical conditions or in certain locations. This increase in ozone concentrations is anticipated to result in relatively small monetary losses (i.e., negative health valuation) through the resulting adverse effects on public health compared to benefits from reductions of other pollutants. Table 4-5 demonstrates that these ozone increases are small compared to the total ozone concentrations in the Bay Area. In addition, as discussed below, the negative health valuation associated with the ozone increase for each measure is outweighed by the positive health benefits for GHGs and PM2.5.

Table 4-5. Increases in Ozone Concentration by SF CAP Measure, Percent of Bay Area Ozone Concentration, and Health Valuation from Ozone Exposure

Measure	Ambient Concentration Increase (parts per trillion)	Percent of 2005 Bay Area Ozone Concentrations	Health Valuation from Ozone Exposure Change (dollars)
8—Renewable Energy Goal	1.596	0.00646	-$378,720
11—Land Use Measures	0.802	0.00325	-$189,651
6—Energy Efficiency Legislation Support	0.621	0.00251	-$147,307
4—RECO Update	0.306	0.00124	-$72,537
1b—Community TDM	0.154	0.00062	-$35,942
5b—Commercial Loan Program	0.071	0.00029	-$16,770
1a—Workplace TDM	0.036	0.00015	-$8,411
3—Electric Vehicle Infrastructure	0.014	0.00006	-$2,979
5a—Residential Loan Program	0.006	0.00003	-$1,503
12—Transit Oriented New Jobs	0.006	0.00002	-$1,431
10—Digester Capture	0.006	0.00002	-$1,382
7—Energy Efficiency Services	0.005	0.00002	-$1,201
2—Ridesharing	0.003	0.00001	-$703
13—Tree Planting	0.002	0.00001	-$402
9—Achieve Zero Waste	–	–	–
Total	*3.627*	*0.01468*	*-$858,939*

Monetary Co-Benefits

The results of this study indicate that all SF CAP measures would result in significant economic benefits by reducing GHG emissions and PM2.5 concentrations. Table 4-6 and Figure 4-3 show the total monetary benefit for each SF CAP measure, and Figure 4-4 shows the total monetary benefit with respect to ozone, PM2.5, and GHGs. The total monetary benefit for each measure is defined as the sum of the MPEM outputs for the health effects valuation (for both PM2.5 and ozone) plus the MPEM output for GHG economic benefit resulting from the GHG emissions reductions (as estimated under the prior study for the City). The air quality monetary benefit, also shown in Table 4-6, is the sum of the monetary benefit for both PM2.5 and ozone. Although the ozone benefit is negative for all measures, the total monetary benefit for all measures is positive because the PM2.5 and GHG benefits greatly outweigh the ozone dis-benefit. The monetary benefit, as defined in this study, does not account for the cost of implementing the measures. The air quality benefit per ton of GHG reduced is also provided to demonstrate the relative air quality benefits of each SF CAP measure. For example, the *Residential Loan Program* measure would achieve an air quality monetary benefit per ton of GHG reduced of \$42.56/MTCO$_2$e. This means that \$42.56 in reduced health costs are saved for every ton of GHG emissions reduced.

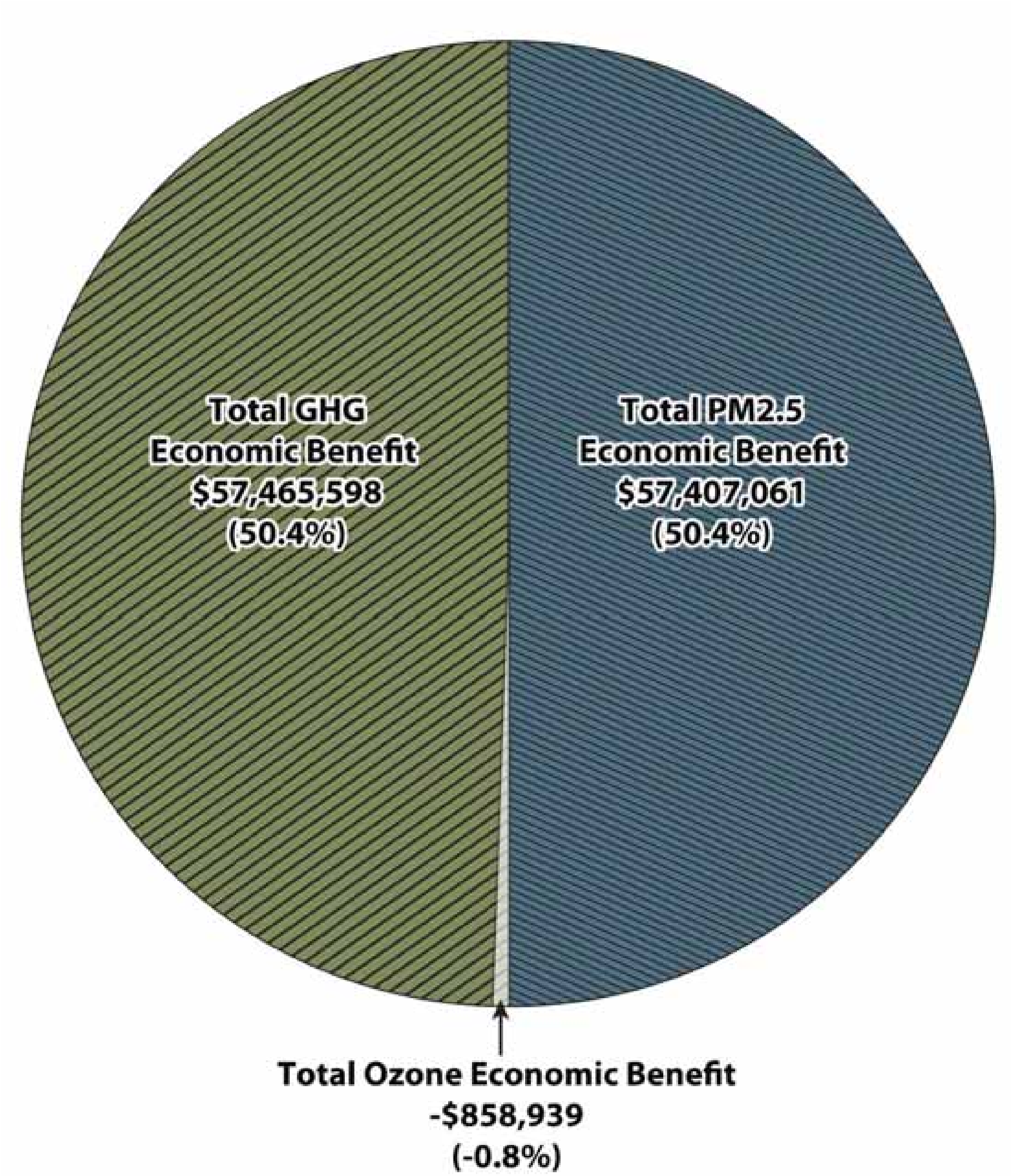


Figure 4-3. Total Monetary Benefit of the SF CAP Measures

Among the SF CAP measures, *Renewable Energy Goal* would achieve the highest total monetary benefit—almost $28 million more than the next-highest measure. *Achieve Zero Waste*, *Energy Efficiency Legislation Support*, *Community TDM*, and *Land Use Measures* would also have sizable benefits ($12 million–$15 million each). The lowest total benefits would result from *Ridesharing*, *Residential Loan Program*, *Tree Planting*, and *Energy Efficiency Services* (less than $300,000 each). Total benefits are generally correlated with the mass of emissions reduced. Accordingly, examining total benefits alone will not reveal the efficiency of different measures in air quality benefits relative to the amount of GHG emissions reduced. Further, each jurisdiction will have specific priorities to consider. Therefore, Table 4-6 provides an additional metric to consider: air quality benefits per ton of GHG efficiency to indicate the relative efficiency of net criteria pollutant reductions.

The City has established an aggressive goal for renewable energy (100% by 2030) that might not be appropriate in other areas of California or the United States. To evaluate the total monetary benefits associated with a renewable energy goal that may be more realistic for other jurisdictions, a sensitivity analysis was performed to determine the monetary benefits for *Renewable Energy Goal* at 75%, 50%, and 25% measure effectiveness. Figure 4-5 displays the results of this analysis. *Renewable Energy Goal* maintains the highest monetary benefit of all the SF CAP measures at 75% and 50% effectiveness, but it is surpassed by *Achieve Zero Waste* and three others at 25% effectiveness.

Table 4-7 ranks the SF CAP measures by each measure's air quality benefit per ton of GHG reduced. *Electric Vehicle Infrastructure* achieves the highest benefit, followed by *Energy Efficiency Legislation Support*, *Commercial Loan Program*, and *Renewable Energy Goal*. Using this metric, the lowest-ranked measure for which criteria pollutant benefits were determined is *Tree Planting*.

EPA's *Assessing the Multiple Benefits of Clean Energy* (2010) provides examples of similar benefits achieved by renewable energy programs throughout the United States. Several jurisdictions across the country have developed renewable energy infrastructure and quantified the associated benefits, including the resulting energy savings and economic and air quality improvements. For example, EPA's 2010 study states that the Texas Emissions Reduction Plan, which couples renewable energy goals with energy efficiency initiatives, will reduce statewide NO_x emissions by 1% (compared to 2005 levels) in 2012.

Table 4-6. GHG and Air Quality Monetary Benefit by SF CAP Sector and Measure

Measure	GHG Reductions ($MTCO_2e$ per year)	GHG Monetary Benefit	Air Quality Monetary Benefit (PM2.5 and Ozone)	Total Monetary Benefit	Air Quality Benefit per ton GHG Reduced ($/$MTCO_2e$)*
Community Transportation Demand Management	–	*$7,956,338*	*$8,715,665*	*$16,672,003*	*$30.67*
1a—Workplace TDM	53,046.63	$1,485,306	$1,627,265	$3,112,571	$30.68
1b—Community TDM	226,677.17	$6,346,961	$6,952,111	$13,299,072	$30.67
2—Ridesharing	4,431.14	$124,072	$136,288	$260,360	$30.76
Electric Transportation	–	*$1,190,317*	*$2,239,799*	*$3,430,117*	*$52.69*
3—Electric Vehicle Infrastructure	42,511.34	$1,190,317	$2,239,799	$3,430,117	$52.69
Energy Efficiency	–	*$8,744,683*	*$13,765,334*	*$22,510,017*	*$44.08*
4—RECO Update	92,225.86	$2,582,324	$3,929,332	$6,511,656	$42.61
5a—Residential Loan Program	1,909.59	$53,468	$81,263	$134,732	$42.56
5b—Commercial Loan Program	22,150.96	$620,227	$990,655	$1,610,882	$44.72
6—Energy Efficiency Legislation Support	194,513.13	$5,446,368	$8,700,335	$14,146,703	$44.73
7—Energy Efficiency Services	1,510.58	$42,296	$63,748	$106,044	$42.20
Renewable Energy	–	*$17,094,695*	*$26,107,386*	*$43,202,081*	*$42.76*
8—Renewable Energy Goal	610,524.81	$17,094,695	$26,107,386	$43,202,081	$42.76
Zero Waste	–	*$15,481,194*	*$95,452*	*$15,576,647*	*N/A***
9—Achieve Zero Waste	544,533.19	$15,246,929	N/A**	$15,246,929	N/A**
10—Digester Capture	8,366.61	$234,265	$95,452	$329,717	$11.41
Land Use	–	*$6,998,370*	*$5,624,485*	*$12,622,855*	*$22.50*
11—Land Use Measures	239,052.29	$6,693,464	$5,322,002	$12,015,466	$22.26
12—Transit Oriented New Jobs	7,598.40	$212,755	$277,103	$489,858	$36.47
13—Tree Planting	3,291.11	$92,151	$25,379	$117,530	$7.71

*An average value is provided for each sector.

**Criteria pollutant benefits were not calculated for *Achieve Zero Waste*. Accordingly, the total monetary benefit for this measure is equivalent to the GHG monetary benefit.

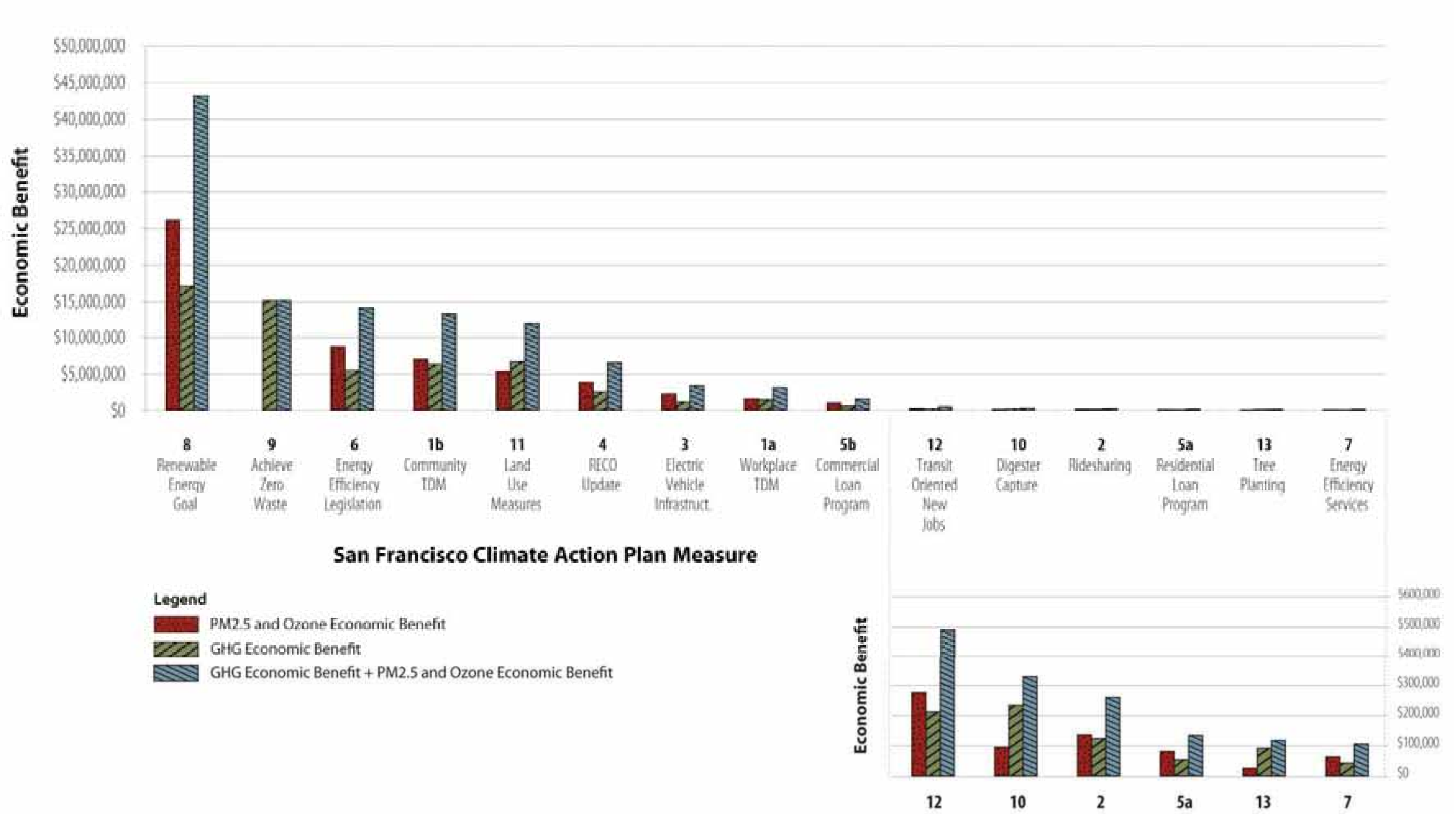


Figure 4-4. Total Monetary Benefit of the SF CAP Measures by Ozone, PM2.5, and GHG

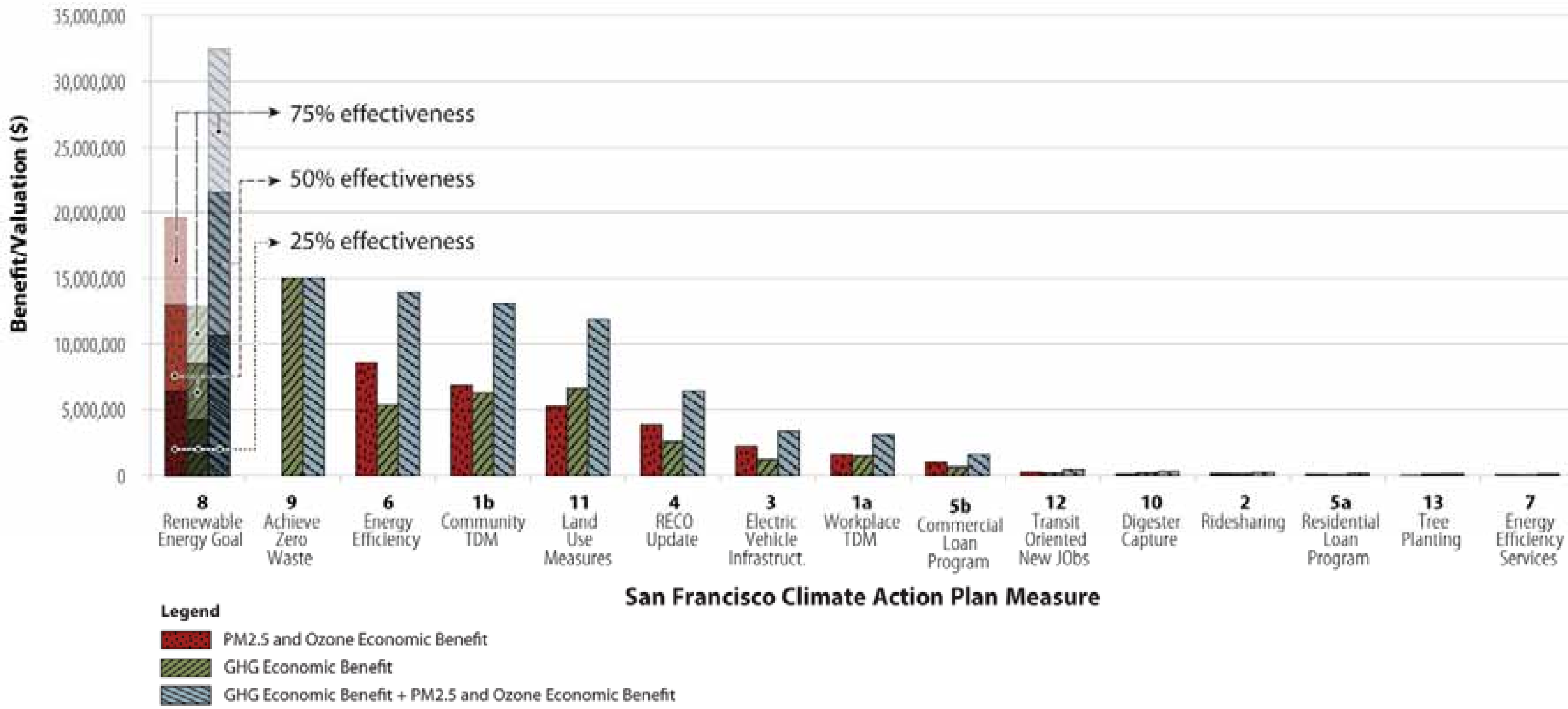


Figure 4-5. Sensitivity Analysis of the Monetary Benefit for Renewable Energy Goal

Table 4-7. SF CAP Measure Ranking by Air Quality Benefit per Ton of GHG Reduced

Measure	Air Quality Benefit per Ton of GHG Reduced ($/MT$CO_2$e)	Rank
3—Electric Vehicle Infrastructure	$52.69	1
6—Energy Efficiency Legislation	$44.73	2
5b—Commercial Loan Program	$44.72	3
8—Renewable Energy Goal	$42.76	4
4—RECO Update	$42.61	5
5a—Residential Loan Program	$42.56	6
7—Energy Efficiency Services	$42.20	7
12—Transit Oriented New Jobs	$36.47	8
2—Ridesharing	$30.76	9
1a—Workplace TDM	$30.68	10
1b—Community TDM	$30.67	11
11—Land Use Measures	$22.26	12
10—Digester Capture	$11.41	13
13—Tree Planting	$7.71	14
9—Achieve Zero Waste	–	–

Chapter 5

Other Societal Benefits of the SF CAP Measures

Chapter 5
Other Societal Benefits of the SF CAP Measures

This chapter provides a qualitative assessment of other potential societal benefits that may result from implementation of the SF CAP measures. This assessment aims to provide a broad perspective on the relative benefit of each measure, beyond the quantitative benefits discussed in Chapter 4 (e.g., air quality benefit per ton of GHG reduced, etc.). This chapter also includes a general assessment of potential costs of implementation for each measure (based on relevant literature values), and discusses how the "overall" benefits of a measure may be considered in a decision-making or planning context.

Qualitative Assessment of Other Societal Benefits

A limited number of benefits are included in this qualitative assessment for illustrative purposes: implementation feasibility, geographic location of criteria pollutant emission reductions, timing of implementation or reductions, equity impact, aesthetic impact, replicability, and climate adaptation[3]. These benefits are defined below. Also provided for each benefit is a list of each SF CAP measure presumed to result the benefit. SF CAP measures were categorized according to results published for other communities for similar measures or based on an assessment of potential outcomes for San Francisco. Accordingly, implementation of these measures in San Francisco may yield different benefits or outcomes for each measure than predicted in this assessment.

Implementation feasibility

Refers to the ease or probability of putting a measure into effect through a plan or action. Two of the three standards below are required to ensure "feasibility" (for this criterion):

- A level of technical complexity that is not overwhelmingly burdensome
- Societal or political support
- Minimal coordination burden
- *SF CAP Measures Resulting in Benefit:* Workplace TDM, Community TDM, RECO Update, Energy Efficiency Legislation Support, Energy Efficiency Services, Digester Capture, and Tree Planting.

Geographic location of criteria pollutant emission reductions

Measures that provide emission reductions that are expected to occur in the Bay Area are prioritized over those for which emission reductions would primarily occur outside the Bay Area. As noted above, the quantitative analysis of criteria pollutant reductions did not account for any reductions that would occur outside the Bay Area.

[3] This set of benefits was chosen for illustrative purposes. However, additional benefits could also be considered, such as improved water quality, reduced criteria pollutant or GHG lifecycle emissions, and mitigation of summer-time urban heat island effect.

- *SF CAP Measures Resulting in Benefit:* Workplace TDM, Community TDM, Ridesharing, Electric Vehicle Infrastructure, Digester Capture, Land Use Measures, Transit Oriented New Jobs, and Tree Planting.

Timing of implementation or reductions

Anticipated timing of putting the measure into effect and achieving actual GHG reductions is relatively short.

- *SF CAP Measures Resulting in Benefit:* Ridesharing, RECO Update, Residential Loan Program, Commercial Loan Program, Energy Efficiency Legislation Support, Energy Efficiency Services, and Digester Capture.

Equity impact

A positive equity impact indicates improved socioeconomic status or improved protection from environmental hazards for individuals, groups, or communities, particularly for vulnerable populations.

- *SF CAP Measures Resulting in Benefit:* Workplace TDM, Ridesharing, Residential Loan Program, Land Use Measures, Transit Oriented New Jobs, and Tree Planting.

Aesthetic impact

Measure is expected to result in a more beautiful environment, including elements such as more trees or a cleaner area.

- *SF CAP Measures Resulting in Benefit:* Workplace TDM, Community TDM, Ridesharing, Electric Vehicle Infrastructure, Achieve Zero Waste, Land Use Measures, and Tree Planting.

Replicability

Some GHG measures will be specific to a region, whereas other measures are more general and can be applied to a variety of locales. Measures that are generic in nature are considered “replicable,” whereas measures that have elements that are very specific to San Francisco are not considered replicable.

- *SF CAP Measures Resulting in Benefit:* Workplace TDM, Community TDM, Ridesharing, Electric Vehicle Infrastructure, Residential Loan Program, Commercial Loan Program, Energy Efficiency Legislation Support, Energy Efficiency Services, Land Use Measures, Transit Oriented New Jobs, and Tree Planting.

Climate adaptation

Supports climate adaptation strategies, or strategies that are intended to reduce the vulnerability of natural and human systems, such as by reducing energy load or by creating flood-resistant infrastructure.

- *SF CAP Measures Resulting in Benefit:* Workplace TDM, Community TDM, Ridesharing, Electric Vehicle Infrastructure, RECO Update, Residential Loan Program, Commercial Loan Program, Energy Efficiency Legislation Support, Energy Efficiency Services, Renewable Energy Goal, Land Use Measures, Transit Oriented New Jobs, and Tree Planting.

Discussion of Qualitative Societal Benefits

As discussed above, although efforts were taken to categorize the SF CAP measures according to real-world examples, because many of the SF CAP measures are new or unique to San Francisco, in practice the implementation of each SF CAP measure may provide a different set of benefits or outcomes than indicated in this assessment. Further, although each benefit included in this assessment is considered distinct, in practice there may be considerable overlap between some of the benefits, and potentially resulting in different real-world outcomes. For example, timing of implementation and implementation feasibility could be related, depending on the nature of the measure and specific implementation issues associated with a particular measure.

Three measures that are presumed to result in the most qualitative benefits include Tree Planting, Workplace TDM, and Ridesharing. Tree Planting is presumed to result in all qualitative benefits considered in this assessment except "timing of implementation or reductions" because the amount of GHG emissions sequestered by trees is proportional to tree growth (and not necessarily tree planting), such that GHG emission reductions may not be achieved for many years. Similarly, for Workplace TDM, GHG reductions from demand management programs are typically not realized until the programs have consistent participation, which can occur over several years. Ridesharing is presumed to achieve all benefits considered in this study except "implementation feasibility" because it may likely require gaining societal or community support through outreach and other types of programs before it can be put into effect.

Cost-effectiveness of Measure Implementation

Although this study did not include an assessment of up-front or capital costs or operational costs associated with each SF CAP measure, for illustrative purposes each measure was matched to a potential range of values associated with the cost of implementing that measure based on current literature values and ICF's experience working on climate action plans (McKinsley Global Institute 2008; San Francisco Planning and Urban Research Association 2009; City of Roseville 2009; Arizona Climate Change Advisory Group 2006; Lutsey 2008; Sonoma County 2008; U.S. Environmental Protection Agency 2000; State of Oregon 2004). The results of this correlation are presented in Table 5-1. The anticipated cost of implementation for each measure is categorized in terms of dollars per $MTCO_2e$—net savings (<$0), low-cost ($0 to $30), medium-cost (>$30 to $100), high-cost (>$100), or unknown. Measures are categorized as unknown if recent studies do not have an equivalent measure and corresponding cost. For some measures, the categorization listed above could not be applied and general descriptions are provided instead. The correlation shown in Table 5-1, although general, suggests a wide range of costs associated with the various measures. A robust analysis of the costs of implementing each measure would provide a more complete picture of the overall costs and monetary benefits of each measure.

Table 5-1. Anticipated Cost of SF CAP Measure Implementation

Measure	Anticipated Cost of Implementation*
Community Transportation Demand Management	
1a—Workplace TDM	High-cost
1b—Community TDM	High-cost
2—Ridesharing	Low-cost
Electric Transportation	
3—Electric Vehicle Infrastructure	Unknown
Energy Efficiency	
4—RECO Update	Net savings
5a—Residential Loan Program	Net savings
5b—Commercial Loan Program	Net savings
6—Energy Efficiency Legislation	Net savings
7—Energy Efficiency Services	High-cost
Renewable Energy	
8—Renewable Energy Goal	Depends on specific means and financing used to achieve this goal
Zero Waste	
9—Achieve Zero Waste	High-cost
10—Digester Capture	Requires site-specific analysis of cost factors
Land Use	
11—Land Use Measures	Depends on specific means and financing used to achieve this goal
12—Transit-Oriented New Jobs	Depends on specific means and financing used to achieve this goal
13—Tree Planting	High-cost

* Cost of implementation is presumed to include both capital costs and savings over time with measure implementation.

Assessing Overall Measure Costs and Benefits

A measure's overall benefit can be considered both quantitatively and qualitatively. Costs and savings associated with measure implementation can be utilized to examine financial feasibility. Costs and savings can be combined with the monetized co-benefits, including those analyzed in this study, to derive estimates of total monetized societal costs/benefits. Co-benefits that cannot be readily monetized are also important considerations that can be considered and weighted based on benefit priority. For some measures, there may also be environmental or social impact considerations (not discussed in this study), that should also be considered.

Decision-makers may choose to prioritize measures for further evaluation or for implementation in a climate action plan, based on the measure's overall benefit, which could be a combined consideration of monetized costs and benefits, qualitative benefits, and environmental and social impacts. Each of these benefits (or dis-benefits) may influence a jurisdiction's priority with regards to implementation of these measures, depending on how the jurisdiction or decision-makers weight each benefit.

Chapter 6

Applying This Study to Other Municipalities

Chapter 6
Applying This Study to Other Municipalities

This study demonstrates that measures to reduce GHG emissions can have multiple economic, social, and environmental benefits for the San Francisco Bay Area. Other municipalities (or air districts, planning agencies, etc.) in the U.S. can use the measure types, results, and study process to shape their own similar analyses or to develop and prioritize potential GHG reduction measures. This chapter considers how similar measures to the SF CAP measures could be applied or modified for use in other jurisdictions, by considering the scalability of the measure types and outcomes and the appropriateness of measures for other contexts. This chapter also provides recommended steps that other jurisdictions can follow to replicate this study's process.

Scalability of Measure Types

The measures analyzed in this study are based on those for consideration and inclusion in the SF CAP update. However, many of these measures can be generalized for use by other municipalities. To demonstrate, Table 5-1 lists each SF CAP measure analyzed in this study, followed by a generic description of each measure. Policymakers in other municipalities can further adapt these generic descriptions to their own jurisdictions in light of their specific political, societal, and environmental conditions. For example, *Renewable Energy Goal* may be modified to require a lower goal (i.e., 50% renewable energy). Alternatively, policymakers can add or remove measures as needed. For example, the *Digester Capture* measure may not be relevant to municipalities that do not own or operate waste collection services.

Table 6-1. Generic Descriptions of SF CAP Measures

SF CAP Measure	SF CAP Measure Description	Generic Description
1a—Workplace TDM	Develop and expand TDM programs to reduce the number of single-occupancy trips for work-related events.	Workplace TDM
1b—Community TDM	Develop and expand TDM programs to reduce the number of single-occupancy trips to transit hubs, shopping centers, and schools.	Community TDM
2—Ridesharing	Promote and expand ridesharing programs.	Promote ridesharing
3—Electric Vehicle Infrastructure	Establish sufficient public and residential EV charging to support a 10% EV market (new car sales) by 2015. In new residential construction, require EV charging infrastructure and ensure access to charging for residents of existing multifamily buildings.	Promote electric vehicles and infrastructure
4—RECO Update	Update the RECO.	Residential energy efficiency for existing homes
5a—Residential Loan Program	Create a loan program to finance comprehensive residential energy efficiency services.	Energy efficiency retrofit loans
5b—Commercial Loan	Create a loan program to finance comprehensive	Energy efficiency retrofit

SF CAP Measure	SF CAP Measure Description	Generic Description
Program	commercial energy efficiency services.	loans
6—Energy Efficiency Legislation Support	Support the implementation of legislation requiring energy benchmarking and energy efficiency audits for commercial buildings.	Support energy efficiency legislation
7—Energy Efficiency Services	Expand energy efficiency rebates and installation services.	Energy efficiency rebates and incentives
8—Renewable Energy Goal	100% renewable electricity by 2030.	Promote renewable energy
9—Achieve Zero Waste	Decrease disposal through recycling and composting by 9% (about 44,000 tons) annually to achieve zero waste by 2020.	Increase diversion
10—Digester Capture	Work with EBMUD to capture 120 tons per day of food waste for use in energy-producing digesters.	Anaerobic digestion of food waste
11—Land Use Measures	Improve building efficiency standards and increase transit, bicycle, and pedestrian level of service.	Develop bicycle, pedestrian, and transit-friendly community
12—Transit Oriented New Jobs	Increase the number of jobs accessible by high-capacity transit.	Transit-oriented job creation
13—Tree Planting	Plant an additional 10,000 trees.	Promote tree planting

Scalability of Measure Results

The GHG and criteria pollutant emission reductions and benefits identified for each SF CAP measure provide information on the types of air quality benefits that can be achieved through similar measures in other municipalities. It is important to note that the measure goals and penetration rates are specific to San Francisco and its specific political, geographic, and societal factors and built environment. For example, *Renewable Energy Goal* assumes 100% renewable energy, which may not be feasible or desirable in other jurisdictions. The sensitivity analysis performed for that measure (which looked at 75%, 50%, and 25% effectiveness) demonstrates that changing the effectiveness of this measure will affect the magnitude of emission reductions, benefits relative to the other measures (Figure 4-5). Further, the criteria pollutant changes shown in Tables 4-3 and 4-4 were quantified using models calibrated to Bay Area meteorology and climatology (see Chapter 3 for additional information on MPEM). Therefore, the results of this study (i.e., the absolute emission and criteria pollutant concentration changes) should be viewed in relative terms when extrapolated to another municipality. Any analysis of local GHG reduction measures must consider local factors in determining GHG reduction effectiveness and local context, as effectiveness and feasibility can vary considerably for different cities and counties across the U.S.

As stated, the results of this study can provide other with municipalities a sense of the magnitude of potential benefits of GHG measures, but the results should not be used to support climate action plan implementation or other policy decisions without additional jurisdiction-specific analysis. Despite this limitation, the SF CAP measures and results could be scaled to establish an initial rough estimation of the potential emissions benefits of the measures to be included in a climate action plan. For example, *Residential Loan Program* targets 2,000 homes in San Francisco. If another jurisdiction chose to target 1,000 homes, this measure's emission reduction effectiveness could be roughly presumed to be reduced by 50%. Other measures could be scaled accordingly, based on the original consumption value of the measure (e.g., kilowatt hours, waste tonnage, population, housing). However, photochemical modeling assumptions unique to the Bay Area limit the ability to apply such an approach to criteria pollutant concentrations and economic benefits.

Scalability of Process

A detailed step-by-step narrative discussing the major steps for performing a co-benefit assessment, based on the process developed for this study, is provided below. Other municipalities can use this process when conducting their own analyses. Following that narrative, Table 5-2 lists the typical agencies responsible for each task and the participants in this study for comparative purposes. It also summarizes resources that may facilitate completion of each step.

1. **Identify feasible GHG reduction measures:** This study considers 13 SF CAP measures that can be considered and/or modified for use in other municipalities. In many cases, municipalities may already be pursuing other types of measures that could be included as feasible GHG reduction measures. Other resources for GHG reduction measures include the California Air Pollution Control Officers Association's (CAPCOA's) *Quantifying Greenhouse Gas Mitigation Measures* (2010) and climate action plans prepared by other local jurisdictions in the United States. In addition, EPA provides numerous resources for state and local governments with regard to climate policy development through its State and Local Climate and Energy Program (see in particular http://www.epa.gov/statelocalclimate/resources/strategy-guides.html). Candidate GHG reduction measures should be selected by taking into account feasibility concerns (i.e., technical and logistical feasibility, as well as community acceptance) and other priorities specific to the municipality.
2. **Consider local air quality and health control programs:** Although the GHG and criteria pollutant impacts of climate action plan measures will likely be evaluated at a regional scale, as in this study, many air quality and public health programs target at-risk populations at jurisdiction or sub-jurisdiction levels. A survey of existing air quality and public health programs aimed at these populations in the jurisdiction, in coordination with jurisdiction officials or local public health agencies may help to refine the list of feasible GHG reductions measures or may be useful for measure prioritization in subsequent steps.
3. **Analyze cost to implement feasible GHG reduction measures:** Costs and savings associated with implementation of each measure should be identified. These costs/savings can be general metrics (i.e., high/medium/low costs or savings) based on appropriate literature values, as available, or more specific cost/savings estimates based on analysis of local data and programs.Measures may be prioritized or excluded based on this analysis. Up-front or lifetime costs of each measure can also be developed and included in the prioritization process. Alternatively costs/savings can be considered on a qualitative basis in this early phase of measure selection with more detailed cost estimation for a smaller set of measures that are most promising in later parts of the climate action planning process.
4. **Select measures for additional analysis:** The measures identified in Step 1 may include several whose benefits cannot be quantified because of limitations in data availability, technical modeling guidance, or funding. Policymakers should seek feedback from stakeholders to determine which measures can be feasibly evaluated for GHG and criteria pollutant reductions

given the existing analysis constraints. Cities may also request that EPA sponsor working groups or collaborative discussions to facilitate this process. A qualitative prioritization process of major criteria (e.g., potential for GHG or criteria pollutant reductions, implementation feasibility, timing of implementation, etc.) may be undertaken, based on existing literature and similar efforts, to determine which measures should be evaluated in subsequent steps. The prioritization process undertaken at the outset of this study is summarized in Appendix D. Although the SF CAP measures were ultimately selected for analysis in this study, due to stakeholder requests and other circumstances, this prioritization process provides an example of a potential process that could be utilized for local planning purposes.

5. **Quantify GHG and criteria pollutant precursor emission reductions from selected measures:** This step involves estimating the GHG and criteria pollutant precursor emission reductions achieved by each measure. A number of tools can analyze GHG reductions. Table 1-3 lists several of these tools, their general purpose, and some strengths and weaknesses. When quantifying emission reductions, municipalities are encouraged to use data specific to their jurisdiction, as opposed to national default values, because this will provide the most accurate calculations.

6. **Determine societal benefits that result from GHG and criteria pollutant precursor emission reductions:** Societal benefits achieved by each measure depend in part on the type and magnitude of emission reductions (Step 5). They include criteria pollutant reductions and an economic valuation of the health benefits associated with these reductions and GHG emission reductions. Although numerous photochemical models can evaluate criteria pollutant reductions for a specific region, few address economic benefits. In this case, EPA and state or regional entities can work with municipalities to provide broader data that may be scaled to the appropriate level. Other societal benefits should be considered and evaluated for each measure, such as timing of implementation, aesthetic impact, equity impact, climate adaptation, and other parameters of importance to the municipality. These other benefits may be evaluated on a qualitative basis, as in this study, or by establishing specific measurements to quantitatively evaluate some or all of the benefits for each measure with local jurisdiction weighting of the relative importance of different benefits.

7. **Determine net social costs or benefits:** The economic valuation of the health benefits associated with each measure (Step 6) should be combined with the cost of implementing each measure (from Step 2 if done in early planning) on a total and per-ton (of GHG reduced) basis to identify *net* societal costs/benefits and net societal costs/benefits per ton (of GHG reduced). These net social costs (or benefits) represent an estimate the overall economic impact of each GHG measure.

8. **Prioritize measures for implementation:** Implementation of GHG reduction measures can be a detailed, and resource-intensive process. To help municipalities prioritize the measures for implementation, the quantitative outcomes of Steps 6 and 7 and the qualitative criteria selected in Step 4 can be used to rank measures. The outcomes of Steps 4, 6 and 7 may be weighted by their relative importance to emphasize certain outcomes in the ranking (e.g., social cost/benefit or short-term and long-term societal benefit), as appropriate to the municipality.

Table 6-2. Responsible Agencies and Resources in Developing a Co-Benefits Analysis

	Responsible Agency		
Step	Typical	EPA Region 9 Study	Resources and Tools
1. Identify feasible GHG reduction measures	• City government • City consultant • Relevant stakeholders	• City and County of San Francisco • EPA consultant (ICF)	• Existing programs (city, regional, state, or national) • Climate action plans prepared by other jurisdictions • EPA State and Local Climate and Energy Program website (http://www.epa.gov/statelocalclimate/) • *Quantifying Greenhouse Gas Mitigation Measures* (CAPCOA 2010)
2. Consider local air quality and health control measures	• City government • Local public health agencies • Relevant stakeholders	• Not applicable	• Existing programs (city, regional, state, or national) • Stakeholder feedback • Environmental analysis guidelines
3. Analyze cost to implement feasible GHG reduction measures	• City government • City consultant • Relevant stakeholders	• Not applicable	• Existing programs (i.e., city, regional, state, or national) • Publicly available data and other resources • Climate action plans prepared by other jurisdictions • EPA State and Local Climate and Energy Program website • CAPPA
4. Select measures for additional analysis	• City government • City consultant • Relevant stakeholders	• EPA Region 9 • EPA consultant (ICF)	• Stakeholder feedback • EPA working groups
5. Quantify GHG and criteria pollutant precursor emission reductions from selected measures	• City government • City consultant • Local air district or state air quality agency	• EPA consultant (ICF) • BAAQMD	• CAPPA • WARM • CTCC • *Transportation Emissions Guidebook* • CalEEMod • Other emission tools listed in Table 1-3

Step	Responsible Agency: Typical	Responsible Agency: EPA Region 9 Study	Resources and Tools
6. Determine societal benefits that result from GHG and air criteria pollutant precursor emission reductions	• City government • City consultant • Local air district or state air quality agency	• EPA consultant (ICF) • BAAQMD	• EPA dispersion, photochemical, and receptor modeling tools and other tools listed in Table 1-3
7. Determine net social costs or benefits	• City government • City consultant • Local air district or state air quality agency	• Not applicable	• Cost estimates from Step 2 • Health valuation outcome from Step 5
8. Prioritize measures for implementation	• City government • City consultant	• Not applicable	• Stakeholder feedback • EPA State and Local Climate and Energy Program website

Chapter 7

Conclusions and Recommendations for Further Study

Chapter 7
Conclusions and Recommendations for Further Study

The objectives of this study were two-fold: (1) to serve as a "proof of concept" for quantifying local air quality co-benefits from local GHG reduction measures; and (2) to provide decision-support tools/information for San Francisco agencies working on climate change and/or air quality. This study leverages a partnership established by EPA Region 9 with the local entities and stakeholders in the Bay Area to maximize the use of local data and tools. The major conclusions/outcomes of this study include the following:

1. Proof of Concept: Quantifying the air quality co-benefits of GHG reduction measures (or vice versa) is feasible using a local photochemical model (such as MPEM). A partnership between a local government agency working on climate policy with a state or local air quality management agency would, in many cases, bring together the expertise needed for the co-benefits analyses.
2. Proof of Concept: MPEM provides an example of improved decision-support for local policy-makers, since it can estimate integrated air quality benefits associated with criteria, GHG, and other pollutants;
3. Local decision-support: The overall monetary benefits estimated by MPEM for the SF CAP measures are considerable (approximately $114 million). This large monetary benefit is due the large health valuations predicted for PM2.5 and GHG, which far outweigh the relatively small negative health valuation predicted for ozone; and
4. Local decision-support: Air quality co-benefits have been provided for a set of San Francisco GHG reduction measures from their SF CAP.

Although the tools utilized in this study are robust and comprehensive, several components of the study could be improved or expanded in subsequent or follow-up studies. These components are listed below, and include either improvement of the technical tools used in the study or expansion of the study criteria and data.

1. **Evaluate up-front costs of each GHG reduction measure.** A cost or cost-effectiveness analysis of local GHG reduction measures can identify the sectors and specific measures that would produce the greatest reductions per dollar spent and can support informed decisions about which measures to implement. ICF recommends incorporation of a quantitative cost analysis that estimates up-front capital investments (e.g., technology purchase and installation) and annual operational cost savings (i.e., those associated with reduced energy use and reduced operating and maintenance costs) over the lifetime of each measure into the study process described in Chapter 5 to prioritize measures for quantification of benefits or prioritize measures for implementation. This analysis should allow for side-by-side comparison of the cost of each measure (e.g., by comparing per-ton values for emission reductions in 2020 in annualized dollars). This approach accounts for the significant variation in the lifetime of individual GHG reduction measures (e.g., energy-efficient household appliances last 10 years, while solar panels could last 30 years) and variation in capital costs and annual cost savings. Further, this analysis should be based on data specific to the jurisdiction, region, or state, and prioritized in that order. Where such data are not available, national data or other proxies can be used. The results of the cost analysis, combined with the health valuation outputs, can be used to determine the *net* social cost of implementing each measure.

2. **Include air toxics, other criteria pollutants, diesel particulate matter, and black carbon in GHG and air quality analysis.** To more fully evaluate the impact of GHG mitigation measures on local air quality, and to compare the contribution of GHG mitigation measures to local air quality policy goals, the analysis of benefits should also address air toxics (or hazardous air pollutants), other criteria pollutants (i.e., carbon monoxide, nitrogen oxides, lead, and sulfur oxides), diesel particulate matter, and black carbon (commonly known as soot). Air toxics are pollutants known or suspected to cause cancer or other serious health effects (e.g., reproductive effects or birth defects), or adverse environmental effects. Examples include benzene, which is found in gasoline; perchloroethylene, which is emitted from some dry-cleaning facilities; and methylene chloride, which is used as a solvent and paint stripper in several industries. Many chemical models and other tools (although not MPEM) can evaluate changes in other criteria pollutants. MPEM can, however, evaluate changes in air toxics resulting from control measures. MPEM also estimates the health valuation (or economic benefit) of measures that would reduce air toxic emissions. Although black carbon can contribute to global warming, its impacts are not well-understood at this time and have not been fully confirmed by the IPCC. As such, MPEM does not include black carbon. However, technology improvements and other controls can be effective at reducing black carbon impacts on local air quality. As the scientific understanding of the role of black carbon in global warming is better defined, it should be incorporated into local climate action planning.
3. **Consider the economic value of GHG reductions.** The economic value of GHG reductions is subject to many factors, and is difficult to establish given the long timeframe and wide range of impacts associated with climate change. MPEM uses a value of $28 per $MTCO_2e$, based on a comprehensive review of studies that have been performed to estimate the cost or value of GHG emission reductions. This value reflects the social cost of carbon; BAAQMD notes in the technical appendix to the *Multi-Pollutant Evaluation Method Technical Document* (BAAQMD 2010a) that this value does not necessarily include all potential global warming–related impacts and costs. As the study of climate change evolves and predictions of its impacts are documented with more accuracy, studies reflecting the social cost of carbon may change. Future studies that account for the social cost of carbon should account for the most recent literature values.
4. **Quantify other non–air quality benefits, where feasible.** Municipalities may have multiple goals or objectives for completing a climate action plan. These may include reducing GHG emissions, improving air quality, decreasing congestion, or addressing climate adaptation. This study considers some of these other goals in a qualitative manner, but does not identify standards or metrics by which these goals can be measured. Quantitative analysis of other non–air quality benefits, where feasible, may facilitate climate action plan adoption or reassure the public that the climate action plan's impact for the community will be extensive and positive.

This study and its outcomes were possible as a result of BAAQMD's comprehensive MPEM, which was designed and developed specifically for the Bay Area, and the availability of local data associated with the SF CAP update and Bay Area photochemistry. However, many air districts or state air quality agencies rely on national models supported by EPA or other entities for regional photochemical modeling, or must rely on state or regional data to address gaps in local data. To expand the study to other jurisdictions, ongoing national initiatives, tools, or guidance should be expanded to support or replicate the goals and outcomes of this study, or refined to allow for more specific local analyses. Specifically, as part of its ongoing support for multi-pollutant analyses, EPA could use the results of this study to develop a guidebook and technical tools for photochemical or societal cost evaluation that can support local municipalities, air quality agencies, or regional planning entities in their evaluation of the multiple benefits of GHG mitigation measures.

Chapter 8

References

Chapter 8
References

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Appendices

Appendix A

Daily and Annual GHG Emission Reductions

Appendix A
Daily and Annual GHG Emission Reductions

Table A-1. Daily GHG Emissions Reductions Resulting From the SF CAP Measures.

Measure #	Measure Name	GHG Reductions ($MTCO_2e$/day)			
		CO_2	CH_4	N_2O	CO_2e
Transportation Demand Management		775.68	0.66	2.17	778.51
1a	Workplace Transportation Demand Management	144.80	0.12	0.40	145.33
1b	Community Transportation Demand Management	618.78	0.53	1.73	621.03
2	Ridesharing	12.10	0.01	0.03	12.14
Electric Transportation		116.47	0.00	0.00	116.47
3	Electric Vehicle Infrastructure	116.47	0.00	0.00	116.47
Energy Efficiency		852.83	1.18	1.63	855.64
4	RECO Update	251.89	0.39	0.39	252.67
5a	Residential Loan Program	5.22	0.01	0.01	5.23
5b	Commercial Loan Program	60.48	0.08	0.12	60.69
6	Energy Efficiency Legislation Support	531.12	0.70	1.09	532.91
7	Energy Efficiency Services	4.13	0.01	0.01	4.14
Renewable Energy		1,666.98	1.34	4.36	1,672.67
8	Renewable Energy Goal	1,666.98	1.34	4.36	1,672.67
Zero Waste		22.90	1,491.88	0.02	1,514.79
9	Achieve Zero Waste	0.00	1,491.87	0.00	1,491.87
10	Digester Capture	22.90	0.00	0.02	22.92
Land Use		684.67	0.02	0.08	684.77
11	Land Use Measures	654.93	0.00	0.00	654.94
12	Transit Oriented New Jobs	20.73	0.02	0.07	20.82
13	Tree Planting	9.01	0.00	0.00	9.02

Table A-2. Annual GHG Emissions Reductions Resulting From the SF CAP Measures.

		GHG Reductions ($MTCO_2e$/year)			
Measure #	Measure Name	CO_2	CH_4	N_2O	CO_2e
Transportation Demand Management		283,121.78	242.45	790.70	284,154.93
1a	Workplace Transportation Demand Management	52,853.76	45.26	147.61	53,046.63
1b	Community Transportation Demand Management	225,853.00	193.41	630.76	226,677.17
2	Ridesharing	4,415.03	3.78	12.33	4,431.14
Electric Transportation		42,511.34	0.00	0.00	42,511.34
3	Electric Vehicle Infrastructure	42,511.34	0.00	0.00	42,511.34
Energy Efficiency		311,284.41	431.98	593.71	312,310.11
4	RECO Update	91,940.55	141.86	143.44	92,225.86
5a	Residential Loan Program	1,903.68	2.94	2.97	1,909.59
5b	Commercial Loan Program	22,076.34	29.11	45.51	22,150.96
6	Energy Efficiency Legislation Support	193,857.83	255.66	399.64	194,513.13
7	Energy Efficiency Services	1,506.02	2.42	2.14	1,510.58
Renewable Energy		608,446.34	488.88	1,589.59	610,524.81
8	Renewable Energy Goal	608,446.34	488.88	1,589.59	610,524.81
Zero Waste		8,359.02	544,534.98	5.81	552,899.80
9	Achieve Zero Waste	0.00	544,533.19	0.00	544,533.19
10	Digester Capture	8,359.02	1.79	5.81	8,366.61
Land Use		249,938.01	8.54	28.07	249,974.62
11	Land Use Measures	239,050.45	0.21	1.63	239,052.29
12	Transit Oriented New Jobs	7,565.58	7.70	25.12	7,598.40
13	Tree Planting	3,289.17	0.63	1.31	3,291.11

Appendix B

GHG Emission Reduction Methodologies

Appendix B
GHG Emission Reduction Methodologies

The following section presents a description of each climate action and discusses the methodology that ICF used to quantify emissions reductions for each action.

Workplace Transportation Demand Management

Workplace transportation demand management (TDM) actions include those that reduce vehicle miles traveled (VMT) within the City of San Francisco, specifically for workplace commuting. VMT reductions come from City commuters driving passenger vehicles and light-duty trucks. These measures will reduce GHG emissions in the city by 53,046 metric tons carbon dioxide equivalent ($MTCO_2e$) by 2020.

The TRIMMs model was used to calculate the GHG reductions from workplace related TDM measures. This model aggregates several “soft” programs, or programs that are designed to induce travel behavior through non-monetary incentives including subsidies for alternative travel modes, Guaranteed Ride Home (GRH) and ridematching programs, and telework and flexible work schedule programs. In addition to the “soft programs”, the model also estimates the impact of a two-thirds reduction of transit trip cost. The application of these measures is translated by TRIMMS into changes in mode-share away from non-transit and high-occupancy vehicle modes.

Here we adapt the TRIMMS methodology used under a similar quantified measure for San Francisco County Transportation Authority (SFCTA) for a 2020 scenario. The previous methodology calculated a 2035 scenario for three representative areas: Downtown, Candlestick/ Hunters Point, and Eastern Neighborhoods. TRIMMS provided mode-shift percentages from drive alone, shared, transit, and non-motorized modes for 2035 for these specific areas, which were subsequently adjusted to apply to new jobs added between 2020 and 2010 city-wide. Pavley-adjusted vehicle emission factors for 2020 were also incorporated into calculations. VMT reductions were scaled only to reflect the effect of all new jobs in San Francisco, because many businesses currently provide similar commuter benefits as those in this measure.

Community Transportation Demand Management

Reductions calculated under this general measure are approximated by two representative sub-measures. The first assumes that 75% of the new adult residents added to the City between 2010 and 2020 and 50% of non-fastpass holding adult residents already living in the City in 2010 will purchase and use a monthly transit fast-pass. The fastpass will encourage residents to take transit over driving alone due to the ability of fastpass holders to take unlimited transit trips, as opposed to the constant operating costs of owning and driving a private vehicle. The second sub-measure requires car-sharing spaces to be installed in all new developments and 50% of existing developments, and excludes reductions from the existing policy for providing car-sharing spaces at Candlestick/Hunters Point. The final GHG reduction from the community TDM measure is the unweighted average reduction between the reductions from the first sub-measure only and the reductions from both the first and second sub-measures. The average reduction for the combined community transportation demand measures will reduce GHG emissions in the city by 226,677 $MTCO_2e$ by 2020.

Ridesharing Program

The existing 511.org ridesharing program seeks to reduce city-wide VMT by reducing single occupancy vehicle commutes to and from San Francisco. The program provides park-and-ride lots along with a Bay-Area wide ride-matching program, in contrast to the employer-specific ride-matching programs under the Workplace TDM measures above. Increasing participation in this program would increase VMT reductions and, subsequently, GHG emissions from reduced gasoline and diesel use. Reductions from this measure may include program users who reside outside the San Francisco city and county lines. Expanding the current user base to 7,505 users by 2015 and continuing the positive trend will reduce GHG emissions by 4,431 $MTCO_2e$ by 2020. This reduction was calculated by multiplying the additional user base by the number of VMT reduced per person, which was assumed to be 1395 VMT per user. This reduction per user was calculated from the SF-provided user numbers and estimated VMT reductions between 2007 and 2010. This VMT per user value was used to calculate the VMT reduced for the annual user base, linearly interpolated between 2010 and 2020, with the given user base goal for 2020 (7,505 users).

Electric Transportation

Electric transportation actions increase the use of electric vehicles within the city, reducing the amount of gasoline and diesel fuel consumed for transportation within the city of San Francisco. Fuel reductions come from City residents and commuters driving electric vehicles (EVs) in place of gasoline light-duty passenger vehicles, which have a higher energy and carbon intensity. These measures will reduce GHG emissions in the city by 42,511 $MTCO_2e$ by 2020.

Calculations of light duty vehicle gasoline emissions offset by the less carbon intensive electric vehicles begins with the number of expected new vehicles to be sold in San Francisco County between 2015 and 2020. New vehicle and VMT data were obtained by running an EMFAC2007 BUR (Burden) output for each year only with vehicles of that respective model year.[1] The electric vehicle sales and VMT were extracted from the EMFAC outputs using the prescribed 10% level of EV penetration into the new vehicle market in San Francisco in 2015. This number of EVs was extrapolated to 2020 using the SFCTA "proactive" and "breakout" scenarios that target a 30% and 50% new vehicle penetration rate by 2035. Gallons of gasoline equivalent for the EV sales in 2020 were estimated by dividing the EV VMT by the CAFE standard of 42.1 mpg estimated for 2020. The total gallons are translated to light duty vehicles (LDV) and EV emissions respectively, using the Low Carbon Fuel Standard Energy Economy Ratio (EER) of 3 and standard conversion factors (11,500g CO_2e/gal for gasoline, 104.21g CO_2e/MJ for EVs). The EER converts between the EV energy per mile and gasoline LDV energy per mile (California Air Resources Board 2009)[2]. The avoided emissions

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[1] Despite the fact that EMFAC's latest version (2007) was published before the recession, forecasts beyond 2010 are consistent with forecasts from the California New Car Dealers Association (2010).

[2] This is based on dynamometer testing between the fuel energy used for the same drive cycle between comparable electric vehicles and light-duty vehicles.

resulted in 39,740 $MTCO_2e$ and 42,283 $MTCO_2e$ for the “proactive” and “breakout” scenario, respectively, or an average of 42,511 $MTCO_2e$.

Energy Efficiency

Energy efficiency measures seek to reduce the amount of electricity and natural gas consumed by residents and business in the city by improving the energy efficiency of existing and new buildings and increasing energy conservation. These measures will reduce GHG emissions in the city by 312,310 $MTCO_2e$ by 2020.

For each measure, a percent reduction in energy use was determined. For example, updating the Residential Energy Conservation Ordinance (RECO) would lead to an energy savings of 15% for participating homes. The participation rate for each action was determined; this figure is in the form of number of households or square feet of commercial space. The percent energy savings was multiplied by the number of homes or square feet of commercial space and by the average annual energy intensity for residential and commercial space (6,600 kWh and 530 therms per home; 12.95 kWh and 0.44 therms per commercial square foot) to determine a net electricity and natural gas savings (San Francisco Planning and Urban Research Association 2009; California Energy Commission 2006; U.S. Energy Information Administration 2003). Energy savings were then converted into $MTCO_2e$ reductions using the PG&E electricity emission factor (0.651 pounds of CO_2 per kilowatt-hour), and natural gas emission factor (11.697 pounds of CO_2 per therm of natural gas) (San Francisco Planning and Urban Research Association 2009).

Renewable Energy

The single renewable energy action seeks to achieve 100% renewable electricity in San Francisco by the year 2030. This measure would greatly reduce the carbon intensity of electricity used by the city in 2020. This measure will reduce GHG emissions in the city by 610,525 $MTCO_2e$ by 2020.

The percent renewable in the year 2020 was determined by taking a polynomial projection of PG&E’s year 2008 renewable energy percentage (11.4%) to the 100% goal in 2030; the resulting percent of renewable electricity in 2020 is 49% (California Energy Commission 2009). Energy projections provided by the City were combined with energy savings achieved through other energy efficiency measures to determine the number of kWh consumed in the city in 2020 that would be generated using renewable resources. It was assumed that this electricity would be essentially carbon neutral (i.e., the $MTCO_2e$ emission factor for this electricity was assumed to be zero).

Zero Waste

Zero waste measures seek to reduce the amount of waste placed in landfills from waste that is generated by the community in San Francisco. By 2020, these actions will achieve a 100% diversion rate, which means that 100% of the waste generated by the City will either be composted or recycled. In addition, some composted food waste would be used in energy-producing digesters. These measures will reduce GHG emissions in the city by 544,533 $MTCO_2e$ by 2020.

In the year 2020, the City will need to recycle or compost an additional 1,000,000 tons of waste in order to achieve 100% diversion. Waste profile information provided by the City of San Francisco was combined with ICLEI's Clean Air Climate Projection 2009 software emission factors to estimate the GHG reductions achieve through these new composting and recycling waste practices (San Francisco Planning and Urban Research Association 2009). Per request by the City, emissions reductions were limited to those reductions occurring at landfill sites. These reductions represent avoided landfill emissions. Lifecycle emission reductions, such as changes in upstream manufacturing emissions due to the use of more recycled materials, were not included in the calculations per request by the city.

For the waste digestion action, a study by the U.S. Environmental Protection Agency (EPA) and the East Bay Municipal Utility District (EMBUD) was used to estimate electricity production from digesting 100 tons of food waste per day (255 kWh per wet ton of food waste) (U.S. Environmental Protection Agency 2008). This electricity would offset non-renewable electricity use in the city, reducing electricity-related GHG emissions. In addition, digested waste would not be placed in a landfill where it would decompose and release methane; avoided fugitive emissions of methane were calculated using the Climate Action Reserve's (CAR) Organic Waste Digestion Project Protocol emission factor from the decay of organic waste for a temperate, dry environment (0.308 $MTCO_2e$/MT Waste) (Climate Action Reserve 2009). Emissions from the incomplete combustion of digester gas were also estimated using the California Air Resources Board's (CARB) Local Government Operations Protocol, and subtracted from the avoided methane emissions (equation 10.1) (California Air Resources Board 2010).

Land Use—City Growth

Land use actions seek to reduce energy use and VMT traveled within the city through sustainable land use planning. This includes consistency with the Sustainable Communities Strategy required by state legislation, as well as increasing the number of households and jobs within the city that are accessible by transit.

Data for seven Priority Development Areas (PDAs) was provided by the city and modeled in URBEMIS to estimate area source (natural gas and other fuel use) and mobile source (VMT) CO_2 emission reductions associated with these PDAs. This data consisted of existing and 2020 land use statistics and forecasts on residential, commercial, industrial, and other land use square footage. In addition, existing and future scenarios of land use measures were also provided by the City. These measures reflect the differences in transit level of service, level of bicycle and pedestrian infrastructure and amenities, and the ratio of affordable housing.

To calculate reductions in 2020 due to land use measures, ICF used the URBEMIS land use emissions model to compare the effect of existing, or business-as-usual, land use measures with future land use measures on future land use assumptions provided by the City. These assumptions included the building square footage of several land use types including housing, general office buildings, schools, parks, hotels, and light and heavy industry. Each land use type is affected by the individual land-use measures differently and, thus, knowing the how the areas are divided by land use type is important in accurately assessing the impacts of the land use measures. Reductions calculated by URBEMIS mainly reflect differences in area source emissions, mostly local natural gas consumption, in addition to emissions reduced from decreased VMT. Reductions in area source emissions mainly reflect proposed gains in Title 24 efficiency (35%). Total reductions from the difference between future and existing land use mitigation scenarios from the 7 PDAs result in a reduction of 239,052 $MTCO_2e$.

Land Use—Transit Oriented New Jobs

Concentrating new employment opportunities around areas with the highest levels of transit service will reduce demand for commute by private vehicles in the City. To quantify the reductions from this particular measure, ICF used the existing (2008) and future (2020) employment numbers from the land use information, provided by the City, for the seven PDAs as used in the previous measure. The annual VMT associated with this additional number of jobs was calculated in two transit scenarios. The first scenario assumed that the areas in which the jobs will be located have auto, or private vehicle, mode share equal to that of the areas in the City that currently have the highest auto mode share (i.e., Mission Bay in 2010). The second scenario assumed that the same jobs will be located in areas with auto mode shares as low as areas with the lowest auto mode share (i.e., Downtown in 2010). Assuming the difference in VMT between the two scenarios is attributed to an equal increase in transit ridership and taking into account the slight increase in emissions due to increased burden on transit results in a reduction of 200 $MTCO_2e$.

Urban Trees

For the urban tree planting measure, the Center for Urban Forest Research (CUFR) Tree Carbon Calculator was used (Center for Urban Forest Research 2010). It was assumed that half of the trees (2,500 per year, or 25,000 by 2020) would be Victorian Box (*Pittosporum undulatum*) and half would be Plum (*Prunus cerasifera*). These two tree species are common urban trees in the City (City & County of San Francisco 2006). Savings in electricity and natural gas through shade tree effects were combined with projected annual carbon sequestration to determine total GHG emission reductions in the year 2020, resulting in a reduction of 3,291 $MTCO_2e$.

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Appendix C

Daily and Annual GHG Criteria Pollutant Precursor Emissions Reductions

Daily and Annual GHG Criteria Pollutant Precursor Emissions Reductions

Table C-1. Daily Criteria Pollutant Precursor Emissions Reductions Resulting from the SF CAP Measures

		Criteria Pollutant Precursor Emissions Reductions (lbs/day)				Criteria Pollutant Precursor Emissions Reductions (tons/day)			
Measure #	Measure Name	ROG	NO_X	PM2.5	SO_2	ROG	NO_X	PM2.5	SO_2
Transportation Demand Management		139.87	389.21	95.27	20.27	0.07	0.19	0.05	0.01
1a	Workplace Transportation Demand Management	26.11	72.66	17.79	3.78	0.01	0.04	0.01	0.00
1b	Community Transportation Demand Management	111.58	310.48	76.00	16.17	0.06	0.16	0.04	0.01
2	Ridesharing	2.18	6.07	1.49	0.32	0.00	0.00	0.00	0.00
Electric Transportation		47.96	70.05	28.68	-41.02	0.02	0.04	0.01	-0.02
3	Electric Vehicle Infrastructure	47.96	70.05	28.68	-41.02	0.02	0.04	0.01	-0.02
Energy Efficiency		76.00	1,303.62	106.63	445.76	0.04	0.65	0.05	0.22
4	RECO Update	25.35	397.82	32.43	97.84	0.01	0.20	0.02	0.05
5a	Residential Loan Program	0.52	8.24	0.67	2.03	0.00	0.00	0.00	0.00
5b	Commercial Loan Program	5.08	91.09	7.46	35.22	0.00	0.05	0.00	0.02
6	Energy Efficiency Legislation Support	44.61	799.88	65.52	309.29	0.02	0.40	0.03	0.15
7	Energy Efficiency Services	0.43	6.60	0.54	1.39	0.00	0.00	0.00	0.00
Renewable Energy		79.07	2,014.60	166.69	1,369.03	0.04	1.01	0.08	0.68
8	Renewable Energy Goal	79.07	2,014.60	166.69	1,369.03	0.04	1.01	0.08	0.68
Zero Waste		0.29	7.36	0.61	5.00	0.00	0.00	0.00	0.00
9	Achieve Zero Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	Digester Capture	0.29	7.36	0.61	5.00	0.00	0.00	0.00	0.00
Land Use		144.72	1,138.91	47.59	2.92	0.07	0.57	0.02	0.00
11	Land Use Measures	140.16	1,124.38	44.38	1.21	0.07	0.56	0.02	0.00
12	Transit Oriented New Jobs	4.44	12.36	3.03	0.64	0.00	0.01	0.00	0.00
13	Tree Planting	0.11	2.17	0.18	1.07	0.00	0.00	0.00	0.00

Table C-2. Annual criteria pollutant precursor emissions reductions from the SF CAP measures.

		Criteria Pollutant Reductions (lbs/year)				Criteria Pollutant Reductions (tons/year)			
Measure #	Measure Name	ROG	NO_X	PM2.5	SO_2	ROG	NO_X	PM2.5	SO_2
Transportation Demand Management		51,053.14	142,060.91	34,775.33	7,399.01	25.53	71.03	17.39	3.70
1a	Workplace Transportation Demand Management	9,530.70	26,520.22	6,491.93	1,381.26	4.77	13.26	3.25	0.69
1b	Community Transportation Demand Management	40,726.31	113,325.38	27,741.11	5,902.36	20.36	56.66	13.87	2.95
2	Ridesharing	796.13	2,215.31	542.29	115.38	0.40	1.11	0.27	0.06
Electric Transportation		17,506.53	25,568.84	10,469.57	-14,971.53	8.75	12.78	5.23	-7.49
3	Electric Vehicle Infrastructure	17,506.53	25,568.84	10,469.57	-14,971.53	8.75	12.78	5.23	-7.49
Energy Efficiency		27,740.04	475,822.75	38,918.72	162,702.94	13.87	237.91	19.46	81.35
4	RECO Update	9,251.97	145,205.74	11,837.63	35,711.73	4.63	72.60	5.92	17.86
5a	Residential Loan Program	191.57	3,006.56	245.10	739.43	0.10	1.50	0.12	0.37
5b	Commercial Loan Program	1,854.38	33,247.48	2,723.57	12,855.84	0.93	16.62	1.36	6.43
6	Energy Efficiency Legislation Support	16,283.76	291,954.43	23,916.31	112,890.33	8.14	145.98	11.96	56.45
7	Energy Efficiency Services	158.36	2,408.54	196.11	505.60	0.08	1.20	0.10	0.25
Renewable Energy		28,860.47	735,330.46	60,840.98	499,694.49	14.43	367.67	30.42	249.85
8	Renewable Energy Goal	28,860.47	735,330.46	60,840.98	499,694.49	14.43	367.67	30.42	249.85
Zero Waste		105.46	2,686.97	222.32	1,825.94	0.05	1.34	0.11	0.91
9	Achieve Zero Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	Digester Capture	105.46	2,686.97	222.32	1,825.94	0.05	1.34	0.11	0.91
Land Use		52,821.12	415,703.34	17,369.73	1,066.12	26.41	207.85	8.68	0.53
11	Land Use Measures	51,160.00	410,400.00	16,200.00	440.00	25.58	205.20	8.10	0.22
12	Transit Oriented New Jobs	1,621.87	4,513.02	1,104.75	235.05	0.81	2.26	0.55	0.12
13	Tree Planting	39.26	790.32	64.98	391.07	0.02	0.40	0.03	0.20

Appendix D
Stakeholder Input and Candidate Measure Prioritization

Appendix D
Stakeholder Input and Candidate Measure Prioritization

Overview of Candidate Measure Prioritization Process

The following describes the process undertaken in this study to prioritize measures for quantification of criteria pollutant precursor emissions reductions. This process included development of a ranking system to establish a priority list of measures, followed by stakeholder review and feedback on the priority list and the system developed to rank measures. Stakeholders who participated in this process represented the following agencies/entities: United States Environmental Protection Agency (USEPA), SPUR, BAAQMD, and SFE. Elmwood Consulting also participated as a technical advisor.

"Candidate" greenhouse gas reduction measures include those measures listed in SPUR's February 2009 "Critical Cooling" Report (Report) (Table D-1). The measures listed in this Report are generally based on those in the 2004 San Francisco Climate Action Plan. The Report provides estimated GHG reductions and implementation costs for the majority of the measures based on analysis conducted by SPUR. These "candidate" greenhouse gas reduction measures were ranked according to the process described below. Stakeholders reviewed the initial ranking and provided feedback in a meeting held on September 7, 2010. The final measure ranking, incorporating stakeholder comments, is also provided in Table D-1. Ultimately, however, due to stakeholder request and other circumstances, the measures selected for analysis in subsequent phases of the study included those currently under consideration for inclusion in the San Francisco Climate Action Plan Update.

Measure Ranking Process and Results

The ranking method for prioritizing the "candidate" measures was developed after review of SPUR's "Critical Cooling" report, the Bay Area Air Quality Management District's MPEM model, and after consideration of the techniques and methodologies that could be utilized when evaluating the measures for criteria pollutant reductions. The ranking methodology includes two types of criteria, qualitative and quantitative, as discussed below. Specific criteria in each category were applied to each SPUR measure to establish each measure's total score (see Table D-1). The scoring is generally based on the analysis results and assumptions provided by SPUR in its Report. In cases where results or information was not available in the SPUR Report, or where significant uncertainty or subjectivity was involved, ICF used its best judgment and prior experience with air quality and climate change analysis in determining the scoring for the various criteria.

Table D-1. Candidate Greenhouse Gas Reduction Measures and Ranking by Score

Measure	Measure Type/Sector	Score
Adopt regional compact land use development	Land Use	216
Impact on SF from Pavley bill	State or Federal Actions	216
Implement variable rate road pricing	Decrease VMT	204
Require retro commissioning in commercial buildings	Energy	192
Implement climate fee on gasoline (AB 2744)	Decrease VMT	192
Update the RECO and require home performance testing	Energy	191
Create bike rental or sharing system	Decrease VMT	183
Build smart grid infrastructure	Energy	181
Use prices to manage the supply of curb parking	Decrease VMT	180
Caltrain electrification	Decrease VMT	179
Build the Phase 2 bicycle network	Decrease VMT	174
Expand energy efficiency rebates and installation services	Energy	172
Expand Pay as You Drive Insurance	Decrease VMT	170
Further increase recycling and composting	State or Federal Actions	162
Update the Residential Conservation Ordinance	Energy	161
Create a loan program to finance comprehensive energy efficiency services	Energy	160
Reinstate the Commercial Energy Conservation Ordinance	Energy	158
Impose a carbon tax (utility users' tax)	Energy	157
Improve signaling to reduce idling and congestion	Reduce Emissions per Mile	157
Create a "green lease" program	Energy	155
Reduce taxiing under jet power at SFO	Reduce Emissions per Mile	155
Implement the TEP recommendations for Muni	Decrease VMT	152
Build the Phase 1 bicycle network	Decrease VMT	152
Create greenhouse gas standard for taxi fleet	Reduce Emissions per Mile	152
Build green waste digesters to produce energy from compost	State or Federal Actions	140
Expand solar PV incentives for municipal or private installations	Energy	137
BRT on Geary	Decrease VMT	137
BRT on Van Ness	Decrease VMT	137
Expand use of commuter benefits by residential developers and HOAs	Decrease VMT	137
Build the Downtown Transit Center/Caltrain extension	Decrease VMT	135
Enforce parking cash-out law	Decrease VMT	133
Expand use of commuter benefits by universities	Decrease VMT	132
Expand commuter benefits for city workers	Decrease VMT	132
Convert the city fleet to biodiesel	Reduce Emissions per Mile	132
Expand small-scale wind	Energy	117

Measure	Measure Type/Sector	Score
Build the Central Subway	Decrease VMT	117
Set aside car-sharing parking spaces on the street (500 spaces)	Decrease VMT	117
Create individualized marketing programs	Decrease VMT	112
State incentives for clean air vehicles (feebates)	Reduce Emissions per Mile	102
Permit more housing in SF 10% over ABAG 2030 allocation	Land Use	95

A number of measures fall below a score of 140, as an arbitrary cut-off. Most of the "Energy" measures are scored above 140 because these measures, as indicated in the SPUR Report, achieve larger GHG reductions and are cost-effective. Many of the "Decrease VMT" measures are scored below 140, primarily because these "Decrease VMT" measures achieve lower GHG reductions and may not be cost-effective.

Stakeholder Input and Review

The stakeholder group provided feedback on the measure ranking and the ranking criteria. Specifically, the stakeholders provided the following major comments: 1) that a "generic name" be provided for each of the measures, to facilitate stakeholder review and to demonstrate applicability of the San Francisco measures to other locales; 2) evaluate certain measures that are ranked low but may be important measures to the region or could be more effective in the future if technology improvements or political actions occur; and 3) include additional measures not included in the SPUR Report but common to Climate Action Plans. These recommendations were incorporated into the analysis in subsequent project phases.

Detailed Ranking Method

As discussed above, the ranking method was developed after review of SPUR's "Critical Cooling" report, the Bay Area Air Quality Management District's MPEM model, and after consideration of the techniques and methodologies that could be utilized when evaluating the measures for criteria pollutant reductions. The ranking methodology includes two types of criteria, qualitative and quantitative, as discussed below. Specific criteria in each category are also listed below, and were applied to each SPUR measure to establish each measure's total score (Table D-1).

Quantitative Screening Criteria

Quantitative screening criteria include cost-effectiveness of GHG reductions, GHG reductions, and societal cost. The cost-effectiveness and GHG reductions are defined by SPUR's Report, and societal cost is an output of MPEM. For each of the criteria below, ICF has developed a ranking system based on the results of the Report, expected MPEM model outputs, and our best judgment regarding the appropriate characterization of the measures.

1. **Cost-effectiveness of GHG reductions**
   Point range: varies based on cost or savings (min = 1 pt; max for SPUR measures = 21.4).

Description: As defined by SPUR in the “Critical Cooling” report, \$/MTCO$_2$e.

Points	Cost Effectiveness Category (\$/MTCO$_2$e)
10 + 0.001*\$/ton saved	Cost-negative
5	Neutral
4	>0–25
3	26–50
2	51–75
1	76–100

Note: For cost-negative measures, tons saved are positive in the equation above.

2. **GHG Reductions**

   Point range: 1 to 100 pts

   Description: As defined by SPUR in the “Critical Cooling” report, MTCO$_2$e per year.

Points	Reductions Category (MTCO$_2$e/yr)
1	>0 to 10,000
1	For every additional 5,000 up to 500,000
100	> 500,000

Note: Cap for reductions >500,000 MTCO$_2$e/yr implemented to avoid extreme weighting by GHG reductions for measures with considerable GHG reductions.

3. **Societal Cost for PM2.5 and Ozone**

   Point range = 1-11 (11 points achieved if measure reduces diesel PM2.5, PM2.5 and its precursors, and ROG/NOx).

   Description: Equivalent to the health effects valuation included as an output of MPEM, equivalent to pollutant concentration reduction scaled by societal cost for a particular pollutant.

Points	Societal Cost Category
5	Reduces direct PM2.5 or PM2.5 precursors*
5	Reduces diesel PM2.5
1	Reduces ROG or NOx

*For PM2.5 precursors other than NOx

Qualitative Screening Criteria

ICF developed qualitative metrics for those criteria that cannot easily be ranked based on quantitative thresholds, but that may be important when prioritizing measures for inclusion in a Climate Action Plan. The scores associated with these criteria are lower than that of the quantitative criteria, reflecting the additional uncertainty and subjective judgment required when applying these metrics.

1. **Criteria Pollutant Emissions Reductions**

   Point Range:

20 pts = major reductions: measure achieves ≥10,000 $MTCO_2e$ reduction.

5 pts = minor reductions: measure achieves <10,000 $MTCO_2e$ reduction.

Description: Criteria pollutant emissions (i.e., precursors of ozone and PM2.5) reductions are an output of MPEM, in lbs/day. Criteria pollutant emissions were assumed to be linearly related to GHG reductions, for the purpose of scoring.

2. **Feasibility of determining air pollution precursor emissions**
   Points = 20 (feasible)

   Description: Feasibility refers to ICF's ability to use readily-available technical tools and data, using a reasonable level of effort, to quantify the air pollution precursor emissions associated with a particular measure.

3. **Implementation feasibility**
   Points = 20 (feasible)

   Description: Feasibility refers to the following, two out of the three of which are required to ensure "feasibility" - 1) a level of technical complexity that is not overwhelmingly burdensome, 2) societal or political support, and 3) minimal coordination burden.

4. **Geographic location of criteria pollutant emissions reductions**
   Point Range:

   20=majority of emissions reductions occur inside of Bay Area

   5=majority of emissions reductions occur outside of Bay Area

   Description: Measures whose emissions reductions are expected to occur in the Bay Area are prioritized over those whose emissions reductions will primarily occur outside of the Bay Area.

5. **Timing of implementation**
   Point Range:

   20=near-term (measure implementation expected before 2015)

   5=long-term (measure implementation expected during or after 2015)

   Description: Measure implementation timing reflects the relative timing of actual GHG reductions.

6. **Equity**
   Points = 20 (positive equity impact)

   Description: A positive equity impact indicates improved socioeconomic status or improved protection from environmental hazards for individuals, groups, or communities, particularly for vulnerable populations.

7. **Persistence**
   Points = 20 (multi-year benefit)

   Description: Addresses the affect of a measure on a population's long-term exposure to greenhouse gas emissions and/or air quality precursor emissions.

8. **Aesthetics impact**
   Points = 20 (positive aesthetic impact)

   Description: Measure is expected to result in a more beautiful environment, including elements such as increased trees or a cleaner area.

9. **Replicability**
   Points = 20 (positive if measure can be readily used in a variety of locales)

   Description: Some GHG mitigation measures will be specific to a region, whereas other measures are more general and can be applied to a variety of locales. Measures that are generic in nature are considered to be "replicable", whereas measures that have elements that are very specific to San Francisco are not considered to be replicable. For example, the measure "Implement variable rate road pricing" is considered replicable, since it is general enough to be applied in many other locales. The measure "Build the phase 1 bicycle network" is not considered replicable, under this criterion, since it refers to a specific bicycle program for San Francisco.

   Note: Generic names were created for each of the San Francisco GHG mitigation measures. These names were created to provide guidance on how each San Francisco measure can be applied in other locales. This should not be confused with the "replicability" criterion, which considers the replicability of the San Francisco mitigation measures.

10. **Climate Adaptation**
    Points = 20 (positive climate adaptation impact)

    Description: Measure is expected to aid climate adaptation strategies, such as by reducing energy load or by resulting in flood-resistant infrastructure.

11. **Economic Impact**
    Points = N/A (see discussion below)

    Description: This criterion is included as a placeholder to highlight the importance of the economic impacts associated with a given climate change mitigation measure. Given the current state of the U.S. economy, there is an increasing pressure to characterize the economic impacts of implementing climate change mitigation measures. Policy makers will want to understand the upfront capital cost and operational costs of mitigation measures, as well as the potential impact that mitigation measures will have on jobs and unemployment. Conducting a full economic impact assessment of the mitigation measures considered in this analysis is beyond the scope of work for this project. As such, the *Economic Impact* criterion is included as a placeholder only and it is recommended that economic impacts of mitigation measures be analyzed by other organizations if funds are available.

    Although there are detailed studies that evaluate the effect of statewide and regional efforts to reduce carbon emissions, there is less information in the literature regarding the local employment and economic impacts of climate change mitigation. For a broad economic perspective, the following studies provide useful information: WCI's *Updated Economic Analysis of the WCI Regional Cap-and-Trade Program* published July 2010 and The Pew Center for Climate Change's *The Competitiveness Impacts of Climate Change Mitigation Policies*, published May 2009. In addition, the following studies provide regional analyses:

The State of Minnesota's *Analysis of the Economic, Environmental, and Public Health Impact and Potential Revenues in the State of Minnesota* published August 2010 and ICF International's *Economic Impact Modeling for the Midwestern Governors Greenhouse Gas Reduction Accord* (March 2010). These studies may be reviewed for applicability of the analyses to one's local community.

References

San Francisco Department of the Environment and San Francisco Public Utilities Commission. 2004. Climate Action Plan for San Francisco: Local Actions to Reduce Greenhouse Gas Emissions. September. San Francisco, CA.

San Francisco Planning and Urban Research Association. 2009. Critical Cooling: Analyzing San Francisco's Options to Reduce Greenhouse Gas Emissions. February. San Francisco, CA.