Community GREENHOUSE GAS Solutions

Prioritizing Emissions-Reducing Strategies

by

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As authors of this Group Project report, we are proud to archive this report on the Bren School's website such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Bren School of Environmental Science & Management.

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The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. It is a three-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

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Abstract

Partnering with AECOM Environment, we address climate change mitigation at the community scale by providing recommendations for effective strategies to reduce greenhouse gas (GHG) emissions. We performed cost-benefit analyses on 20 GHG reduction strategies such as installing efficient appliances, taking public transit and installing solar panels. Combined with relevant geographic requirements, these analyses informed development of our software model and serve as the basis for tailored GHG reduction plans. Dubbed SAFEGUARD, our software prioritizes reduction strategies based on cost effectiveness. SAFEGUARD addresses the political feasibility of implementing strategies by allowing the user to override the software's economic prioritization. Accompanying the software are a user manual and detailed methods describing the processes used to build the model and determine the required inputs. We used the City of San Buenaventura (Ventura), California, as a case study to test the model and methods that comprise our GHG reduction toolkit. Beyond the broad discussion of the project's motivation and methods included in the report, our deliverables include an inventory of Ventura's GHG emissions, the SAFEGUARD model and its resulting recommendations for Ventura. We have created a useful tool for consultants and governments to determine optimal greenhouse gas reduction strategies at the community scale.

Acronym Guide

AECOM	Architecture, Engineering, Consulting, Operations and Maintenance
BTU	British Thermal Unit
CA	California
CalEPA	California Environmental Protection Agency
CARB	California Air Resources Board
CBA	Cost-Benefit Analysis
CCAR	California Climate Action Registration
CCP	Cities for Climate Protection
CEA	Cost-Effectiveness Analysis
CEQA	California Environmental Quality Act
CESA	Clean Energy States Alliance
CFL	Compact Fluorescent Lamps
CO2e	Carbon Dioxide Equivalent
CTCC	(CUFR) Tree Carbon Calculator
CUFR	Center for Urban Forest Research
DOE	Department of Energy
EIA	Energy Information Administration
EMFAC	Emission Factors
EPA	Environmental Protection Agency
ESRI	Environmental Systems Research Institute
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GPF	Gallons Per Flush
GPM	Gallons Per Minute
GWP	Global Warming Potential
HVAC	Heating, Ventilating, Air Conditioning
ICLEI	International Council for Local Environmental Initiatives
kWh	Kilowatt Hour
LCV	League of Conservation Voters
LED	Light Emitting Diode
LPG	Liquid Petroleum Gas
MPG	Miles Per Gallon
MPO	Metropolitan Planning Organization
MTCO2E	Metric Tonne Carbon Dioxide Equivalent
NGO	Non-governmental organization
NPV	Net Present Value
NRDC	National Resources Defense Council
NREL	National Renewable Energy Laboratory
PMT	Passenger-Miles Traveled
PV	Photovoltaic
RPS	Renewable Portfolio Standards
SAFEGUARD	Strategic Analysis For Environmental GHGs Under AB-32 Regulatory Demands
SCE	Southern California Edison
SCS	Sustainable Communities Strategies
USDA	United States Department of Agriculture
USGS	United States Geographical Survey
VMT	Vehicle-Miles Traveled

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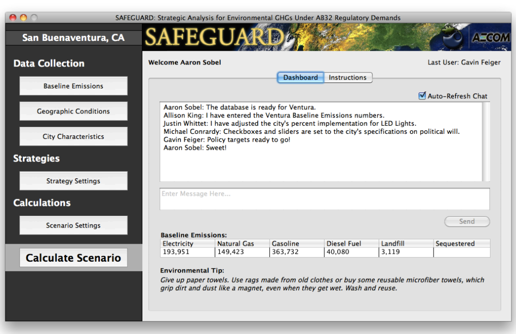
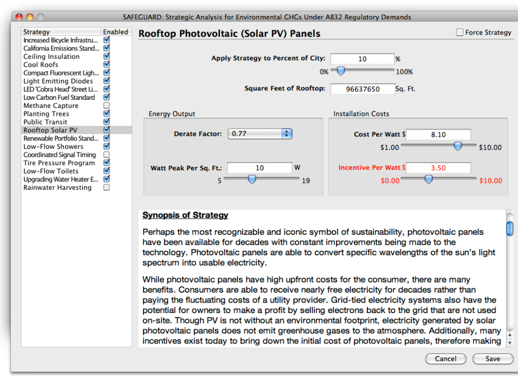
Finally, we thank our families and friends for their support and patience.

Executive Summary

Partnering with AECOM Environment, we address climate change mitigation at the community scale by providing recommendations for effective strategies to reduce greenhouse gas emissions (GHG). We performed cost-benefit analyses on 20 GHG reduction strategies such as installing efficient appliances, taking public transit and installing solar panels. Combined with relevant geographic requirements, these analyses informed development of our software model and serve as the basis for tailored GHG reduction plans. Dubbed SAFEGUARD, our software prioritizes reduction strategies based on cost effectiveness. SAFEGUARD addresses the political feasibility of implementing strategies by allowing the user to override the software's economic prioritization.





Accompanying the software is a user manual and detailed methods describing the processes used to build the model and determine the required inputs. We used the City of San Buenaventura (Ventura), California, as a case study to test the model and methods that comprise our GHG reduction toolkit. Beyond the broad discussion of the project's motivation and methods included in the report, our deliverables include an inventory of Ventura's GHG emissions, the SAFEGUARD model and its resulting recommendations for Ventura. We have created a useful tool for consultants and governments to determine optimal greenhouse gas reduction strategies at the community scale.

The Significance of Communities

Climate change is unequivocal and largely human-caused.1 To avoid the consequences of climate change, the whole world will need to take part in a coordinated effort to reduce emissions to the level deemed necessary by the best science available. Despite nearly 18 years of effort, starting with the creation of the United Nations Framework Convention on Climate Change (UNFCCC) in Rio de Janeiro and continuing through, most notably, Kyoto, and, most recently, Copenhagen, a politically feasible global policy has not been constructed. Unwilling to wait for an overarching mandate, smaller actors are beginning to enact strategies feasible within their sphere of influence.

The urgency of climate change mitigation along with the slow nature of large-scale politics begs communities to begin efforts toward the reduction of greenhouse gas emissions. Communities respond to citizen pressure, prepare for predicted community-level mandates, pursue economic benefits of efficiency and desire resource security. Often the idea of states as laboratories for the country are posed in order to solve problems. Through the same logic communities fulfill a similar laboratorial role. Community economic structures provide opportunities for grants, loans, subsidies and other funding from every level of government as well as private industry. In turn, communities are subject to benefits of economic sustainability through environmental sustainability. Ultimately lack of power and authority within the centralized global or national structure as well as necessity to act quickly requires a strong role and commitment at the local level.

Policy-Driven Reduction Targets

Each path toward a solution requires an end goal. While there is no current government mandate on cities, the entire state of California established the nation’s first cap on GHGs. California's Global Warming Solutions Act of 2006 (AB 32) establishes a near-term greenhouse gas reduction goal of 1990 emission levels by 2020 and, combined with a related executive order (S-3-05), calls for a reduction of 80% below 1990 levels by 2050. SAFEGUARD scales these goals to the community-level providing cities with targets of their own.

Determining Strategy Feasibility

Geographic

Geographic feasibility is determined through physical attributes of a given city and is imperative for determining reduction strategy feasibility. Trees cannot be planted without space to plant them, buildings cannot be insulated if there is not a building to insulate and rainwater cannot be collected if there is no rain.

Economic

This project accepts the assertion that worldwide climate mitigation is warranted, and focuses on the economics of reducing emissions on a localized, city scale. In the context of California's policy goals for reducing emissions—and assuming that communities wish to meet these policy goals—we perform a cost-effectiveness analysis of attaining reduction goals at the least cost to the community. By compiling strategy-specific cost-benefit analyses and emissions calculations, our model prioritizes emissions reduction strategies by one of two criteria (at the user's preference): lowest cost-per-reduction or shortest payback-per-reduction.

Political

Political feasibility is the decisive criteria determining the success or failure of a greenhouse gas reduction strategy. Geographic and economic factors allow technical prioritization of reduction strategies, but political feasibility is the determining factor for final action. While quantitatively measuring political feasibility is interesting and may be useful at certain levels, failings of currently established methods prompted us to pursue a different approach. SAFEGUARD's design addresses the political feasibility of greenhouse gas reduction strategies within a community through extensive customizable options within each of the strategies. Each strategy includes a checkbox to enable or disable a strategy in the analysis, regardless of economic efficiency. Additionally, each strategy has a slider allowing the user to specify the amount of the strategy that could feasibly be employed.

Emissions Reduction Strategies

The heart of the analysis, and the bulk of our research, lies in a menu of 20 emissions-reducing strategies. Recognizing that there are potentially hundreds of GHG reduction strategies, we focused closely on 20 strategies over the course of our project. We thoroughly researched and analyzed each of these twenty strategies, performing a complete cost-benefit analysis (CBA) of implementation and calculating potential emissions savings for the community. SAFEGUARD's design allows the inclusion of more strategies in the future. As the results of our case study indicate, more strategies will be necessary to achieve the long-term emissions reduction goals.

Case Study: San Buenaventura, CA

For the city of Ventura, SAFEGUARD provides a profitable set of emissions-reducing strategies, which Ventura can apply to achieve the 2020 goal, returning to 1990 emissions.

With the current set of strategies and estimated implementation levels for Ventura, SAFEGUARD is unable to counteract the business as usual emissions growth and reach the 2050 reduction goal. However, with more strategies and increased implementation Ventura may be able to reduce to 80% below 1990 levels.

Table of Contents

Introduction

Climate change, due to increased greenhouse gas (GHG) levels, largely from anthropogenic sources, is a scientifically accepted problem of increasing magnitude (Solomon et al., 2007). In the United States, individual cities and states have begun mitigating GHG emissions on their own accord, in spite of a lack of binding national or international regulation.

The driving forces behind communities' desire to reduce emissions are diverse; motivation may lie in economics, preemption of regulation, political or community pressure, or more general environmental stewardship. These sources of motivation vary between—and even within—cities. No matter the motivation, reducing GHGs is a large undertaking, operating in highly uncharted legislative and implementation territory.

As communities strive to reduce their GHGs, they may be confronted by technical, financial and political constraints. Meeting these challenges requires an interdisciplinary GHG management approach that allows a community to understand its baseline GHG footprint, evaluate the optimal strategies for reducing this footprint, and determine the financial and political feasibility of the potential reduction strategies.

Our project addresses climate change mitigation at the city level through the creation of original software, SAFEGUARD, which optimizes economic effectiveness of greenhouse gas reduction strategies to reach an emissions target, while accounting for geographic constraints and political feasibility within a given community.

This project intends to guide communities, regardless of their size, location, economy, and political willpower, in their efforts to reduce GHG emissions.

Project Objectives and Approach

The objective of this project was to develop a comprehensive GHG reduction toolkit for communities, using the city of San Buenaventura (Ventura), California as a case study. This required academic and market research as well as extensive programming to build the software that is the centerpiece of our toolkit. The project is organized into four steps:

1. Baseline Greenhouse Gas Inventory

In 2007, Ventura conducted a baseline assessment, or inventory, of its *municipal* GHG emissions – city owned and operated facilities and vehicles. We extended the inventory to the community scale (including all emissions in the city limits), and documented the procedures to ensure replicability.

2. Emissions Reduction Strategies

We entertained a preliminary list of approximately 80 GHG reduction strategies, however limited time and resources required prioritization. Strategies were chosen to address the high emissions sectors determined in the baseline and to reflect three general methods: efficiency, conservation and renewable energy production. We identified twenty high-priority strategies based on reduction potential, fuel source and personal interest. We conducted an in-depth analysis, including cost-benefit analysis and potential emissions savings calculations, for each strategy selected.

3. Strategy Feasibility: Economics and Politics

We conducted extensive academic research to assess the geographic and technical constraints of each strategy. We measured economic feasibility with cost-benefit analyses based on thorough market research. The individual cost-benefit analyses are combined into an overall cost-effectiveness analysis to determine the best mix of GHG reduction strategies for a given community. Assessment of political feasibility was ultimately put in the hands of the person using the software, setting the level of potential implementation for a given city. A guidance document is supplied to help determine strategy feasibility and barriers to implementation (Appendix III).

4. Toolkit

This widely applicable toolkit prioritizes GHG reduction strategies for any given community. The centerpiece of the toolkit is a model that optimizes strategy recommendations based on geographic, economic and political constraints. Our model is in the form of proprietary software, *Strategy Analysis For Environmental* GHGs *Under AB-32 Regulatory Demands* (SAFEGUARD). Successful use of SAFEGUARD requires detailed inputs. The accompanying *SAFEGUARD User Manual* contains instructions for using SAFEGUARD and determining required data and inputs.

We ultimately provide recommendations for reducing GHG emissions in San Buenaventura (Ventura), California and a toolkit to assist in recreating the process in other communities. AECOM Environment will receive a comprehensive report with the toolkit that includes our methods, model, detailed reduction strategies, and the Ventura case study. We will provide the city of Ventura with our results and recommendations for consideration in current and future City plans and programs.

Chapter 1: Significance

California's Current Climate Change Policies

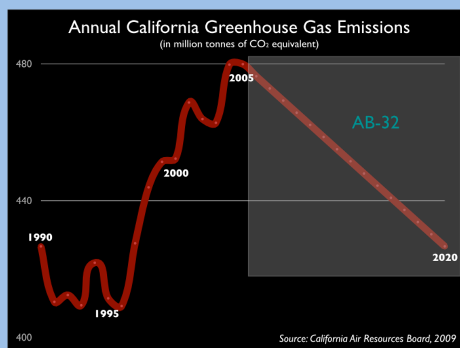


Figure 1.1: California's Global Warming Solutions Act of 2006 requires a return to 1990 emissions levels by 2020

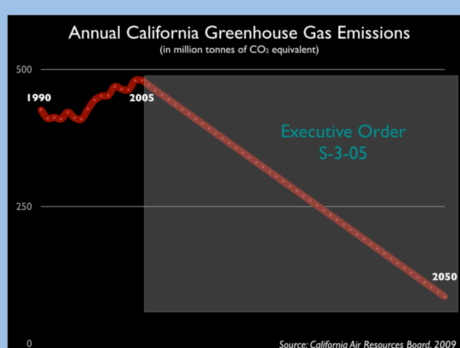


Figure 1.2: Executive order S-3-05 calls for a reduction of 80% below 1990 levels by 2050.

As public discourse and political agendas have increasingly addressed the issue of climate change mitigation, the question has now become: how to act? Local and state-level governments are expected to be subject to new regulations, forcing them to account for and lower their greenhouse gas emissions. Climate change is likely to be the driving force behind several regulations that will dramatically shape California's infrastructural and economic landscapes over the next decade and beyond.

The State of Climate Change Policy

Climate change, the net warming of the Earth due to the build-up of greenhouse gases (GHG) in the atmosphere, is unequivocal and largely human-caused (Solomon et al., 2007). Climate change is a global problem requiring a global effort to mitigate greenhouse gas emissions. In order to avoid the dire consequences of climate change, the whole world will need to take part in a coordinated effort to reduce emissions to a level determined by the best possible science. Despite nearly 18 years of effort, starting with the creation of the United Nations Framework

Convention on Climate Change (UNFCCC) in Rio de Janeiro and continuing through, most notably, Kyoto, and, most recently, Copenhagen, a politically feasible global policy has not been constructed. Unwilling to wait for an overarching mandate, smaller actors are beginning to enact policies that are politically feasible within their sphere of influence.

In the US, California is the only state with a legislative mandate to reduce GHG emissions. **California's Global Warming Solutions Act of 2006 (AB 32)** is a mere thirteen pages long. It establishes a near-term greenhouse gas reduction goal of 1990 emission levels by 2020 and, in conjunction with a related executive order (S-3-05), calls for a long-term reduction of 80% below 1990 levels by 2050 (CARB, 2010). The California Air Resources Board (CARB) created a scoping plan for the implementation of AB 32. The scoping plan includes a list of early action items, including a tire pressure program and an accelerated renewable portfolio standard. While there is no explicit mandate directing communities or cities to conform to specific levels or methods of emissions abatement, local government is given authority and responsibility for housing, zoning, and transportation planning (CARB, 2010). Further legislation has been passed to help achieve the goals of AB 32.

The centerpiece of state climate change legislation, AB 32, only applies to California. However, if federal climate change legislation moves forward in the coming years, AB 32 will ideally be "a scale model of the national system" (Doniger, 2009). In fact, Rep. Henry Waxman, a Californian, has co-authored the prominent federal climate change bill (ACES) with Rep. Markey (head of the key Subcommittee on Energy and the Environment). ACES narrowly passed the House in June of 2009 and two similar bills, the Clean Energy Jobs and American Power Act (Kerry-Boxer) and the CLEAR Act (Cantwell-Collins) are currently working their way through the Senate. Former Vice President Al Gore has asked President Obama to pass a climate bill by Earth Day in April of 2010 (Lerer, 2009). The Obama administration has encouraged the EPA to take action against climate change and the Agency has quickly responded, publishing the final rule in the Federal Register (EPA, 2009) and approving California’s waiver to regulate GHG emissions from automobile tailpipes.

Focusing on AB 32, and California's other climate change legislation (highlighted at right) will allow this project to, at least, address GHG mitigation required in California. Narrowing the scope, our project focuses on cities in California, even though there is no direct mandate for cities to achieve specific GHG reduction goals. Even without explicit orders to reduce emissions, communities within and beyond California are actively engaged in increasing numbers.

For example, over 1,000 Mayors have signed on to the U.S. Conference of Mayors Climate Protection Agreement (U.S. Conference of Mayors, 2010). This initiative was launched in 2005, on the same day the Kyoto Protocol was ratified by 141 countries, not including the U.S. (U.S. Conference of Mayors, 2008). Mayors have signed the agreement pledge to meet or beat the Kyoto Protocol targets and urge state and federal governments. Why are communities choosing to act? The following responses to that question shed some light on the emerging community-level movement:

AB 32 Supporting Legislation

Assembly Bill 1493, 2002
Pavley Bill for Auto Efficiency
Carmakers must meet increasingly stringent fuel economy standards that phase in between 2009 and 2016

Senate Bill 1078, 2002
Renewable Portfolio Standard (RPS)
Currently a combination of two state bills and two executive orders requiring California to achieve 33% renewable power by 2033

Executive Order S-01-07, 2007
Low Carbon Fuel Standard (LCFS)
Sets a goal to reduce the carbon intensity of fuels within the state by 10% or more by 2020

Senate Bill 97, 2007
GHG CEQA Guidelines
Requires the Governor's Office of Planning and Research to create California Environmental Quality Act (CEQA) guidelines for the mitigation of greenhouse gas emissions or the effects of greenhouse gas emissions

Assembly Bill 811, 2008
Local Renewable Energy Financing
Establishes tax and financial arrangements to promote renewable energy generation as well as energy efficiency improvements permanently fixed to real-estate properties

Senate Bill 375, 2008
Regional Transportation Planning
Assigns each Metropolitan Planning Organization (MPO) a greenhouse gas reduction target for the automobile and light truck sector for the years 2020 and 2035. To ensure MPOs are on track to reach their goals, development of a Sustainable Communities Strategy (SCS) is required as part of their Regional Transportation Plans

“Cities represent the most personally accessible level of government for affecting change, and also represent the greatest concentration of infrastructure available for affecting sustainable design changes and practices. GHGs reduced in communities are dollars saved by those communities. Carbon dollars tend to be dollars exported from communities. Therefore, the more a city reduces its GHGs, the more wealth stays locally in that city.”

-Craig Whan, AECOM Environment

“Global climate change is frankly overwhelming to most people -- and people are inclined to ignore things that are overwhelming. The advantage of working at the local level is that almost every change that reduces greenhouse gas emissions has tangible positive benefits in other areas: saving money, reducing our dependence on foreign sources of energy, creating local jobs and laying the foundation for a more sustainable way of life.”

-Rick Cole, City Manager, San Buenaventura, CA

Segregated actors, representing the public and private sector across geographic and socioeconomic boundaries, have reached the same conclusion: climate change must be addressed from the bottom-up. Our group shares this belief, and our project intends to help communities navigate what will be an increasingly carbon-constrained future.

The Role of Communities

Community and Local Economics

The use of environmental economic theory is imperative to understanding environmental action on all scales of government. Here we are interested in local level governments and economics for addressing the issue of climate change. In the context of federalism, community economic structures can use funds from multiple resources. Community opportunities for grants, loans, subsidies and other funding come from every level of government as well as private industry. The economic drivers within a community then steer the use of these funds towards a desired end. Various community attributes can steer action toward climate mitigation or environmental aid.

Increasing the willingness to pay of citizens increases the likelihood that a community will act on the issue of climate change. Multiple contingent valuation studies demonstrate individuals' willingness to pay for varying non-use environmental aspects (Schkade & Payne, 1994). Further research indicates that this willingness to pay is often related to the visibility and distance from a given service (Concu, 2007; Hanley, Schläpfer, & Spurgeon, 2003). Action on climate change is a global undertaking, however it may be difficult to gain worldwide support (and, especially, funding) because many parties would not see the actions taken. The relation of distance and willingness to pay may partly explain why the world does not act as a whole.

Communities are well suited to overcome the issue of visibility, as those in the community will see GHG reduction strategies implemented within a community. A community's willingness to pay may increase if the citizens can see the solar panels installed or the tree planted. Individuals are more apt to allot funds if the results of the expenditure are close to them as well as visible.

While distance and visibility may provide an increased willingness to pay, communities are additionally incentivized to act because environmental sustainability can lead to economic sustainability. Integrating the environment and economics while aiming at social objectives can increase sustainability in all sectors (Roseland 2000). More specifically, evidence suggests that enhancing buildings and building uses towards consideration of the environment as well as GHG mitigation positively affects economic sustainability (Manewa, Pasquire, Gibb, & Schmidt, 2009). Communities have the ability as well as power to make these changes to establish both economic and environmental sustainability.

"No community is an island in our interconnected world. But neither does it make sense to surrender local identity, local assets and local prosperity to an increasingly precarious global economy. Thinking globally, acting locally isn't just a slogan. It's the right policy for promoting ways we can decouple from dysfunctional dependency. Buying local, eating local, building local are not absolutes, but they are increasingly smart choices."

-Rick Cole, Ventura City Manager

Our research and model demonstrate that it is possible to enact climate change mitigation strategies that are economically advantageous while achieving the targets of AB 32. The next step is to cultivate a political environment willing to implement GHG reduction strategies; the community can reap the economic benefits while the world gains another step toward mitigating climate change.

Community Level Politics

The global nature of climate change requires a unified international effort to abate GHG emissions, however the urgency of this issue and the slow nature of global-scale politics shift the burden to smaller-scale entities. The idea of states being laboratories for the country is posed in order to experiment with solutions to problems. Similarly, communities can fulfill a laboratorial role. Localized efforts allow for quick action at a level of governance that is familiar with its own constituency and community abilities. The importance of communities in mitigating climate change has been emphasized through political and legal actions in California and various local organizations throughout the world.

In the vein of James Madison's concept of "messy federalism", many politicians, judges and lawyers have used the phrase "states as laboratories" to express the power of states as innovators that propel ideas to higher levels of government. This principle can be scaled down to a more localized level: "communities as laboratories". Communities have the power to experiment with new technologies and influence behavioral changes to mitigate climate change. Community action can push forward policy at higher levels of government by showing good faith effort as well as realistic solutions to problems.

Understanding a community's potential for action requires being as close to the actors as possible. Community derived solutions allow those closest to the problem—local governments—to use an "implementer's perspective" approach (Stich & Eagle, 2005). This results in a higher probability of success, due to the more direct path between implementation and the specific set of behaviors that solve the problem (Redlinger & Shanahan, 1986).

Whether by implementing smart-growth strategies, enhancing public transportation or producing renewable energy, proof exists that many communities are acting now. In a speech to the United Nations at COP 15, California Governor Arnold Schwarzenegger further emphasized the role of communities and local governments as an important part of the solution. He recounted that 80% of GHG mitigation is believed to occur at the sub-national level (Schwarzenegger 2009).

California has demonstrated significant effort in the arena of climate change policy. AB 32 is currently the highest level of climate change legislation within the United States. Additionally, in 2007, the State of California filed a lawsuit against San Bernardino County for failing to incorporate climate change into its blueprint for growth. This shows that California is serious about communities' role in implementing climate change legislation; the state will continue to nullify growth plans that fail to address emissions reductions (Reuscher 2007).

The urgency of climate change, along with uncertainty about how to specifically address the issue, make communities an important factor in finding effective solutions. In this project, we provide a toolkit for communities to make well-informed decisions about prioritizing climate action.

Chapter 2: Community Emissions Inventory: Ventura, CA

In order to measure the effect of our reduction strategies, we need a starting point – an emissions inventory. The inventory sets a baseline to establish targets for reduction goals and measure the impact of reduction strategies. The methods we use can be applied to any city; however, in order to test these methods we use the City of San Buenaventura (Ventura), CA as a case study.

Inventory Basics

Although a requirement does not exist yet for local governments, CARB encourages local governments in the state of California to address climate change by conducting inventories of emissions and making climate action plans to implement strategies in their jurisdiction. Another organization, *ICLEI – Local Governments for Sustainability*, encourages local governments throughout the world to take steps toward addressing climate change in their community.

This inventory is an expansion of the government operations inventory reported to the California Climate Action Registry (CCAR) and includes all emissions from activities taking place within the City boundaries. The government operations inventory includes all emissions from facilities, vehicles, and solid waste generation owned and operated by the City. Whereas the community-wide inventory includes emissions from all activities within the City's boundaries including all commercial and residential transportation, energy use, and solid waste generation.

Choosing a year to conduct the baseline inventory depends on many factors including accepted practice, policy, and data availability. Throughout California many cities are choosing 2005 as an inventory year to align with the state targets for reductions. California's Global Warming Solutions Act of

2006, AB 32, references both the year 1990 and 2005 when establishing targets for emissions reductions. In an effort to conduct the most accurate and useful inventory possible, we used the year 2007. This year had the best available data, and our citywide inventory will align with Ventura's government operations inventory, which was also conducted for 2007.

Ventura, CA: Setting and Motivation

In choosing a city for a case study, our client recommended selecting a member of the CCAR. Additionally, we hoped to choose a community that exhibits environmental initiative.

Ventura is located approximately 30 miles south of Santa Barbara and 60 miles north of Los Angeles, along California's South Coast. The City has an area of 21.1 square miles (54.6 km^2) and just over 100,000 inhabitants (U.S. Census Bureau, 2009).

The City of Ventura is a member of CCAR and has shown a high level of political will to reduce the community's GHG emissions. Ventura reported a 2007 government operations inventory to CCAR, including emissions from facilities and vehicles owned and operated by the City. The City also released an administrative report detailing the plans behind the "Green Initiative" for the city. The Green Initiative takes an inventory

Case Study:
San Buenaventura (Ventura), CA

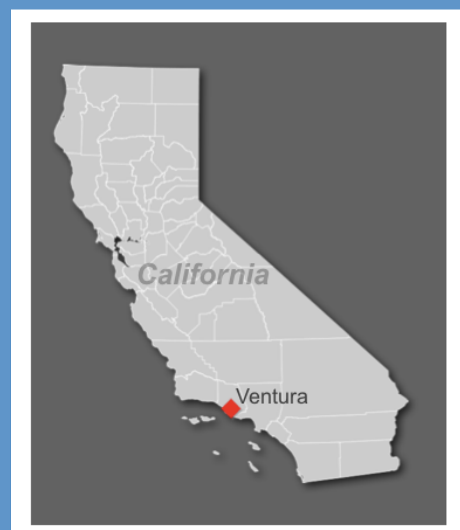


Figure 2.1: Location of Ventura, CA

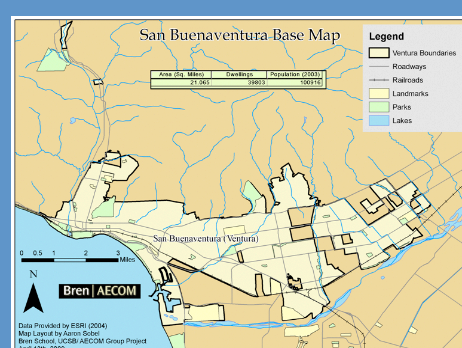


Figure 2.2: Ventura, CA city limits

of all environmental services in the city and recommends changes to those services that improve the environmental sustainability of the city. With regards to greenhouse gases, however, the “Green Initiative” makes limited recommendations and acknowledges that the level of implementation for the recommended changes is low (Calkins, 2007).

Additionally, Ventura drafted a *Post Peak Oil Plan*, which identifies many low-carbon solutions, but addresses neither economic nor political feasibility of these strategies (Chen, Deines, Fleischmann, Reed, & Swick, 2007). In our report, we hope to bridge this informational gap by prioritizing strategy recommendations based on these criteria.

By using data provided by the city and local utilities, we were able to establish a baseline that the city can refer to in the future as they implement strategies to reduce emissions.

Methods and Sources

Currently, there is no established protocol for conducting an inventory of community-wide GHG emissions. CARB has created a Local Government Operations Protocol (LGOP) in collaboration with The Climate Registry and ICLEI, and is currently working toward establishing a Community Protocol. For this inventory of Ventura’s community-wide emissions, we used LGOP as a guide,adapting it to suit a larger scope. The Protocol contains guidelines for recognizing sources of emissions, collecting data, coefficients to use in calculations, and information on reporting emissions. Table 2.1 summarizes the six GHGs included in LGOP, their main sources of emissions, and the global warming potential of each gas.

Emission sources are divided into three different scopes; scope 1 includes direct emissions from inside the inventory boundaries, scope 2 are indirect emissions, and scope 3 do not fall into either of the other scopes and are optional to include in the inventory. Examples of scope 1 emissions include burning of natural gas and tailpipe emissions. Scope 2 is exclusively for electricity generation since the use of electricity is within the inventory boundaries while the GHG emissions from electricity production occur offsite. Scope 3 includes emissions from solid waste. Waste is a scope 3 emission because of the time-delay of emissions from decomposition and because the landfill where the waste is sent is located outside the city boundaries. (California Air Resources Board et al. 2008)

Table 2.1: Greenhouse Gases

Gas	Chemical Formula	Activity	Global Warming Potential (CO_2e)
Carbon Dioxide	CO_2	Combustion	1
Methane	CH_4	Combustion, Anaerobic Decomposition of Organic Waste (Landfills, Wastewater), Fuel Handling	21
Nitrous Oxide	N_2O	Combustion, Wastewater Treatment	310
Hydrofluorocarbons	Various	Leaked Refrigerants, Fire Suppressants	12–11,700
Perfluorocarbons	Various	Aluminum Production, Semiconductor Manufacturing, HVAC Equipment Manufacturing	6,500–9,000
Sulfur Hexafluoride	SF_6	Transmission and Distribution of Power	23,900

(California Air Resources Board et al. 2008)

ICLEI – Local Governments for Sustainability is a non-profit membership organization with offices located all over the world. Their goal is to assist local governments as they commit themselves to combating climate change and achieving sustainability. The City of Ventura is an ICLEI member and able to use the tools and software that ICLEI provides to local governments. ICLEI has developed CACP 2009 (Clean Air and Climate Protection), software that assists local governments in calculating GHG inventories for both government operations and community-wide activities. CACP takes in sources of emissions in their raw units and outputs the CO_2e in metric tonnes emitted from those sources. The total CO_2e is calculated by weighting the gases by each respective global warming potential and adding them together. This common unit allows for comparison between the various sources of emissions while accounting for the varying types of GHG emitted from these sources.

Data Sources

The following sections outline what data was collected for each activity contributing emissions to the inventory and which agencies provided this data. These activities were divided into three sections: transportation, electricity and natural gas use, and solid waste generation. Additionally, we provide guidance to assist other communities in future inventories and their necessary data acquisition.

Transportation

We collected the transportation data in vehicle miles traveled (VMT) for the City. SCAG (Southern California Association of Governments), the metropolitan planning organization for the region, uses a trip demand model in order to calculate average daily weekday VMT for each of the counties in their jurisdiction. The most recent model estimates were for the year 2003 and this report is publicly available on SCAG's website. Annual VMT for the year 2007 was the data we needed for this City of Ventura inventory. In order to generate this number, we made the following calculations using the estimates provided by SCAG:

First, we applied a population growth rate to the VMT number for 2003 in order to estimate VMT in 2007. We then scaled down this countywide VMT number to the city level, proportionally Ventura County's population to City of Ventura's population in 2007. Then, we multiplied this number by 365 days to get an annual VMT, however, the daily VMT calculated represented only weekday travel. In order to remedy this discrepancy, the number was multiplied by 94%, an established conversion factor for converting weekday to average daily VMT (Kim Sturmer 2009). The final number calculated was nearly 776 million miles annually. When this number was entered into CACP, the California default vehicle profile was applied to determine the fleet-wide fuel efficiency. After determining the fuel efficiency, the total number of gallons of fuel was calculated and the CO_2 coefficient for the burning of gasoline and diesel was used to estimate the CO_2 emissions from vehicle transportation. Vehicle tailpipe emissions also include CH_4 and N_2O. These emissions, however, are dependent on just the miles travelled by the vehicle, not the amount of fuel used. See Appendix I for the default vehicle profile and coefficients use in the transportation calculations.

For other communities in California, the agencies most likely to have transportation data available are the Metropolitan Planning Organizations, city departments of transportation, and the California Department of Transportation. Trip demand models are currently the most sophisticated models for estimating vehicle miles traveled in a given area.

Electricity and Natural Gas

We estimated the GHG emissions from electricity and natural gas use using total kWh of electricity and therms of natural gas used throughout the City. For Ventura, there is one electricity provider, Southern California Edison and one natural gas provider, Southern California Gas Company. There are many privacy restrictions associated with accessing energy use information from utilities, so there was some difficulty in acquiring the data necessary. Fortunately, the Ventura County Regional Energy Alliance worked with Southern California Edison and Southern California Gas Company and already obtained data from 2007 for all of Ventura County. Electricity and gas use for the City of Ventura was separated out using the zip codes within the City's boundaries. This data was organized into two categories, residential and commercial, and totaled about 638 million kWh and 28 million therms (see Appendix I for the breakdown of electricity and natural gas use in Ventura). The coefficient for CO_2e emissions from natural gas is a constant, but the coefficient associated with electricity use varies from one utility to another depending on how their electricity is generated. For Ventura, we used a coefficient specific to Southern California Edison.

Any of the utilities throughout the state should be able to deliver this data to a community wishing to conduct an inventory, however privacy regulations may make it difficult to obtain. Also, the more detailed the information is the better; if the energy use is broken down into many categories (such as residential, commercial, industrial), the reduction strategies can be more specifically targeted toward a source of emissions. The EPA has CO_2e coefficients available through their eGRID database; this database contains both state averages and specific coefficients for utilities.

Solid Waste

Although emissions from solid waste are optional scope 3 emissions, we included them in this inventory. The City of Ventura monitors its waste generation closely and provided total tons of waste sent to the landfill in 2007. The material breakdown of this waste, characterized by California Integrated Waste Management board, included primarily paper and food waste. The city operates its own green waste programs, so those emissions were not included in the calculated emissions from landfills. In total, Ventura sent 119,505 tons of waste to the landfill; 32% of which was paper, 38% food, and 30% other waste (CalRecycle 1999) (Appendix I contains a detailed breakdown of the waste and coefficients used). Many landfills have a methane capture in place; the landfill where Ventura sends its waste captures 90% of methane and uses the gas to power microturbines (where electricity generation is sent back to the grid) and fans to dry out sewage sludge.

Most local governments monitor solid waste generation for the jurisdiction. Additionally, landfill managers monitor where the waste is picked up from and can usually provide an estimate of waste generation for a specific area. It is also important to learn from the landfills if a methane capture system is used and, if so, how much methane is captured. The makeup of the waste is also important for determining emissions from decomposition; the California Integrated Waste Management Board has estimates of the composition from all cities.

Table 2.2: Community Wide Inventory Data and Associated Emissions

Sector	Data Source	How to Acquire	Raw Data	CO_2e emissions (metric tons)
Transportation	SCAG	Local Metropolitan Planning Organization	775,797,795.72 Vehicle Miles Traveled	401,259
Electricity	Southern California Edison	Local Utility	638,441,233 kWh	183,975
Natural Gas	The Gas Company	Local Utility	27,937,976 Therms	147,843
Waste	City of Ventura	Environmental Services Division	119,505 Tons	3,119
Municipality	City of Ventura	Environmental Services Division	14,109 Metric tons CO_2e	14,109
Total				**750,305**

Assumptions and Limitations

This inventory does not include all sources of GHG emissions; due to time constraints, availability of data, and accuracy of available data, priority was given to the largest sources of emissions. Other sources include emissions from refrigerants, agriculture, rail transportation, and air transportation. Many of these emission sources are difficult to quantify at the community scale. Furthermore, the contribution of emissions from these sources to the complete inventory is de minimis. In the Local Government Operations Inventory, a de minimis level of 5% is used, meaning any emissions that represent less than 5% of total emissions are below the level of significance (California Air Resources Board et al. 2008).

We made estimates in conducting the inventory, but the transportation sector in particular has many estimates and assumptions. The main difficulty in estimating transportation emissions is that they must be modeled; whereas other sources, including electricity, natural gas, and waste, can be measured directly. SCAG uses a trip demand model, which is currently the best way to assign vehicle miles traveled to a certain region (Southern California Association of Governments 2008).

Another assumption in conducting the community-wide inventory is that Ventura has only control over emissions within its City boundaries. In fact, the City does have some influence on residents, businesses, and the community in general just outside the official boundaries of the City. This also exemplifies the need for not just community action in addressing climate change, but also a regional effort to coordinate inventories and reduction strategies.

Results

Figure 2.3, below, graphically displays Ventura's GHG emissions from the community as a whole. The largest source of emissions was gasoline use in vehicles, followed by electricity use. More than half of the City's emissions can be accounted for by transportation fuels (53%), while electricity and natural gas use in homes and buildings accounts for 45%. The remainder of the inventory is from small contributions due to waste generation and the City's municipal operations.

The City already completed a thorough inventory of its emissions from government activities prior to this project; this inventory is displayed in Figure 2.4 (detailed numbers surrounding the government operations inventory are provided in Appendix I). Although the government operations only make up 2% of the City's total emissions, the City government can set an example for residents and businesses in Ventura by reducing their individual contribution to the City's GHG emissions. For the City government, their largest source of emissions was from water distribution, followed by the emissions from wastewater treatment. As strategies for reduction are explored, some strategies will reduce emissions from just the government operations while others will reduce emissions on a larger scale throughout the community.

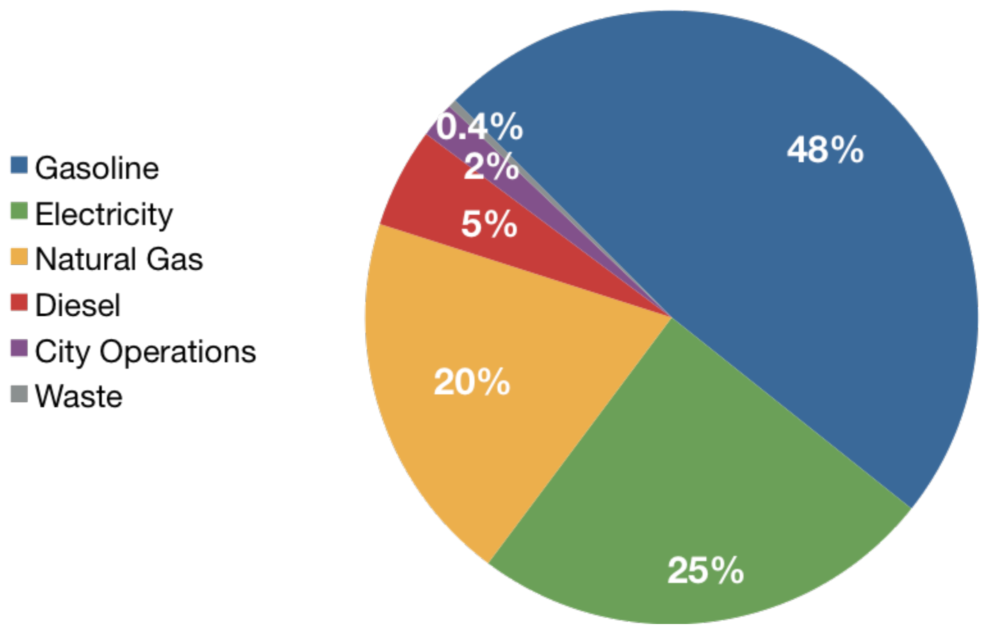


Figure 2.3: Ventura 2007 Community-Wide GHG Emissions Inventory

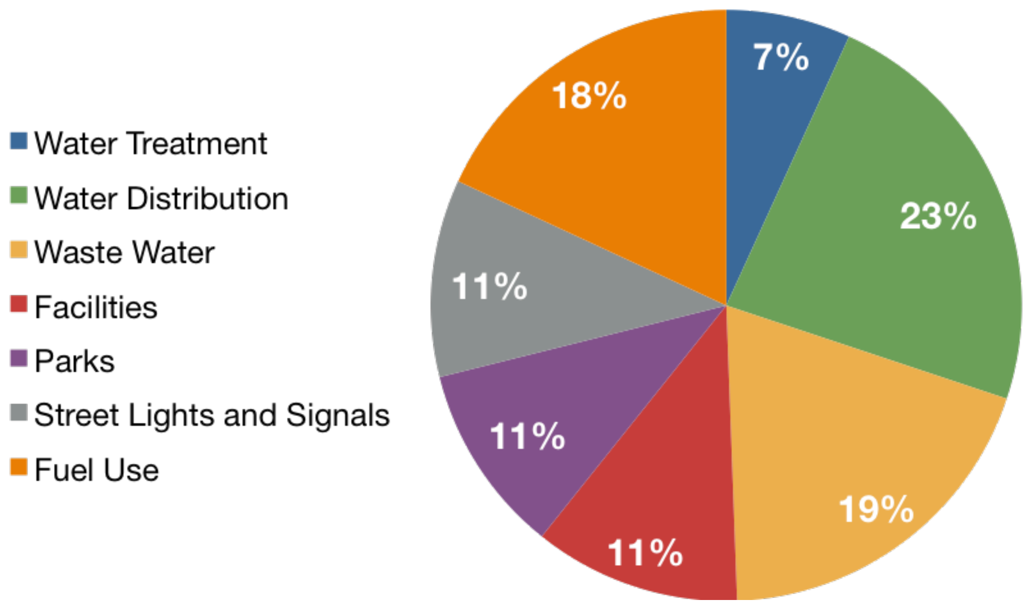


Figure 2.4: Ventura 2007 Government Operations Inventory

Table 2.3: GHG Emissions Comparison

	Total Emissions (metric tonnes CO_2e)	Population	Per Capita Emissions
City of Ventura	750,305	102,739	7.3
California*	479,800,000	36,458,000	13.2
United States	7,150,000,000	299,398,000	23.9

* 2007 inventory data for California was unavailable; these numbers are for 2006.
Sources: *California Air Resources Board, US EPA*

Table 2.3 compares Ventura emissions to those of California and the United States as a whole. The per capita emissions of Ventura were much less than the California per capita emissions and significantly less than the average per capita emissions for the entire United States. This is primarily due to Ventura's mild climate, resulting in fewer emissions due to reduced heating and cooling requirements. Additionally, Ventura is home to very little industry, so California and the United States as a whole have more of those emissions to account for.

Chapter 3: Economic Feasibility

Economics of Controlling Greenhouse Gases

Global climate change is an example of what is referred to in environmental economics as a collective action problem. The action of one individual – here, emitting GHGs – is not by itself necessarily harmful. However, the aggregate impact of the actions – in our case, decades of global GHG emissions – of multiple individuals can have significant consequences. These unintended consequences of actions are known as externalities, and are unaccounted for in traditional market calculations.

Greenhouse gas emissions are a new breed of externality, and represent perhaps the biggest market failure of all time. The long-term nature of climate change costs and the difficulty in valuing the transformation of the planet make traditional tools like cost-benefit analysis (CBA) difficult to apply in a climate change context (Stern 2008). Economists have asserted, however, that despite (and perhaps because of) the uncertainties involved in climate change, bold action to slow climate change is an economically sound decision (Tol 2003, Maddison 1995, Stern 2008).

This project accepts the assertion that worldwide mitigation is warranted, and focuses instead on the economics of reducing emissions on a localized, city scale. In the context of California's policy goals for reducing emissions—and assuming that communities wish to meet these policy goals—we perform a **cost-effectiveness analysis** (CEA) of attaining reduction goals at the least cost to the community. By compiling strategy-specific CBA and emissions savings calculations, our model prioritizes emissions reduction strategies by one of two criteria (at the user's preference): lowest cost-per-reduction *or* shortest payback-per-reduction.

Emissions Reduction Strategies

Myriad strategies exist for reducing GHG emissions. The heart of the analysis—and the bulk of our research—lies in a menu of twenty emissions-reducing strategies. We mean not to imply that we have vetted all strategy possibilities. Considering the timeframe and scope of this project, we focused closely on twenty strategies, with the understanding that more may be included in the future, and—as we will see—more strategies will be necessary to achieve the long-term goals of addressing climate change

We thoroughly researched and analyzed each of these twenty strategies (listed at right), performing a complete CBA of implementation as well as calculating potential emissions savings for the community.

As a proof of concept and a model designed for broad applicability, we sought to research and program a diverse set of strategies into our model, representing reductions from various energy sectors. We chose strategies based on three key criteria:

1. Strategies to reduce emissions from each sector in the emissions inventory: Gasoline, Diesel, Electricity, Natural Gas, and Waste.
2. Strategies from varying approaches to reducing emissions: Energy efficiency, renewable energy production, sequestration, emissions capture, and policy innovation.
3. Strategies that could be implemented broadly, not necessarily only in Ventura.

GHG Reduction Strategies

Air Conditioning Efficiency
Attic Insulation
Bicycle Infrastructure
California Corporate Average Fuel Economy (CAFÉ) Standard
Compact Fluorescent Lamps
Cool Roofs
Landfill Methane Capture
Light Emitting Diode (LED) Lamps
LED Street Lights
California Low Carbon Fuel Standards
Low-Flow Showerheads
Low-flow Toilets
Planting Trees
Public Transportation
Rainwater Harvesting
Rooftop Solar Photovoltaic Cells
California Renewable Portfolio Standard (RPS)
California Tire Pressure Program
Traffic Signal Timing
Water Heater Efficiency

Our research includes upfront costs of installation or implementation, annual cost savings, annual maintenance costs, and energy- or direct emissions-savings associated with each strategy. For a detailed look at the inputs, requirements, assumptions, and sources of each strategy, please see Appendix IV.

Compiling Strategies into a Cost-Effectiveness Analysis

Abiding by the city's geographic and demographic constraints, we calculate the upfront cost of implementing an emissions reduction strategy. Each strategy is then assigned a coefficient,which determines the order of implementation. We provide the user two alternatives for this ordering procedure.

Option 1: Least Upfront Cost
Cities operate under limited budgets, which are further constrained by competing priorities. Despite long-term cost savings, an oft-cited concern with implementing low-carbon strategies is the large upfront cost. Option 1 of our cost-effectiveness analysis gives prioritized recommendations for achieving reductions while minimizing these initial costs.

The coefficient for Option 1 is the ratio of its emissions saved to the upfront cost:

$$\chi = \frac{tonnes\ CO_2e}{Initial\ Cost}$$

The strategies are listed in order of the highest X coefficient. We then move down the list, tallying emissions saved by each strategy, until either:

1. The emissions reduction goal is achieved; or
2. Each strategy is fully implemented according to the city's geographic and demographic constraints. This indicates that we were unable to reach the emissions goal with our twenty reduction strategies under the provided level of implementation.

Option 2: Shortest Payback Period

If a city possesses capital to direct toward emissions savings, but wishes to recoup its investment in the shortest time period possible, Option 2 provides recommendations for how to achieve this goal, prioritizing strategies based on the highest ratio of emissions saved to payback period:

$$\rho = \frac{tonnes\ CO_2e}{Payback\ Period}$$

Payback period is calculated by weighing the initial costs and yearly cost savings in a discounted fashion, as follows:

$$Payback\ \ Period_{strategy} = T_{PP}, \qquad \text{when}:$$

$$Cost_{initial} - \sum_{t=0}^{T_{PP}} \frac{Payback_{annual} - Cost_{annual}}{(1+r)^t} \leq 0$$

Similarly to Option 1, emissions savings are counted strategy-by-strategy, beginning with the highest ρ ratio, until the emissions target is reached or we run out of strategies.

This option will recommend firstly the strategies that will not only effectively reduce emissions, but will most quickly regain the initial investment.

Summary

Using our model, SAFEGUARD, we provide an economically prioritized list of GHG-reducing strategies for a community to undertake, based on a user-specified cost-effectiveness analysis of either lowest upfront cost or shortest payback period.

The economic feasibility of abating emissions largely influences its likelihood of implementation, however it is not the whole story. The order of these prioritized recommendations will change depending on each strategy's level of implementation.

Community willingness to introduce GHG-saving strategies depends on many factors, many of which are unique to each locale. The examination of political feasibility is an important next step to establishing a realistic outlook of the future of community greenhouse gas controls.

Chapter 4: Political Feasibility

Introduction

While geographic constraints and economic cost-effectiveness are critical to broad implementation of GHG reduction strategies, political feasibility is the determining factor in the success or failure of a strategy.

The role of communities is central to the success of emissions mitigation. Communities have the ability to act quickly and create innovative solutions. Successful implementation in one community demonstrates the achievability of strategies and provides an example that other entities can follow. To truly determine locally achievable strategies, however, one must understand the political nature of the relevant community.

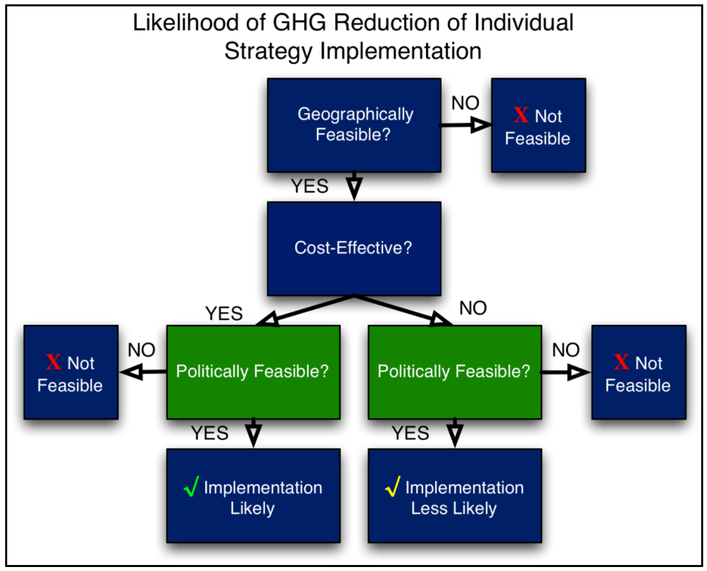
Measuring Political Feasibility

Quantifying political feasibility is a difficult and contentious undertaking, as it is closely tied to public opinion (often very diverse). Surveys and polls are well-established methods for determining public opinion, but are costly and time consuming (Groves et al., 2004). Other indicators, such as party affiliation and involvement with interest groups, have been evaluated as measurements of political will, but strong correlations have yet to be found (Daley & Garand, 2005). Instead of expending effort on controversial and indefensible measurements, we have included adjustable implementation levels within SAFEGUARD, allowing the strategy recommendations to reflect the realistic political will of the community.

To most realistically gauge the political will at the individual level, our project brings political feasibility to the level of the city manager or a similarly situated individual with an excellent grasp and understanding of local political variations. Regarding local opinion, local people are best suited to address them. SAFEGUARD's design relies on input from politically attuned city officials with sufficient knowledge and understanding of their community.

Political Feasibility Aspect of Model

We address the political feasibility of GHG reduction strategies for a community through extensive customizable options within each of the strategies.



SAFEGUARD prioritizes recommendations based on cost-effectiveness. However, addressing the political feasibility of GHG reduction strategies requires an extra step. The customizable features of the model address political feasibility, allowing the user to explore the details of, and make decisions about, each strategy. While economics often determine political feasibility, the user ultimately controls whether or not to include a strategy in the analysis. Each strategy includes a checkbox to enable or disable a strategy in the analysis, regardless of economic efficiency.

Additionally, each strategy has a slider allowing the user to specify the amount of the strategy that could feasibly be employed. Additionally, the user can alter default values included within each strategy to reflect changes in prices or technology.

The customization options in SAFEGUARD address community concerns through the lens of the user. Likely, different users will provide different perceptions of political feasibility. Running a sensitivity analysis of the model indicates that changes to political feasibility, selecting checkboxes and adjusting sliders, greatly alters whether policy goals are ultimately achieved. The more and better information the user has, the more helpful SAFEGUARD can be in its recommendations.

The willingness of the population to act is ultimately the determining factor in whether or not a strategy will be implemented. The measure of this willingness is encompassed in political feasibility. Even if SAFEGUARD can prove a strategy is more economically feasible than another, a manager or implementer still may not be interested based on political reasoning. The customizability of SAFEGUARD, with checkboxes and sliders, allows for this feasibility to be determined by those closest to the community itself.

To support the customizable features, we provide guidelines to help the user determine political feasibility:

Guidelines for Determining Political Feasibility

Political factors and considerations when selecting strategies (checkboxes):

- Is the money there?
  - Is there a relevant and easily identifiable revenue stream?
  - Up-front cost
  - Long-term funding
    - i.e. grants, loans, incentives, payback
  - What are the other priorities?
    - i.e. education, roads, police
- Who pays and who benefits?
  - State, city, citizens, homeowners
    - i.e. city pays for public transit, citizens benefit
- Does the city have legal authority to do this?
  - i.e. limited taxing authority, LED streetlights ownership
- Will the city need to change codes or zoning?
  - i.e. wind, solar panels
- Is there a relevant agency?
  - Is the agency competent, capable, efficient, non-corrupt and willing?
    - i.e. Department of Transportation, Water District
- Are the relevant actors willing and capable?
  - i.e. residents, businesses

- Is there a need to build a coalition extending beyond the city itself?
    - i.e. methane capture and energy generation
- Is there likely to be serious political opposition?
- See write-ups for specific barriers of individual strategies

Political factors and considerations when adjusting applied amount of strategies (sliders):

- Consider the population that has already adopted a strategy and adjust to include all capable of doing so in the analysis.
    - The economic analysis should address whether the city will do it after the financial situation is known.
- Once initial economic analysis is run then consider the following:
    - Available resources of those responsible for implementation
        - Will there be a need for advisory services to help people take the relevant actions?
    - Available funds and resources for public outreach and education
        - Will there be a need for a PR campaign to inform people regarding what is expected?
- See write-ups for specific barriers of individual strategies

Summary

Reducing GHG emissions requires navigating a complex and variable political environment. SAFEGUARD's highly customizable design allows the user to address political feasibility at the community level. Checkboxes allow the user to determine the city's broader interest, including or excluding entire reduction strategies. Sliders enable the user to fine-tune reduction strategies, setting the level of implementation feasibility. To aid in the process of checkbox and slider adjustment, we provide a convenient political consideration framework.

Chapter 5: SAFEGUARD and the Role of Modeling

SAFEGUARD is a proof of concept tool for communities seeking the most cost-effective methods to reduce their GHG emissions. While the background and technology that make up SAFEGUARD are complicated, the software itself is meant to remove the user from that complexity. This section will introduce some of the mindset that went into creating SAFEGUARD. Here we will explain some of the technical underpinnings of the software, the way we designed SAFEGUARD to work, and some of the scientific background and logic that converges to meet our goals.

At its most basic level, SAFEGUARD is a data collection tool and a calculator. Once the collection of data is completed, the software is ready to create a report to help guide policy makers to effectively reduce their community's emission levels. Strategies are like pieces of an equation and city-specific data are the variables in that equation. SAFEGUARD runs through thousands of these equations within seconds and ranks strategies in order from most cost-effective to least cost-effective. It continues this ranking process until there are no strategies left to run or the GHG reduction goal is reached. The results are displayed in an easy-to-read, printable format.

Why Modeling Is Relevant

The goal of the model was to create a scalable, enterprise-worthy toolkit that would be effective for analyzing GHG strategies in communities. It could be a leverage tool for consultants to win contract bids for this new and upcoming type of work. SAFEGUARD was built from the ground up, based upon the theory that a tool for addressing greenhouse gas reductions should be accessible, timesaving and extendable.

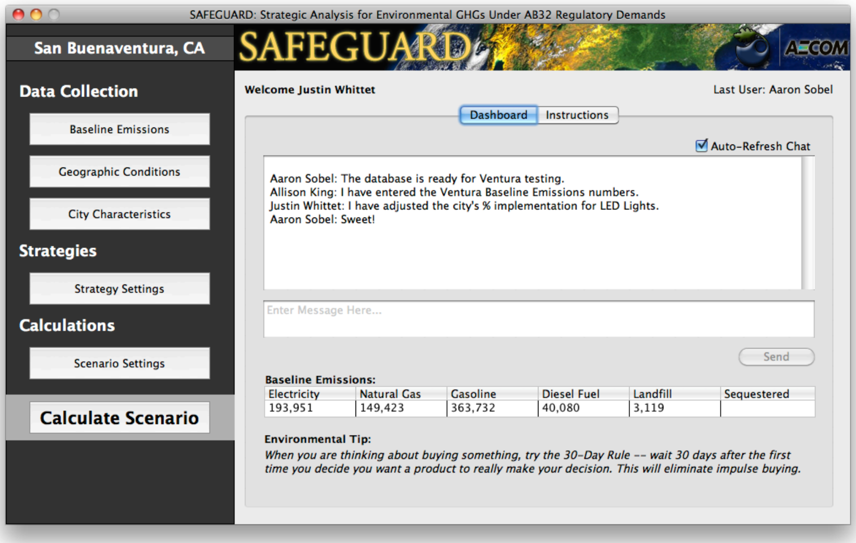


Figure 5.1: SAFEGUARD's interface was designed to simplify the entire process for users. All steps have instructions and relevant information readily available so users can spend less time searching. Information is kept timely by using a built-in web browser for data collection and the software's ability to see if it is the most current version.

Accessibility means that users do not need weeks of intensive training to begin using the tool. It also means that multiple computers can run the software and access the latest version of the data.

The software is designed to be timesaving. Consulting companies sell their employees' time, and that time is valuable. This means that the software needs to help improve workflow. In SAFEGUARD, data collection is streamlined and tedious calculation work is delegated to the software to avoid costly mistakes.

SAFEGUARD's plug-in framework allows continuous updates and expansion. Similarly to how modern web browsers allow users to add to the base functionality, SAFEGUARD was written with template plug-ins to allow for additional strategies in the future. If prospect communities have particular affinities for a new strategy, the consulting company using SAFEGUARD can use the plug-in template to add the strategy. With the new plug-in, all future SAFEGUARD analyses can then benefit from the ability to use the newly coded strategy in their own analysis.

The Tool

We wrote our software from scratch using REALbasic programming language, a language similar to Visual Basic. An important advantage of using REALbasic is the ability to create identical copies of the program that run on all three major operating systems (Mac OS X, Windows and Linux) using one common code base.

The Database

We selected a client-database model to organize all the data that users would collect. A central server hosts all of the data. This allows users to focus on their project rather than file revisions. We selected MySQL for the database due to its set of features, including networking capabilities and security features. Multiple consultants can work on a project from multiple locations with only an internet connection required. Perhaps most importantly for a consulting corporation using the toolkit, the database allows for control over the information collected. There can be multiple collaborators per city and many cities per consultant.

The database includes updated information on the newest known coefficients for emissions from each kWh of electricity generated or default values for costs of fuels.

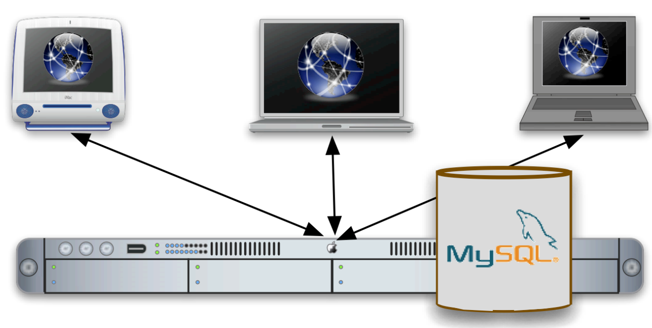


Figure 5.2: All the data for SAFEGUARD lives on a central server and can support multiple SAFEGUARD clients simultaneously on a local network or over the Internet. Data is protected through multiple layers of logins, permissions and encryption.

In order to protect the security of the database, we created a simplistic three-tier encryption algorithm. MySQL requires its own login and password but each user still needs their own account and access to view a particular city's data.

Baseline Emissions

SAFEGUARD is a tool for reducing community-wide emissions. As such, any city must complete an initial baseline for emissions prior to using SAFEGUARD. Many tools and methodologies exist for this task, such as those from ICLEI and CCAR, though the approach of measuring emissions for an entire community is still a work in progress. The baseline emissions ask for six categories: electricity, natural gas, gasoline, diesel fuel, landfill, and sequestration. CO_2e is the common unit for all of this data. See *Chapter 2* for more information about conducting the community-wide GHG inventory.

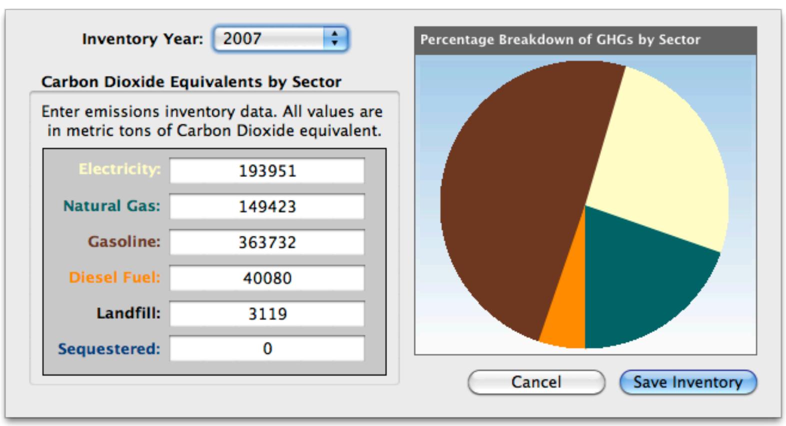


Figure 5.3: The results from the greenhouse gas inventories that communities conduct are entered into SAFEGUARD to create a starting point for reductions.

Strategies

A strategy is a means of reducing CO_2e emissions. SAFEGUARD's main purpose is to be a guidance tool for cities to reduce their emissions through smart selection of strategies. These vary from simplistic changes like changing light bulbs to more complex strategies such as increasing public transportation.

Each strategy was intensively researched and reviewed by the group. Assumptions and specifics of each of strategies can be found in the appendices of this paper. This same information is also available to the user within SAFEGUARD's strategy settings window.

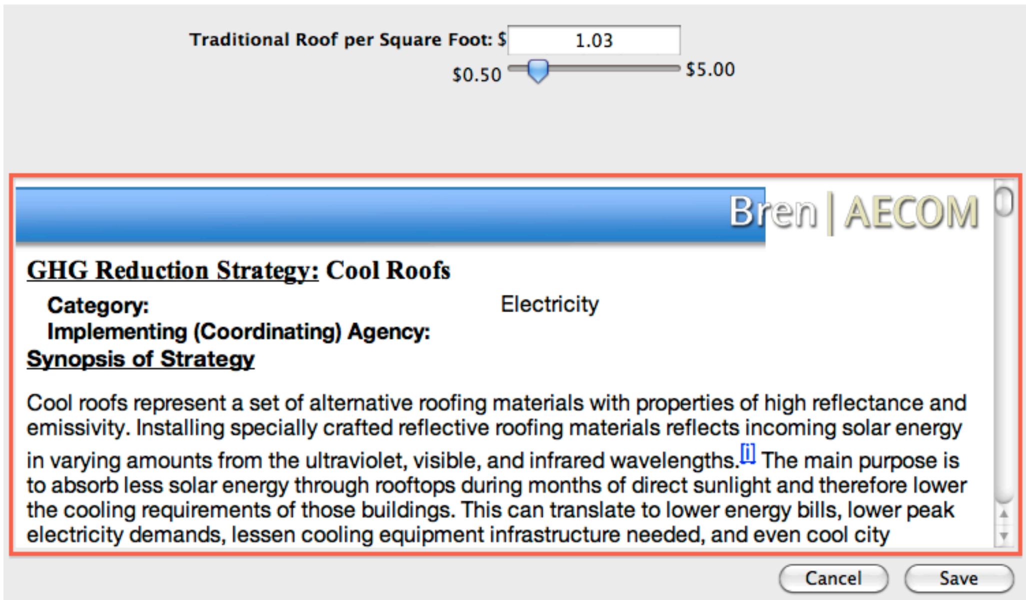


Figure 5.4: Each strategy has its documentation available within SAFEGUARD's strategy settings window. This explains the basics of the strategy, as well as documenting the sources of the data used to code the strategy.

By default, SAFEGUARD automatically selects Strategies to meet the specified emissions reduction goal in the most cost-effective manner. In an effort to make the tool more useful for communities, the user has the ability to "force" the strategies through, including their emissions savings and cost analysis into the recommendations regardless of where they would otherwise rank in the analysis.

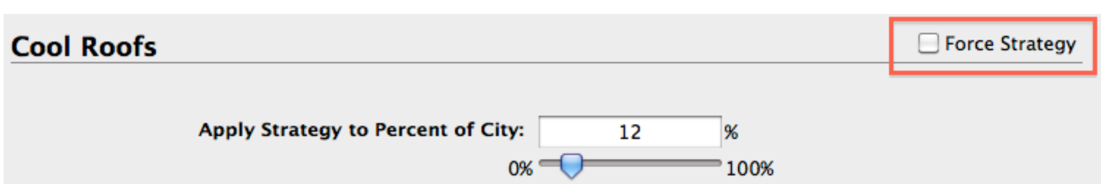


Figure 5.5: A checkbox is available for each community-level strategy to allow the strategy to run in the scenario regardless of the economic efficiency.

Strategies as Plug-ins

We developed strategy modules to write the code behind each individual strategy and created a template to follow for adding more strategies to the software. The modules are implemented based upon a plug-in structure where 90% of all the functional code is written and contained within the module and the other 10% is interface creation in the software. The template was written and updated frequently to account for new methodology or stretching past the initial conception of the model. Each strategy module contains the user variables required and the calculations specific to the strategy. The calculations include: the amount of fuel savings, the emissions reductions, cost savings, net present valuation, and payback period. Finally, the module incorporates everything into the final report.

Each community-based strategy module is designed with two outcomes: a cost-effectiveness ratio for ranking the strategy (based upon capital cost or payback period) and results of the emissions and economic analyses. The ratio-ranking system is not applied to state strategies, which are implemented by the state without community control. Still, the city benefits from emissions saved thanks to state strategy implementation.

The strategies included thus far focus mainly on physical and behavioral changes that would either reduce or offset emissions. An example of offsetting emissions is the rooftop photovoltaic panels strategy, which assumes any electricity generated by the PV panels offsets the emissions of electricity that would be generated offsite. During the process of the model's creation, we realized that the model could also include strategies with emissions reductions from state-implemented mandates, increased education and even behavioral changes. As long as well-documented research demonstrates causality, most any means of reducing CO_2e emissions can be modeled in SAFEGUARD. Our twenty strategies are just a start.

Calculations

SAFEGUARD needs strategy-specific data to calculate costs, benefits, effects on fuel use and the resulting GHG reductions. We emphasized ensuring replicability as we collected the necessary inputs. The user guide illustrates the methods and sources used to determine each input. We found general geographic and city inputs, as well as individual strategy requirements, using referenced sources and websites. We do not expect inputs within individual strategies to change independent of inflation or technology advances, however, the user can edit these numbers if better estimates become available. The city-specific variables required to run the model can generally be found using reputable websites. For direction, the pertinent website and instructions for its use are displayed live in a window adjacent to the data field in SAFEGUARD. Some inputs require specific technical expertise; total roof space, for example, requires utilization of GIS mapping tools. In these few cases, detailed instructions are given in the SAFEGUARD user manual, but assistance from other government offices or consultants may be needed.

In order to reduce from the baseline emissions, we use five primary variables for converting from fuel use to CO_2e. Generally, each strategy reduces the need for a fuel, and this decrease in fuel use is translated to emissions reductions using the following conversion factors: CO_2e per gallon of gasoline, CO_2e per gallon of diesel fuel, CO_2e per therm of natural gas, CO_2e per kWh of electricity and CO_2e per ton of landfill waste. These were not the only means of reducing emissions but serve as the primary means of doing so. Transportation in particular serves as an example of how the emission per unit of fuel was only a portion of the emissions reduction possibilities.

Table 5.1: Carbon Dioxide Emissions Per Fuel Type

Fuel Type (per Unit)	Example Values (tonnes of CO_2e per unit of fuel type)
Electricity (per kWh)	0.00043
Gasoline (per Gallon)	0.00887
Diesel Fuel (per Gallon)	0.01010
Natural Gas (per Therm)	0.00530
Waste (per Short Ton)	0.98883

(Sam Bateman 2009)

Emissions coefficients are not hard-coded into the software, but are automatically pulled from the database. This allows for easy updates, should newer data become available. For example, the CO_2e per gallon of gasoline (used for several strategy calculations) is pulled from the database in the newest form available. If the State low carbon fuel standard strategy is implemented, however, the amount of CO_2e per gallon of gasoline will decrease. SAFEGUARD can update to the new fuel-emissions conversion factor, and use that number in all strategies that concern gasoline use (California Energy Commission 2009).

GHG emissions from electricity use are highly variable—based upon a complex mixture of both generation sources and base load versus peak generation capacity. The emissions of CO_2e from natural gas power plants are, on average, lower than those from coal-fired power plants, and renewable power facilities such as wind turbine farms have essentially zero CO_2e emissions in the energy production phase (Wade, Ashley, and Jesse 2005).

EPA has created the eGrid dataset, a helpful tool for estimating these emissions for any given locality, based on the emissions intensity at local power plants (EPA 2009). Additional sources such as the California Energy Commission have provided similar information for their specific grid emissions. SAFEGUARD currently has data for Southern California Edison, Pacific Gas and Electric, San Diego Gas and Electric, and an average of California power generation.

The user has three options for determining the reduction target: AB 32 goals, S-3-05 goals, and a specific percentage reduction. In order to reduce to the year 1990 emissions levels or even 80% below them, the actual 1990 emissions level for the community must be determined. It is highly unlikely that a community has 1990 data, as community GHG accounting is a newly emerging field. We established a method for back-calculating an estimate of 1990 emissions, reducing proportionally along emissions trends for the entire state of California. This statewide data is available from the California Air Resources Board (CARB 2005).

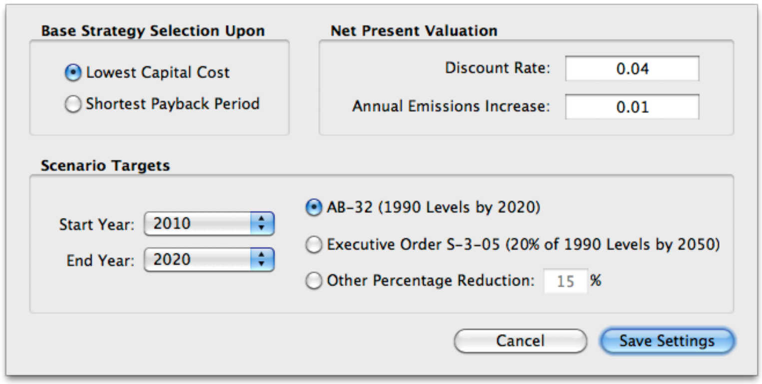


Figure 5.6: The scenario targets follow linear paths to the ultimate goal of the AB-32's 1990 level of emissions and Executive Order S-3-05's 80% less than 1990 level emissions.

State-mandated strategies are the first strategies to run. They are assumed to have no cost of implementation to the community, although their benefits are realized. Examples of these are the Renewable Portfolio Standards, Low Carbon Fuel Standards and the California Tire Pressure Program. The state strategies will have an effect on community's CO_2e emissions without any new policies from the local governments. The user has the option, however, to run scenarios without the state strategies to see what the city can do on its own.

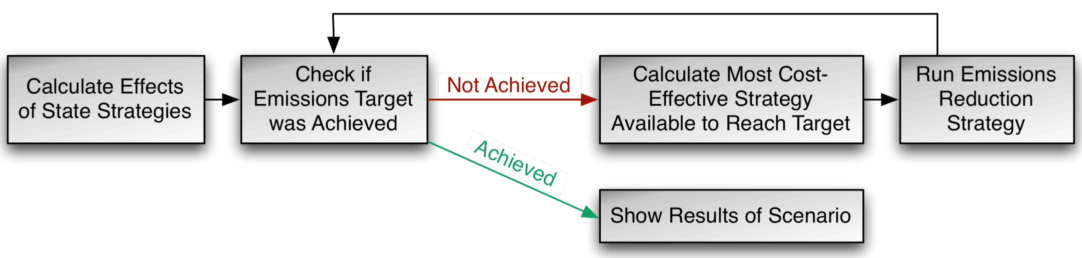


Figure 5.7: The above steps are taken each time a scenario is calculated. Strategies are run continuously until the greenhouse gas emissions target is reached for the community or SAFEGUARD runs out of strategies to run.

An ongoing loop runs until either:

1. The emissions reduction targets for the city are met, or
2. SAFEGUARD runs out of available strategies to run.

A subroutine runs each strategy calculation to see which of the available strategies has the best possible cost-effectiveness ratio, as detailed in

Chapter 3. Each successive ratio is compared against the current best ratio until all available strategies are compared. The strategy with the best ratio is then run, and the results are calculated and stored in arrays to be deconstructed in the reporting phase.

The cycle of comparing ratios and calculating results is merely seconds long but encompasses a multitude of calculations. It also incorporates the intricacies of the impacts that one strategy may have on others.

Results

The SAFEGUARD report displays the most important pieces of information necessary to understand the results of the analysis, including:

- Emissions breakdown before and after strategy implementation
- Indication of whether or not the emissions target was achieved
- Total capital costs of all strategies needed to reach the emissions target
- Net present value of implementation and cost savings
- Payback period of implementing relevant strategies
- Average annual per capita energy cost savings
- Assumptions such as emissions growth and economic discount rate

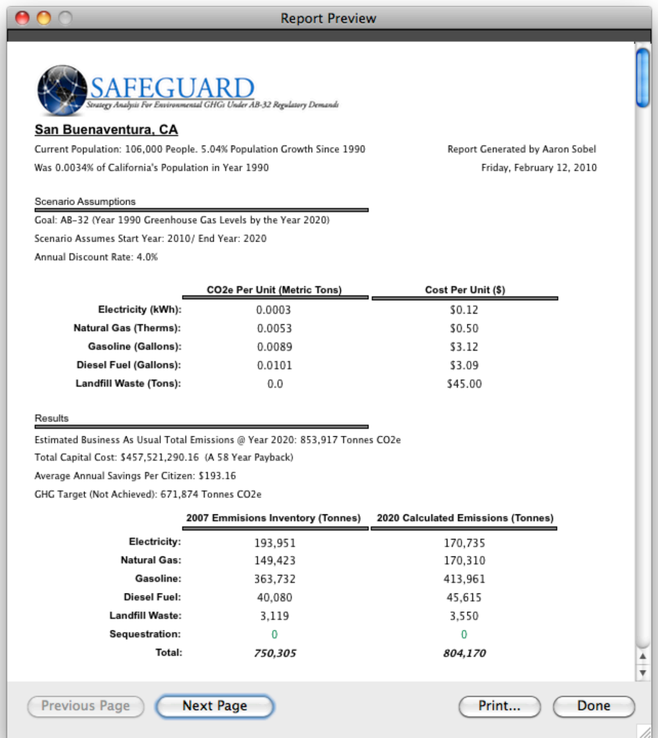


Figure 5.8: The reports front page shows the overall results for the city and some of the most basic assumptions that were made. It shows the greenhouse gas emissions baseline for the city and the expected emissions for the city with the implemented strategies at the target year. The calculated emissions also include the emissions growth that occurs in the interim based on a business as usual approach. This BAU value is user-supplied and defaults at one percent compounded interest annually.

Similarly, for each strategy that runs, an individual report of its results and assumptions is included. The report presents the annual emissions reduced at the target year and the net present value, payback, and per-capita savings for each strategy. The strategy reports are ordered from the most cost-effective to the least cost-effective, aligned with the user's selected scenario settings.

Conclusions

SAFEGUARD simplifies the very complex process of estimating emissions reduction possibilities for communities. While the precise reduction targets necessary to alleviate the worst concerns of global climate change are always under debate, the pursuit of cost-effective emissions savings is valuable information. SAFEGUARD attempts to recognize patterns in the calculations process and leverage those consistencies in order to assist communities as they make the necessary changes to become more sustainable. Though the tool was designed to be used by a consulting company, it is usable by almost anyone with at least a cursory knowledge of environmental science. It is a proof of concept in its current form, but the framework design holds potential for widespread, useful implementation.

Chapter 6: SAFEGUARD in Action: The Case of Ventura, CA

Armed with city-wide baseline emissions and fully researched reduction strategies, the model was almost ready to run. Technical qualities of strategies will vary with time, but are similar across the United States. However, city-specific inputs vary widely from community to community and influence how costs, benefits and technology interact. For example, rooftop solar panels cost the same amount regardless of geographic location, but the amount of solar irradiation determines energy production. In turn, energy production determines payback and GHG reduction. Each strategy relies on at least one city-specific variable, or input, in order to accurately calculate costs, benefits and GHG reduction potential. This chapter describes these inputs and presents the results of the SAFEGUARD analysis of Ventura, CA.

Model Inputs

The city-specific variables necessary for SAFEGUARD to accurately prioritize reduction strategies for a given city are listed here, organized by categories accessed from SAFEGUARD's main window.

Table 6.1: Required SAFEGUARD Inputs by Window

Input	Recommended Source	Relevant Strategy
	Baseline (Inventory)	
Electricity	Utility	Inventory
Natural Gas	Utility	Inventory
Gasoline	Department of Transportation (in vehicle-miles traveled)	Inventory
Diesel	Department of Transportation (in vehicle-miles traveled)	Inventory
Landfill	Waste Hauler	Inventory
Sequestered (optional)	Dependent on sink (i.e. # of trees from Public Works)	Inventory
	Geographic Conditions	
Building Climate Zone	www.energy.ca.gov/maps/building_climate_zones	Cool Roof

	Geographic Conditions (continued)	
Sunlight	Choose from menu (source: NREL)	Rooftop Solar
Annual Precipitation	www.weatherbase.com	Rainwater Collection
Heating & Cooling Degree Days	www.weatherdatadepot.com	Insulation
Full-Load Air Conditioning Hours	www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls	Air Conditioning
	City Characteristics	
Square Feet of Roof Space	Landsat imagery of GIS building shape layer	Cool Roof, Rooftop Solar
Electricity Provider	Choose from menu (utility-provided coefficient)	Various
Fuel Prices	Relevant utility rate schedule, market research	Various
Population	quickfacts.census.gov	Growth Projections
Number of Homes	factfinder.census.gov	Various
Number of 100 Watt Street Lights	City Public Works Department	LED Street Lights
Power per Water Distribution	City or Water Provider (in kWh/Million Gallons)	Various
Power per Water Waste Treatment	City or Water Provider (in kWh/Million Gallons)	Various
Weekday Passenger-Miles Traveled	nhts-gis.ornl.gov/transferability (need City census tracts from GIS files, for example)	Public Transit, Bike Infrastructure
Private Vehicle Mode Share	Department of Transportation (relevant Association of Governments in CA)	Public Transit, Bike Infrastructure
Average Private Vehicle Occupancy	Department of Transportation (relevant Association of Governments in CA)	Public Transit, Bike Infrastructure
Number of Signaled Intersections	City Public Works	Coordinated Signal Timing

Model Results

We performed analysis on three scenarios for the city of Ventura to show the effect of the political feasibility settings. The primary scenario used application percentages suggested by Ventura Environmental Services Supervisor Joe Yahner. We then raised the application percentages to 50% and 100% of full potential for all strategies. For each of the three levels of application, we analyzed two emissions target scenarios: one for the AB 32 2020 goal and one for the executive order 2050 goal. These six scenarios are detailed below.

Base Scenario

After consulting with Joe Yahner, we set the application rates of the selected strategies to his recommended levels (Table 6.2). Per Ventura's request, strategies were prioritized based on highest emissions reduction per dollar of capital cost.

SAFEGUARD determined the optimum mix of strategies to reach the AB 32 goal, but the ambitious Executive Order goal was unattainable. The top-down State strategies always run first and are responsible for the majority of the reductions required under AB 32. The reduction scenarios and recommended strategies can be seen in figures 6.1 and 6.2. The strategies recommended for the AB 32 goal are, in order: CFLs, increased bike infrastructure, LEDs, low-flow shower heads, efficient water heaters and increased public transit. This mix of strategies has an estimated capital cost of $67,967,270 and a payback period of two years, if implemented at year one. Without the State strategies, the AB 32 goal cannot be reached with these levels of application for our twenty strategies. Regarding the Executive Order goal, this level of application resulted in emissions of 10% above 1990 levels in 2050. The twenty strategies were unable to fully offset the assumed business-as-usual emissions increase.

Table 6.2: Political feasibility recommended by Ventura, sliders set at estimated application rate

Strategy	Estimated Application	Justification
Compact Fluorescent Light Bulbs (CFLs)	30%	~10% existing. Incentives needed
Cool Roof	12%	~15% of commercial buildings
Efficient Water Heaters	10%, 5%, 40%	Upgrade, Solar, Reduce temperature (temp. encouraged by gas company)
Increased Bike Infrastructure	12%	City wants to encourage cycling
LED Street Lights	5%	City only owns ~800, will convert ~500
Light Emitting Diode (LED) Light Bulbs	5%	Expensive & not easily installed
Low-Flow Shower Heads	15%	~25% existing
Low-Flow Toilets	10%	~10% existing
Planting Trees	5,000 trees	Includes residential. Force strategy & include non-market benefits
Public Transit	10%	Currently little interest
Rooftop Solar Photovoltaic (PV)	10%	City offers discounted rain barrels
*Note that State-mandated strategies run at 100%, assuming full compliance with the law.		

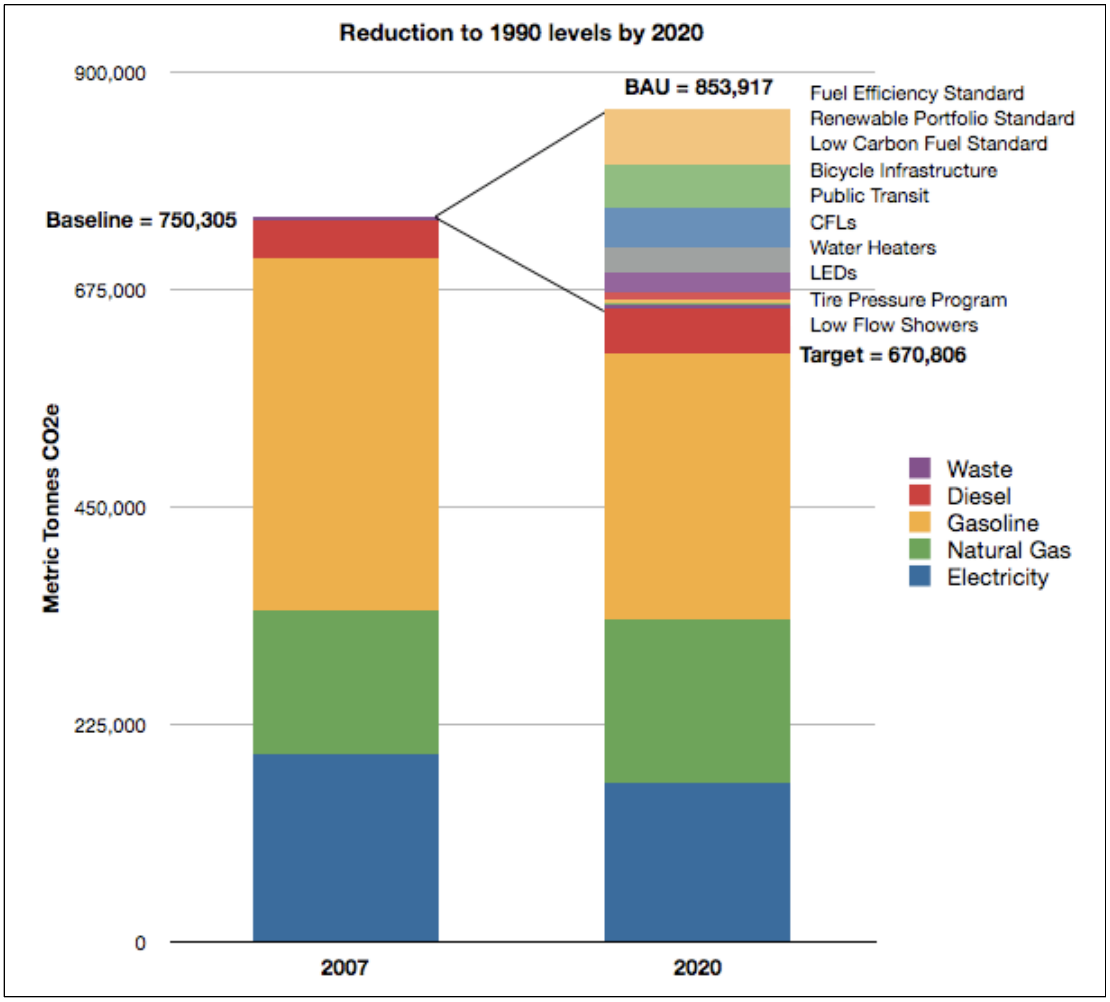


Figure 6.1: AB 32 reduction goal achieved with Ventura-specified strategy application levels

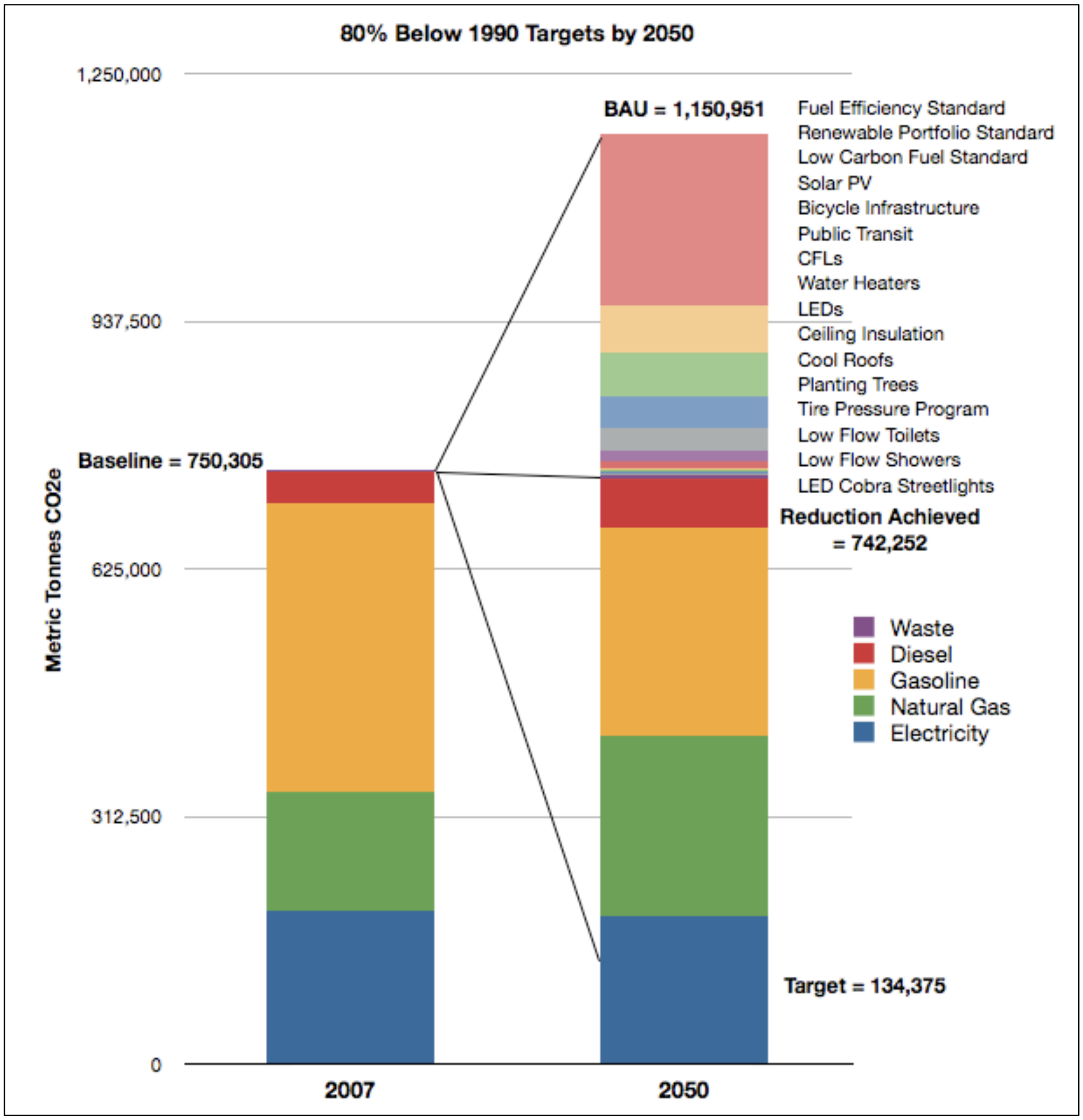


Figure 6.2: Executive Order reduction goal not achieved with Ventura-specified strategy

Preliminary Recommendations

Focusing on the legally binding AB 32 goal of returning to 1990 emission levels by 2020, we recommend Ventura support the State strategies and focus on the two or three most cost effective strategies as determined by SAFEGUARD. The State-mandated strategies are predicted to achieve 22% of the goal. As shown in the City's Political Feasibility scenario, six additional strategies would be needed to achieve the AB 32 goal at a capital cost of about $68 million. This cost does not include maintenance costs or the costs associated with implementation (i.e. coordination and resources required by the relevant actors). Alternatively, the 50% Feasibility scenario shows that only two strategies would be needed to reach the AB 32 goal. The two most cost effective strategies, in terms of upfront costs, are CFLs and increased bike infrastructure. The capital cost of switching half of all light bulbs in the city to CFLs and building enough bike infrastructure for one quarter of Ventura's residents to rely on a bicycle for transportation would be $38,505,000.00. This is almost $30 million less than the previous scenario. That savings could be applied to incentives, outreach and education that would help to achieve the 50% application rates needed.

In Amsterdam, the bike capital of the world, almost 40% of trips are taken by bicycle and Portland, Oregon has seen an increase of over 8% bicycle mode share after building over 200 miles of infrastructure in about 15 years. Based on this anecdotal evidence, it is possible that Ventura could significantly increase its bicycle mode share by building new infrastructure.

Sensitivity Analysis

50% Feasibility Scenario

In an attempt to reach the Executive Order goals of 80% below 1990 levels by 2050, we raised the application levels, or political feasibility, of each strategy to 50% of full potential. The actual percentage was not raised to 50% for some strategies due to overlaps and strategy-specific issues. Strategy combinations that overlap—public transit with bicycles and cool roofs with solar PV—were set at 25% each. The number of trees planted was raised by 50% to 7,500. The number of homes reducing water heater temperature was raised from 40% to 70% and the number of homes using solar water heating was doubled, from 5% to 10%.

This scenario revealed that AB 32 goals could be reached with only two strategies in addition to the State strategies: CFLs and increased bike infrastructure. Because these strategies have the lowest capital cost per emission reduced, the model estimated a total capital cost of $38,505,000 with a payback of one year. Removing State strategies from the simulation required two additional strategies, planting trees and ceiling insulation, to the six strategies recommended above in order to reach the AB 32 goal. The 2050 target was still not achieved; as Figure 6.3 shows, SAFEGUARD found a maximum potential reduction of 12% below 1990 levels by 2050 at a capital cost of $1.32 billion and a seven-year payback.

100% Feasibility Scenario

In a further attempt to reach the Executive Order goals, we raised the application levels, or political feasibility, of each strategy to 100%. As with the previous scenario, the actual percentage was not raised to 100% for some strategies to address overlaps and strategy-specific issues. Strategy combinations that overlap—public transit with bicycles and cool roofs with solar PV—were set at 50% each. The number of trees planted was raised to 10,000. The number homes reducing water heater temperature was raised from 70% to 100% and the number of homes using solar water heating was raised from 10% to 15%.

As in the 50% application scenario, only CFLs and bike infrastructure were needed in addition to State strategies to achieve the AB 32 at a total cost of $38,850,000 and a payback period of one year. Still, however, the 80% reductions below 1990 levels were not achieved. The maximum potential reduction of all currently programmed strategies at full implementation is 46% below 1990 levels (see Figure 6.3) with a capital cost of $2.56 billion and an eight-year payback period.

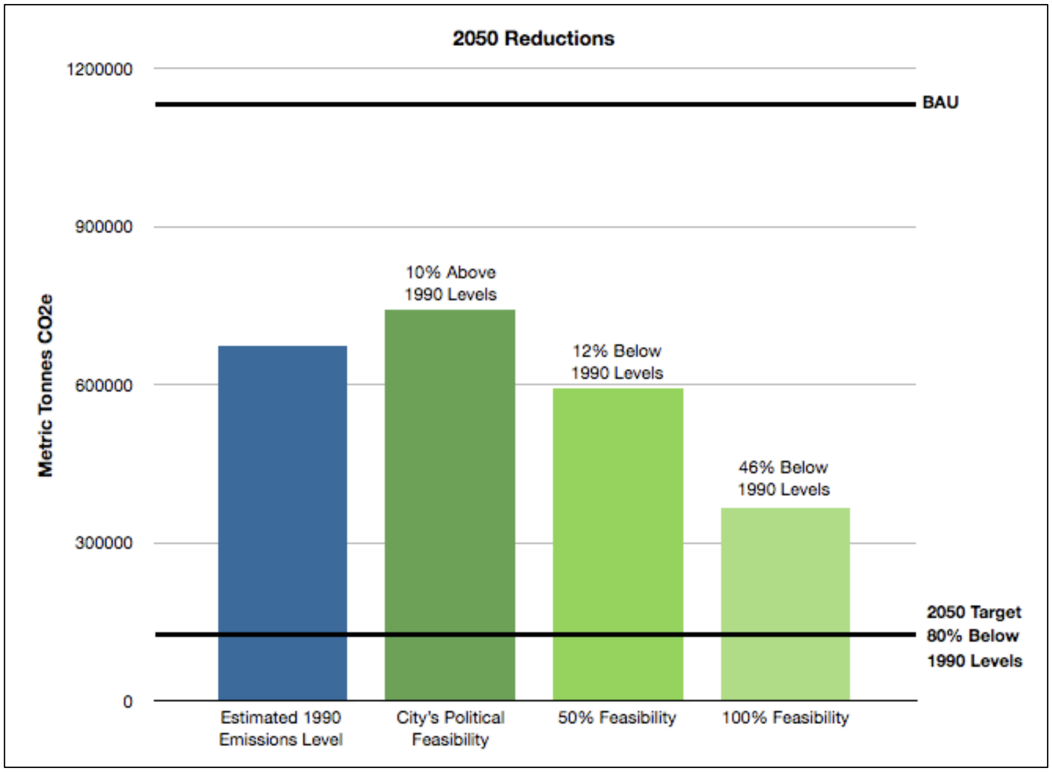


Figure 6.3: GHG reductions towards the Executive Order goal under multiple feasibility

Detailed Recommendations

Recommended Actions for Ventura

- Invest in incentives and outreach to increases use of compact fluorescent lamps (CFLs) and light emitting diode LED light bulbs in homes. Full details regarding payback and net present value can be found in the SAFEGUARD report.
    - A 50% increase in CFLs equates to 276,000 CFLs replacing 60W incandescent lamps at an estimated capital cost of $345,000. CFLs have a lifespan of about five years. Annual $C0_2$ reduction by 2020: 13,226.6 metric tonnes.
    - A 5% increase in LEDs reflects converting 27,600 incandescent bulbs requiring an upfront cost of approximately $1,379,724. LEDs last for about fifty years so this strategy would also apply towards future reduction goals with no additional cost. Annual CO_2 reduction by 2020: 2,082.5 metric tonnes.
- Invest in bicycle infrastructure, building approximately 127 miles of bike lanes and related facilities at a capital cost of $38,160,000. Annual maintenance is estimated at $826,000. This strategy would eliminate 79,426,018 vehicle-miles traveled annually. Annual $C0_2$ reduction by 2020: 28,994.1 metric tonnes.
- Invest in public outreach, education and incentives.
    - CFLs cost about $1.25 each and are generally cheaper if purchased in bulk. Incentives for purchase could be supplied by the city in conjunction and with a preference for local businesses. Outreach and education efforts can be combined for encouraging use of CFLs and LEDs, and minor behavior changes. Emissions- and cost-savings depend on the number of bulbs replaced and the number of hours each bulb is used. Behavioral changes such as turning lights off as much as possible can save additional emissions. Coupling outreach efforts to conserve power and incentives to replace, where possible, more than 12 bulbs per home could be beneficial.

This campaign could even be part of, or lead up to, a broader energy conservation program – unplugging chargers and appliances, reducing water heater temperatures, increasing refrigeration temperatures, hanging clothes out to dry and the like.

- LEDs cost about $50 each but last up to 50 years—a long-term investment. This may be better for government, businesses or upscale homes (target market). We recommend outreach and education along with CFLs and other electricity demand behavior changes, as above.

- Cycling is a good fit for Ventura due to the gentle weather and terrain. Direct consumer incentives can be provided for bicycle purchase and maintenance, giving preference to local businesses. The federal government provides a $20 monthly incentive for cycling to work (SFBC, 2009). Additional commuter-targeted incentives could include: parking cash-outs and business incentives for providing secure storage, locker and shower facilities. Ventura can further encourage cycling by providing more bike racks on buses and providing education. Bicycle classes focusing on etiquette, laws, riding in traffic and maintenance can be organized by the city, a willing NGO or a public-private partnership (PPP). Similar agencies or coalitions could operate a bike co-operative for education, purchase, maintenance and recycling. A successful example of a co-op exists in Santa Barbara (Bici Centro, 2010). City-wide efforts to advertise the benefits and acceptance or "coolness" of cycling can help build a healthy and active cycling culture. Special events can focus on commuters, such as a bike-to-work week instead of just one day. To increase GHG savings from the transportation sector, outreach and education campaigns could emphasize walking and other forms of non-motorized transportation. An example of promoting cycling and walking is occasional weekend street closures. Successful cases include Ciclovia in Bogota, Columbia; Sunday Parkways in Portland, Oregon, and Sunday

Streets in San Francisco, California (LivableStreets, 2009; Portland, OR Office of Transportation, 2010; Sunday Streets, 2010). This type of event could use sponsors to share costs. Bike share programs, such as one example in Paris, France, have also been shown to increase ridership and can generate money for city if coupled with outdoor advertising (Nadal, 2007). A bike share feasibility study has been conducted for San Francisco, CA (SPUR, 2009).

Next Steps

- Determine agencies and organizations that are capable of designing and providing incentives and conducting education and outreach.

- Conduct further research into strategies. Many technical details can be found in the individual strategy write-ups contained in Appendix IV. Investigation of successful examples of implementation, organization and outreach efforts can use case studies, non-profit organizations, and companies providing light bulbs and bikes as good points of departure.

- Expand light bulb conversion analysis to include businesses. While not included in this analysis, SAFEGUARD could calculate these potential savings with additional data.

Chapter 7: Deliverables & Discussion

This project includes three main deliverables:

1. **A citywide emissions inventory for the City of Ventura**
2. **SAFEGUARD software**
3. **SAFEGUARD analysis and recommendations for Ventura**

The community inventory sets a baseline for the City to monitor progress toward achieving their reduction target. The SAFEGUARD software is a modeling tool for cost-effectively choosing politically feasible emission reduction strategies. This is a valuable tool for environmental consultants providing recommendations to community residents and officials that are taking action to reduce their emissions. The analysis for Ventura proves the capabilities of the model and its ability to provide an initial list of reduction strategies that can be implemented in the City of Ventura in order to achieve the AB 32 goal of returning to 1990 levels by the year 2020. The City can now conduct further research into the implementation of these strategies and complete a more accurate estimate of costs and associated emissions reductions. The intent of this project is that many more communities will utilize the SAFEGUARD software and find its analysis helpful in establishing a preliminary plan to reduce GHG emissions from all the community's residences and businesses.

Ventura City Emissions Inventory

In order to run the analysis with our case study city, Ventura, we conducted a city-wide baseline emissions inventory for Ventura for the year 2007. This was Ventura's first citywide emissions inventory, and it was delivered to the Ventura Environmental Services Supervisor, Joe Yahner, in October 2009.

The emissions inventory numbers and details can be found in *Chapter 2.*

SAFEGUARD Software

The main deliverable to our client, AECOM, and the centerpiece of the project is our software, **SAFEGUARD: Strategy Analysis for Environmental GHGs Under AB-32 Regulatory Demands.** This software was built from the ground up using REALbasic, and runs our model using a clean, user-friendly interface.

A complete description of the building blocks of SAFEGUARD can be found in *chapter 5: SAFEGUARD: The Role of Modeling*. SAFEGUARD also comes with an integrated user manual.

Sensitivity Analysis

As the result of SAFEGUARD is an ordered list of strategies, a somewhat unorthodox sensitivity analysis was conducted to examine the effects various inputs on the output strategy recommendations. By varying utility prices, we draw comparisons to the initial Ventura output results. Other variations we examined include changing implementation percentages, and including or excluding the top-down, State strategies.

Table 7.1: Changing Fuel Prices.

Utility Prices	2007	Low Scenario	High Scenario
Electricity	$0.12	$0.08	$0.16
Natural Gas	$0.50	$0.40	$1.25
Gasoline	$3.19	$2.50	$5.00
Diesel	$3.09	$2.50	$5.00
Water	$0.008	$0.006	$0.01

Varying these utility prices, we tested the sensitivity of the strategy prioritization, annual savings, and payback period.

Significant fuel sensitivity findings:

1. Key differences arose when increasing electricity prices: payback period reduced by one year, and both solar PV and cool roof strategies moved up in the ordered list of optimized strategies. More money is saved by these electricity demand-reducing strategies when electricity costs more.

2. Also, when gasoline prices increased, payback period reduced by one year and annual per capita savings increased higher than any other sensitivity scenario. This is tied closely to the significance of State strategies' drastic reduction of gasoline consumption at virtually no cost to the city.

Three less significant but notable findings:

1. Conversely to finding 1 above, lower electricity costs moved solar PV lower on the list (cool roofs was already at the bottom so it did not move down).
2. Lower natural gas prices moved cool roofs up the list, as implementing cool roofs increases natural gas consumption for home heating. Therefore, the cheaper natural gas is, the more cost-effective cool roofs are.
3. Lower water prices moved low-flow toilets down the list, as they therefore would save less money with each flush.

Table 7.2: Analysis with and without State strategies

	2020	2050
With State Strategies	Attain reduction goal 2 year payback	Do not attain reduction goal 5 year payback
Without State Strategies	Do not attain reduction goal 13 year payback	Do not attain reduction goal 10 year payback

As the table indicates, without the top-down, State strategies included in the analysis, the 2020 emissions reduction goal is not achieved for Ventura. As expected, the payback period is increased without the State strategies. However, interestingly, payback period without the State strategies decreased from 2020 to 2050. This occurs due to a link between VMT growth over time and increasing bicycle and public transit infrastructure. That is, as VMT grows over time, so does money saved from these strategies.

Without the State strategies, emissions savings from electricity, gasoline, and diesel are decreased for the other strategies. Eliminating the State strategies results in higher emissions intensity from these fuels, in turn decreasing emissions savings when the fuel is burned.

Adjusting implementation without State strategies:

The more citizens willing to implement each highly recommended strategy, the lower the total capital cost of reaching the 2020 goals becomes. With higher levels of implementation for the most cost-effective strategies, more emissions are reduced with those top choices and fewer of the less cost-effective strategies are required to reach the target.

Without the State strategies, we find that up to 50% implementation is necessary to achieve 2020 goals in Ventura. By 2020, it is likely that California will in fact not achieve full implementation of the State strategies we simulate, most notably the renewable portfolio standard. If this is to be the case, a city like Ventura should focus their attention and resources on the cheapest and most effective strategies – CFLs, bicycles, LEDs, showerheads, and water heaters – in order to achieve 1990 emissions levels even without the State strategies.

Chapter 8: Conclusions and Future Directions

The SAFEGUARD model provides cities with a preliminary estimate for the most cost-effective, politically and geographically feasible strategies to achieve the GHG emissions policy goals for California. Although the software has its limitations, it can be a useful tool for providing cities with a starting point as they research GHG reduction strategies. There are many assumptions in the analysis; however, the results still provide valuable insight for the Ventura community and city government. Future research can address some of these limitations and assumptions and expand upon the work done in this project.

Assumptions

Our software model, SAFEGUARD, is the key deliverable of this project. At this stage, it is designed for use by cities in California. With minor adjustments, the software could be used on a larger scale, such as a region or state, or on a smaller scale, such as a business. The strategies included in SAFEGUARD are by no means an exhaustive list. There are many strategies—smart growth, city planning, and long-term transportation planning—that, while difficult to quantify using our concept, will undoubtedly play a significant role in controlling GHG emissions.

As with most cost-benefit analyses, the distribution of the costs and benefits is not accounted for. At the community level, there are diverse actors and agencies that bear the costs and reap the benefits of implementing reduction strategies: residents, city government, regional agencies, state agencies, businesses and industries. Though the costs and benefits are not assigned to specific actors or agencies, the analysis still represents the most efficient way to reduce emissions.

There are four State strategies included in the model: California Fuel Efficiency Standards, Renewable Portfolio Standard, Low Carbon Fuel Standard, and Tire Pressure Program. These strategies are backed by state legislation and have goals that extend to 2016 or 2020. One large assumption in the model is that these programs are successful in achieving these goals. Also, the model does not assume future goals beyond 2020 even though it is likely that these goals will be extended as California strives to attain the 2050 GHG reduction target. These strategies are implemented at the State level and the reduction benefits are experienced all over the State. Because the direct costs for implementation come from outside the boundary of the City of Ventura, there are no costs included for these strategies. The model assumes that these strategies are implemented to the same extent across all regions of the State; in reality, this may not be the case.

With energy efficiency technology, a phenomenon known as the rebound effect has been observed. Studies have shown that the estimated energy savings from the enhanced energy efficiency are reduced by the behavioral response of higher consumption to the increase in efficiency (e.g., people drive more after purchasing a hybrid vehicle). Thus, the resulting emissions reductions are less than what would be calculated if behavior remained the same. The rebound effect is difficult to quantify and there is no consensus about the magnitude of this effect. There are mechanisms for controlling rebound through incentives, but these are not well developed and were not included in the model.

Recommendations for Future Research

A clear next step for the expansion of this model is to include more strategies in the software. The twenty strategies that are programmed into SAFEGUARD do not represent all of the possibilities for reducing emissions. These strategies alone are unable to counteract the assumed business-as-usual emissions to reduce Ventura's emissions 80% below 1990 levels by 2050. A combined effort will be necessary to bring the City's emissions down to this level: the State must strengthen existing policies, the City must increase the feasibility of implementation for strategies. However, for a more realistic picture, more strategies must be integrated into SAFEGUARD. As new technologies and GHG-controlling methods become available, it will be important to continually update the menu of strategies.

Political feasibility is inherently difficult to quantify. Joe Yahner, Ventura Environmental Services Supervisor, provided estimates for political feasibility. In the future, a survey may be a helpful tool for achieving more accurate values for which strategies can be implemented and to what extent. This survey could ask residents and business owners about their willingness to implement strategies from the list. Another option would be to hold town hall style meetings to gain this same information from discussion with community members.

With the exception of planting trees, public transit, and bicycle infrastructure, the cost benefit analyses include only market values. The non-market values included for these strategies include reduced air pollution, indirect cooling effects provided by shade from trees, and other health benefits. Future research conducted on additional non-market values would make our CBAs even more robust. The inclusion of non-market values may reduce net costs and affect the strategy prioritization of the model.

Communities over the world are looking at ways to reduce GHG emissions and adjust to a carbon-constrained future. In fact, many sub-national parties are working to address climate change regardless of the existence of a national or international agreement. The governments of California and Jingshu, a province in China, have signed an agreement of collaboration and cooperation as the two states work toward the common goal of low-carbon communities. The results of SAFEGUARD analyses for California communities can be shared with communities in China. Additionally, a model similar to SAFEGUARD could be developed to address the specific needs of Chinese communities. As it currently stands, SAFEGUARD is designed specifically for cities within California. However, with adjustments and further research, this model can be used to analyze communities at any scale or location.

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*Please note: appendices have self-contained references.

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Appendix I: Greenhouse Gas Emissions Inventory Background

Transportation Emissions Details

California Vehicle Profile

The numbers below represent the percent of California's vehicle fleet for the year 2007.

Vehicle Type	% of California's Vehicles
Gasoline Powered Vehicles	
Passenger Cars	32.4
Light Trucks	60.6
Diesel Powered Vehicles	
Heavy Duty Vehicles	5.4
Light Trucks	1.3
Passenger Cars	0.3

CH4 and N2O Emissions from Vehicles

CH_4 and N_2O emissions make up less than 2% of total emissions from vehicles. The vehicle miles traveled determines the amount of CH_4 and N_2O emitted and varies depending on the model and age of the vehicle. In ICLEI's CACP 2009 software, there is a default setting to use when this breakdown of age and model of all vehicles is not known, as was the case for Ventura's community-wide inventory. This default setting creates default values to use for CH_4 and N_2O emissions based on the statewide average for ages and models of vehicles in 2007.

Vehicle Type	CH_4 emissions (grams/mile)	N_2O Emissions (grams/mile)
Gasoline Powered Vehicles		
Passenger Cars	0.028	0.029
Light Trucks	0.031	0.043
Diesel Powered Vehicles		
Heavy Duty Vehicles	0.0051	0.0048
Light Trucks	0.00099	0.0015
Passenger Cars	0.0005	0.001

Conversion Factors

Fuel Type	Emission Factor (Tonnes CO_2/gallon)
Gasoline	0.0088
Diesel	0.0101

Electricity and Natural Gas Use Emissions Details

Zip Code	Residential Electricity Use (kWh)	Residential Natural Gas Use (therms)	Commercial Electricity Use (kWh)	Commercial Natural Gas Use (therms)
93001	58,053,399	5,163,256	33,143,851	5,236,690
93002	7,727	-	436,689	-
93003	98,243,306	8,180,841	261,755,787	4,025,410
93004	54,736,556	4,460,770	32,036,750	510,998
93005	-	-	168	-
93009	-	-	-	360,011
TOTAL	211,067,988	17,804,867	427,373,245	10,133,109

Waste Emissions Details: Ventura's Waste Profile

Waste Type	Tons of Waste Sent to Landfill	Percent of Total Tons of Waste
Paper	35,741	32.41%
Plastic	10,582	9.60%
Metal	6,432	8.75%
Construction	9,652	8.75%
Glass	3,793	3.44%
Mixed Residue	2,028	1.84%
Household Hazardous Waste	295	0.27%
Special Waste	53	0.05%
Other Organic	41,706	37.82%
TOTAL	110,282	100%

Emissions Factors

Waste Type	Emission Factor (tonnes CH_4/ton of waste)
Paper Products	1.94
Food Waste	1.09
Plant Debris	0.62
Wood/Textiles	0.55
All Other Waste	0

Appendix II: Equations

Net Present Value

$$NPV_{strategy} = Cost_{initial} + \sum_{t=0}^{T} \frac{Cost_{annual} - Payback_{annual}}{(1+r)^t}$$

r = discount rate
t = year
T = life of the project

Payback Period

$$Payback\ Period_{strategy} = T_{PP}, \qquad \text{when :}$$

$$Cost_{initial} - \sum_{t=0}^{T_{PP}} \frac{Payback_{annual} - Cost_{annual}}{(1+r)^t} \leq 0$$

Emissions Cost-Effectiveness Coefficients

$$\chi = \frac{tonnes\ CO_2e}{Initial\ Cost} \qquad \rho = \frac{tonnes\ CO_2e}{Payback\ Period}$$

Emissions Savings

Fuel Type	**Fuel Emissions Factor**	**Emissions Savings Equations**
Electricity	$GHG_{elec} = \frac{tonnes\ CO_2e}{kWh}$	$\text{Emissions Saved}_{strategy} = \Delta kWh \times GHG_{elec}$ OR $\text{Emissions Saved}_{strategy} = kWh \times \Delta GHG_{elec}$
Natural Gas	$GHG_{nat.\ gas} = \frac{tonnes\ CO_2e}{therm}$	$\text{Emissions Saved}_{strategy} = \Delta therms_{strategy} \times GHG_{nat.gas}$
Gasoline	$GHG_{gasoline} = \frac{tonnes\ CO_2e}{gallon_{gasoline}}$	$\text{Emissions Saved}_{strategy} = \%fleet_{gasoline} \times \frac{\Delta VMT}{MPG_{gasoline}} \times GHG_{gasoline}$ OR $\text{Emissions Saved}_{strategy} = \%fleet_{gasoline} \times \frac{VMT}{\Delta MPG_{gasoline}} \times GHG_{gasoline}$ OR $\text{Emissions Saved}_{strategy} = \%fleet_{gasoline} \times \frac{VMT}{MPG_{gasoline}} \times \Delta GHG_{gasoline}$
Diesel	$GHG_{diesel} = \frac{tonnes\ CO_2e}{gallon_{diesel}}$	$\text{Emissions Saved}_{strategy} = \%fleet_{diesel} \times \frac{\Delta VMT}{MPG_{diesel}} \times GHG_{diesel}$ OR $\text{Emissions Saved}_{strategy} = \%fleet_{diesel} \times \frac{VMT}{\Delta MPG_{diesel}} \times GHG_{diesel}$ OR $\text{Emissions Saved}_{strategy} = \%fleet_{diesel} \times \frac{VMT}{MPG_{diesel}} \times \Delta GHG_{diesel}$
Waste	$GHG_{waste} = \frac{tonnes\ CO_2e}{ton_{waste}}$	$\text{Emissions Saved}_{strategy} = \Delta tons_{waste} \times GHG_{waste}$ OR $\text{Emissions Saved}_{strategy} = tons_{waste} \times \Delta GHG_{waste}$

Appendix III: Political Feasibility Guidelines

Political factors and considerations when selecting strategies (checkboxes)

- Is the money there?
    - Is there a relevant and easily identifiable revenue stream?
    - Up-front cost
    - Long-term funding
        - i.e. grants, loans, incentives, payback
    - What are the other priorities?
        - i.e. education, roads, police
- Who pays and who benefits?
    - State, city, citizens, homeowners
        - i.e. city pays for public transit, citizens benefit
- Does the city have legal authority to do this?
    - i.e. limited taxing authority, LED streetlights ownership
- Will the city need to change codes or zoning?
    - i.e. wind, solar panels
- Is there a relevant agency?
    - Is the agency competent, efficient, non-corrupt and willing?
        - i.e. Department of Transportation, Water District
- Are the relevant actors willing and capable?
    - i.e. residents, businesses
- Is there a need to build a coalition extending beyond the city itself?
    - i.e. methane capture and energy generation
- Is there likely to be serious political opposition?
- See write-ups for specific barriers of individual strategies

Political factors and considerations when adjusting strategy application levels (sliders)

- Consider the population that has already adopted a strategy and adjust to include all capable of doing so in the analysis.
    - The economic analysis should address whether the city will do it after the financial situation is known.
- Once initial economic analysis is run then consider the following:
    - Available resources of those responsible for implementation
        - Will there be a need for advisory services to help people take the relevant actions?
    - Available funds and resources for public outreach and education
        - Will there be a need for a PR campaign to inform people regarding what is expected?
- See write-ups for specific barriers of individual strategies

Appendix IV: Menu of Strategies

GHG Reduction Strategy: **Air Conditioning Efficiency**

Category:	Electricity
Implementing (Coordinating) Agency:	Homeowners, Business Owners

Synopsis of Strategy

Energy consumption from air conditioning (A/C) use, as well as the associated GHGs, are a significant concern in warm climates such as inland California communities. In the average air-conditioned home, A/C is responsible for over 2000 kWh of electricity consumption, equating to about 3500 pounds of CO_2 (US DOE, 2010). Central air conditioning systems, which cool air through a system of supply and return ducts, are more

Replacing inefficient A/C setups with energy efficient central air systems can be a cost-effective decision, however due to high upfront costs, most people will not replace their system until the old one breaks. Here we examine the difference in GHG emissions and costs between an inefficient central A/C unit and a new, energy-efficient model.

The US EPA and US DOE have collaborated to build a very helpful tool in estimating these emissions, costs, and benefits. Known as the Central Air Conditioning Calculator ("CAC Calc"), this excel-based tool examines the life cycle cost for ENERGY STAR qualified central air conditioners. This is available for free download at <http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls>.

Cost per Unit Implemented

A new central A/C system with a high SEER efficiency rating of 14.5 is said to cost $3413 to buy and install. This is about 20% higher than a conventional unit of SEER 13.0, listed at $2857 (US EPA, US DOE, 2009).

Achievable Energy Reduction

Depending on the regional climate, represented in Full Load Cooling Hours, the efficient unit can save more than 1000 kWh per year of its life cycle. This is presented in the CAC Calc as total life cycle kWh savings, but can be scaled down to annual electricity demand reduction.

Price per CO_2e Reduction

$$\frac{Cost}{CO_2e} = \frac{\text{Price premium} + \left(\frac{\text{life cycle kWh savings}}{\text{years of life cycle}}\right)\left(\frac{\text{cost}}{\text{kWh}}\right)}{\left(\frac{\text{life cycle kWh savings}}{\text{years of life cycle}}\right) \times \left(\frac{CO_2e}{kWh}\right)}$$

Data Sets Necessary

- CO_2e per kWh of electricity generated
- Cost per kWh of electricity generated
- All other inputs are generalized within the CAC Calc tool, which has editable assumptions on the second tab of the excel workbook.

Possible Synergistic or Overlapping Strategies

- Cool Roofs
- Ceiling Insulation

Works Cited

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AECOM

GHG Reduction Strategy: **Attic Insulation**

Category:	Natural Gas, Electricity
Implementing (Coordinating) Agency:	Homeowners, Business Owners

Synopsis of Strategy

Heat flows naturally from a warmer to a cooler space. This means that in the winter, heat moves out of our homes and buildings, and in the summer, heat flows from outside in. Insulation inhibits heat flow, not only keeping us more comfortable in our homes, but also saving energy and GHG emissions from heating and cooling as well.

This strategy, due to data availability, looks only at the impacts insulation has on costs and emissions from gas heaters. For coastal California, this is likely a fairly accurate picture of what ceiling insulation can do. However, in arid inland communities, the benefits of energy-saving insulation will likely be much greater than those expressed here.

Cost per Unit Implemented

Adding R-11 insulation is assumed to cost $0.18 per square foot (USDOE 2010).

Achievable Energy Reduction

This analysis assumes, according to the USDOE procedure, the presence of a fairly efficient gas heater in the home or office, with an efficiency rating of .88. If a less efficient heater is present, energy savings from insulation will be even greater.

Also assumed is existing insulation with a thermal resistance rating of R-19, typical of structures built in the 1970s. Buildings of this age are ideal candidates for insulation retrofit. By adding R-11 insulation to the existing R-19, a total efficiency of R-30 is achieved, as is recommended by DOE.

A very handy Insulation Investment Calculator is available online at <http://chuck-wright.com/calculators/insulpb.html>. Inputs include old R-value, added R-value, cost of installation, HDD (see below), and heater fuel type and efficiency. With additional inputs, this calculator can output cost-savings information. Safeguard will do this automatically, however, as well as calculate localized GHG emissions savings.

Inputs			
Old R value	19	Added R value	11
Area	1 (Square Feet)	Cost of Insulation	$ 0.18
Climate			
Heating Degree Days (*)	2792	Cooling Degree Days (*)	0
Energy Cost			
Natural Gas	$ 0.50 per Therm	Electricity	$ 0.08 per Kilowatt Hour
Heating / Cooling System			
Type of Heat: Natural Gas			
Heating COP (*)	0.88	Cooling COP (*)	3.1
Calculated Energy Savings			
Energy Saved per Year	1293 BTU = 0.3787 KWH		
$$ Saved per year	$ 0.00734	Return on Investment	4.082 % per year

Screen Shot of the Insulation Investment Calculator

With the above inputs, we can save 1293 BTU per square foot installed per year, which is equal to .01293 therms per square foot per year.

Price per CO2e Reduction

$$\frac{Cost}{CO_2e} = \left(\frac{therms/ft^2}{year}\right) \div \times \left(\frac{\text{cost}}{\text{ft}^2}\right) \div \times \left(\frac{CO_2e}{therm}\right) \div$$

Data Sets Necessary

- Existing insulation R-value
- Added insulation R-value
- CO_2e per therm of natural gas
- Heating Degree Days, by location: Heating degree days (HDD) is an indicator of how much energy will be required to heat a home or business for a year. Derived from local temperature trends, HDD is the average degrees below “room temperature” per day for the locality, annualized by multiplying by 365 days. A free resource for this information is at <http://www.degreedays.net/>, where local weather station data is incorporated into a 5 year average HDD.

- City roofspace data can be used to estimate the maximum square footage of ceiling insulation that can be installed. This is obtainable using GIS mapping tools, as exhibited in the Cool Roof and Solar PV strategies as well.

Possible Synergistic or Overlapping Strategies

- Central Air Conditioning
- Cool Roofs

Works Cited

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GHG Reduction Strategy: **Bicycle Infrastructure**

Category:	Transportation
Implementing (Coordinating) Agency:	City (Public Works, Transportation departments), State DOT, National DOT

When I see an adult on a bicycle, I do not despair for the future of the human race.

~H.G. Wells

Synopsis of Strategy

The bicycle is most efficient mode of ground transportation on a calorie per passenger-mile basis. Cycling is three times more efficient that walking, 25 times more efficient than riding a bus or train and about 50 times more efficient than driving alone (Lowe 1989).

Increasing cycling infrastructure and facilities has been shown to increase cycling rates and improve health (Krizek, Barnes, and Thompson 2009; Pucher, Jennifer Dill, and Susan Handy 2010; Pucher and Charles Komanoff 1999). Increased cycling is also likely to increase the use of public transit. Cycling extends the range of public transit and, in turn, public transit extends the range of cycling.

A multitude of studies has shown that the cost of increased or improved bicycle infrastructure is greatly outweighed by the benefits. For example, University of Minnesota professor Kevin Krizek looked at 25 studies on the economics of cycling facilities. Every study including a cost-benefit calculation found benefits to outweigh costs by at least 50%; with some Norwegian studies showing benefits at three to fourteen times the costs (Durning 2007). While it is difficult to monetize the costs and benefits of bicycle infrastructure in a widely applicable way, there are some reliable methods.

A comparison of increased and improved bicycle infrastructure in Boulder, Amsterdam, and Copenhagen revealed that spending approximately $30 per capita, annually over 10-15 years, would raise bicycle commute mode share to 25% for short trips (Daniel Jacobson and Dr. Leavitt 2009). A one-quarter increase in cycling mode share for trips of three miles or less reflects an overall mode shift of 16-20% to cycling and walking combined (Daniel Jacobson and Dr. Leavitt 2009). A review of four studies found that a mode shift of 5-10% can be reasonably expected (VTPI 2010).

An empirical study found that each 1 mile of bike infrastructure for every 100,000 people correlates to a 0.069% increase in cycling mode share (Jennifer Dill and Theresa Carr 2003). The price per mile of bicycle infrastructure and related facilities ranges from as little as a few thousand dollars per mile to as much as a one million dollars a mile, with an average of $300,000 per mile (Thomas Gotschi and Kevin Mills 2008).

A very accurate web-based tool for calculating capital and maintenance costs was developed by University of North Carolina Highway Safety Research Center and can be used to determine more accurate capital costs (UNCHSRC 2010). Capital costs depend on the specific combination of various bike lanes, paths, and facilities while the maintenance costs are set at $6500 per mile. This "Benefit-Cost Analysis of Bicycle Facilities" calculator also estimates benefits and demand, but demand is reported as the increased number of cyclists and the benefits are not all-inclusive. A more robust calculation of the market and non-market benefits of cycling, conducted by the VTPI, attributes a per-mile benefit of $0.71 for cycling, based on a 60-40 mix of peak and off-peak travel (Litman and Doherty 2009). This per-mile benefit takes into account twenty internal and external benefits and both market and non-market values. Even this detailed estimation neglects some benefits (health and fitness, user enjoyment, additional environmental, community livability, etc.) and should be considered a low estimate. Per-mile estimates range as high as $2.73 (VTPI 2010). SAFEGUARD allows the user to choose whether or not to include non-market values. The research outlined here yields three methods for estimating the monetary costs of increased bicycle infrastructure:

1. The method requiring the fewest inputs is the population-based method. Multiplying the annual per-capita cost of $30 by the community population for 12 years (in between 10 and 15) gives the capital cost of building bicycle infrastructure. Dividing this total cost by $300,000 per mile estimates the total number of infrastructure miles that can be built. The annual maintenance cost of the infrastructure is then found by multiplying the number of miles and the per-mile maintenance cost of $6,500. This method is based on a cycling mode shift of approximately 12% (based on the 16-20% and 5-10% estimates referenced above). To scale this, calculate percent change in capital cost, mode share, or miles of infrastructure desired and apply the percent change to the other inputs. This is done in SAFEGUARD.

2. The second method requires either desired miles of cycling infrastructure or percent mode shift.

The conversion of 1 mile per 100,000 people resulting in 0.069% increased mode share can be used to find number of miles based on mode shift or mode shift based on number of miles. The capital cost is found using the average of $300,000 per mile and maintenance costs are $6,500 per mile. While the causality of this method is yet to be proven, the proven correlation between increased infrastructure and mode share supports the above method.

3. The web-based tool requires detailed information about types and amounts of desired infrastructure.

The web-based tool yields very accurate costs based on miles of various types of bike infrastructure and numbers of signs, racks, and other facilities. The demand results say little about changes in mode share and the benefits are not all-inclusive.

A comparison of the first two methods, using the population of Ventura and a mode shift of 12%, found a difference in capital costs of less than 3%. The SAFEGUARD model uses method #1 to fill in default values, but the fields can be edited, allowing the user to input desired number of miles or desired mode shift and more accurate capital and maintenance costs calculated with the external tool.

Benefits are calculated using community person miles traveled (PMT) and average vehicle occupancy. Community PMT is calculated using the National Household Travel Survey (NHTS) Transferability tool (US DOT 2007). Detailed instructions are given in the “Public Transit” strategy. According to the NHTS, 88% of all trips in the U.S. are taken in a private vehicle and average vehicle occupancy for all trip types is 1.63 (Hu and Reuscher 2004), these numbers can be used if more specific data is not available. Ventura County has a private auto mode share of approximately 90% and average vehicle occupancy of 1.4 (SCAG 2003). Community PMT is multiplied by 0.90 to find the number of miles available for mode shift to cycling. This available PMT sis then multiplied by 0.12 (or desired mode shift entered in SAFEGUARD, if different) and this number is divided by 1.4 to find the equivalent vehicle miles traveled (VMT). The resulting reduction in VMT is multiplied by the per passenger-mile benefit given above, or the value entered in SAFEGUARD. Greenhouse gas reduction potential is calculated by multiplying reduced VMT and the EPA-estimated 0.000433 $MTCO_2e$ per VMT (EPA 2009).

Assumptions

- Starting with low cycling mode share (<2%)
- Capital cost of $300,000 per mile
- Maintenance costs of $6,500 per mile
- Market (use value) benefits of $0.37 per passenger-mile
- Non-market (non-use value) benefits of $0.24 per passenger-mile
- Mode share, miles of infrastructure needed, and capital cost all scale with each other, based on percentage change from the 12% mode share base case described above.

Achievable Energy Reduction

- mode-share change / average vehicle occupancy = VMT change
- VMTchange * mpg * carbon content/gal = CO_2e reduced.

Data Sets Necessary

- City population
- Community person miles traveled (PMT)
- Externally calculated capital costs (optional)
- Desired miles of infrastructure (optional)
- Desired mode shift to bicycling (optional)

Possible Synergistic or Overlapping Strategies

- Public Transit
- State strategies:
    - CAFE standards
    - Low carbon fuel standard

Ventura - Specific Example Calculations

- Contained in discussion

Barriers to Implementation

- Lack of transit link for longer trips
- Stigma of using a bicycle (lack of bike culture)
- Poor existing health of some residents
- Monetary incentives (correcting for lack of understanding of non-market benefits)
- Outreach and education. This can overcome most barriers listed here

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GHG Reduction Strategy: California Emissions Standard for Vehicles

Implementing (Coordinating) Agency: CARB

Synopsis of Strategy

The Air Resources Board has adopted amendments to the "Pavley" regulations that reduce greenhouse gas (GHG) emissions in new passenger vehicles from 2009 through 2016.

The amendments, approved by the ARB on September 24, 2009, are part of California's commitment toward a nation-wide program to reduce new passenger vehicle GHGs from 2012 through 2016. ARB's September amendments will cement California's enforcement of the Pavley rule starting in 2009 while providing vehicle manufacturers with new compliance flexibility. The amendments will also prepare California to harmonize its rules with the federal rules for passenger vehicles.

The U.S. EPA granted California the authority to implement GHG emission reduction standards for new passenger cars, pickup trucks and sport utility vehicles On June 30, 2009.

The first California request to implement GHG standards for passenger vehicles, known as a waiver request, was made in December 2005 and was denied by the U.S. EPA in March 2008. That decision was based on a finding that California's request to reduce GHG emissions from passenger vehicles did not meet the Clean Air Act requirement of showing that the waiver was needed to meet "compelling and extraordinary conditions." The June 30, 2009 decision rejected the earlier denial reasoning by returning to and applying EPA's traditional waiver review principles.

The ARB's Board originally approved regulations to reduce GHGs from passenger vehicles in September 2004, with the regulations to take effect in 2009. These regulations were authorized by the 2002 legislation Assembly Bill 1493 (Pavley).

The regulations had been threatened by automaker lawsuits and were stalled by the U.S. EPA's delay in reviewing and then initially denying California's waiver request. The parties involved entered a May 19 agreement to resolve these issues. With the granting of the waiver on June 30, 2009, it is expected that the Pavley regulations will reduce GHG emissions from California passenger vehicles by about

22 percent in 2012 and about 30 percent in 2016, all while improving fuel efficiency and reducing motorists' costs. (California Air Resources Board 2008).

Assumptions

One major assumption is that the state succeeds in implementing the new standards. Additionally, in order to make quantitative estimates, an average rate for new cars purchased each year was used, 3%.

Costs are assumed to be zero for Ventura and their residents. Costs for new vehicles may increase, however, there will not be a less expensive alternative since the regulations apply to all vehicles. In other words, the costs will be incurred when a new car is purchased regardless of intent to reduce emissions.

Cost/Savings per Unit Implemented (capital + annual maintenance)

Because the annual savings changes from one year to the next, the total NPV also changes for each year. The savings is dependent on the fuel efficiency of new vehicles during a particular year and the number of new vehicles purchased that year. These considerations are incorporated in the model. Capital cost is assumed to be zero.

Achievable Energy Reduction

- 55.5 MMTCO2E Statewide in California cumulatively up until 2016
- 158.4 MMTCO2E Statewide in CA cumulatively up until 2020
- 16.4 MMTCO2E in the year 2016 (annual emission reduction)
- 31.7 MMTCO2E in the year 2020 (annual emissions reduction)
- Source: (Benjamin, Michael et al. 2008)

Table 4. California CO_2 Equivalent Emission Standards and Estimated Fuel Economy in California

Model Year	PC/LDT1			LDT2[a]			Fleet[b]		
	CO_2E[c] (g/mi)	%GHG Red	FE[d] (mpg)	CO_2E[c] (g/mi)	%GHG Red	FE[d] (mpg)	CO_2E[c] (g/mi)	%GHG Red	FE[d] (mpg)
2002[e]	312	-	28.5	443	-	20.1	354	-	25.1
2009	323	0.0%	27.2	439	0.9%	20.0	360	0.0%	24.4
2010	301	3.5%	29.2	420	5.2%	20.9	338	4.6%	26.0
2011	267	14.4%	32.9	390	12.0%	22.5	304	14.2%	28.9
2012	233	25.3%	37.6	361	18.5%	24.3	271	23.5%	32.4
2013	227	27.2%	38.1	355	19.9%	24.5	265	25.2%	32.7
2014	222	28.8%	39.0	350	21.0%	24.9	260	26.6%	33.4
2015	213	31.7%	40.6	341	23.0%	25.5	251	29.1%	34.5
2016	205	34.3%	42.1	332	25.1%	26.2	243	31.5%	35.7
2017	195	37.5%	44.2	310	30.0%	28.0	229	35.2%	37.7
2018	185	40.7%	46.5	285	35.7%	30.4	215	39.3%	40.1
2019	180	42.3%	47.8	270	39.1%	32.1	207	41.5%	41.6
2020	175	43.9%	49.1	265	40.2%	32.7	203	42.8%	42.5

[a] Equivalent to EMFAC LDT2 and LDT3 vehicle classes.
[b] California fleet mix is 70 percent passenger cars (PC) and light duty trucks (LDT1) and 30 percent light duty trucks (LDT2/LDT3).
[c] CO_2 equivalents account for all GHGs (CO_2, N_2O, CH_4, HFCs).
[d] Fuel economy (based on tailpipe CO_2 emissions levels in Table 3).
[e] Estimated based on DMV and vehicle registration and certification data.

Data Sets Necessary

Source: (Benjamin, Michael et al. 2008)

Possible Synergistic or Overlapping Strategies

- Federal CAFÉ standards
- VMT reducing strategies: Public Transit and Increased Bicycle Infrastructure
- Low Carbon Fuel Standard
- CARB Tire Pressure Program

Ventura - Specific Example Calculations

The emissions saved from the California Fuel Efficiency Standard were calculated by applying the business as usual growth rate to the annual VMT, then applying two different fuel efficiencies in order to find the total gallons of fuel used. First, we separate a percent of the VMT as new vehicles and apply the new fuel efficiency standard for that year to get the gallons of fuel used by those vehicles. The remaining VMT is multiplied by the average fuel efficiency for the previous year in order to obtain the gallons of fuel used by the older vehicles. These two numbers are added together to get the total fuel use for that year. See the table below for the total gallons of gasoline used, fleet average fuel efficiency and CO_2 emissions for each year from 2008 to 2020.

Year	Total Gasoline used (gallons)	Fleet Average Fuel Efficiency	CO_2e (metric tonnes)	CO_2e Reduced each year (metric tonnes)
2008	28,481,979	25.9	252,635	0
2009	28,533,677	25.8	253,094	-459
2010	28,528,060	25.8	253,043	50
2011	28,437,278	25.9	252,239	805
2012	28,266,575	26.1	250,724	1,514
2013	28,094,732	26.2	249,200	1,524
2014	27,913,873	26.4	247,596	1,604
2015	27,717,333	26.6	2458,53	1,743
2016	27,505,147	26.8	243,971	1,882
2017	27,266,471	27.0	241,854	2,117
2018	26,999,855	27.3	239,489	2,365
2019	26,721,355	27.6	237,018	2,470

Barriers to Implementation

- Lawsuits by car manufacturers
- EPA waiver request

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California Air Resources Board. 2008. Climate Change Proposed Scoping Plan, a F ramework for Change. October.

GHG Reduction Strategy: Compact Fluorescent Lamps (CFLs)

Category: Electricity

Implementing (Coordinating) Agency: End User

Synopsis of Strategy

Compact Fluorescent Lamps (CFLs) are far more efficient than conventional incandescent bulbs. Most of the energy from an incandescent bulb is wasted as heat, and only a small percentage of the output is within the visible spectrum (i.e., light!). CFLs use about 75% less electricity to produce the same amount of light as a comparable incandescent bulb, and last about 10 times longer.

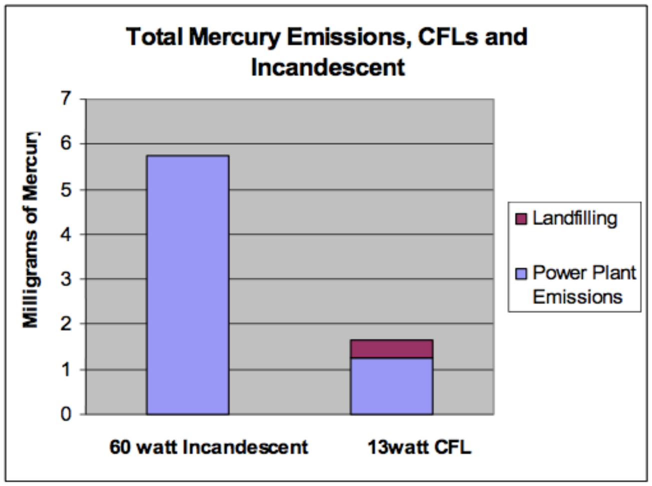
How it works:

"*In a CFL, an electric current is driven through a tube containing argon and a small amount of mercury vapor. This generates invisible ultraviolet light that excites a fluorescent coating (called phosphor) on the inside of the tube, which then emits visible light.*" (DOE, 2010)

While more expensive than a conventional bulb, a CFL generates significant energy cost savings, and will pay for itself in about 6 months. In the realm of alternative low-energy lighting, however CFLs are far more inexpensive than LED lights.

A note about mercury:

CFLs contain a very small amount of mercury (about 4 mg in each bulb). No mercury is released when the bulbs are intact or in use. While the mercury could eventually end up in the environment if the bulb breaks, the lower energy demand associated with CFLs means that less mercury is emitted from power plants.



Graph from energystar.gov's Mercury Factsheet.

Cost per Unit Implemented

Assumed price premium for ENERGY STAR Qualified CFL Unit: $2.50

This is a conservative estimate, as CFLs can cost less when buying in bulk, and prices have been steadily dropping. Non-ENERGY STAR Qualified setups can cost as little as a dollar.

Achievable Energy Reduction

Assuming that someone installing CFL lamps in their home will keep the lights on for the same amount of time, CFLs can serve the exact purpose of their predecessors while using, on average, 5.33 times less electricity to do so. CFLs produce about 64 lumens per watt, while incandescent bulbs produce only about 12 lumens per watt.

$$\text{Electricity Saved} = \left(1 - \frac{12\ {}^{lumens}\!/\!_{watt}}{64\ {}^{lumens}\!/\!_{watt}}\right) \times (\text{original watts}) \times (\text{hours of use}) = \mathit{kWh\ saved}$$

Lightbulb Comparison Chart

Description	Wattage	Light Output (lumens)	lumens/watt	Lifetime (hours)	lifetime (years)
Incandescent, Soft Output	25	225	9	1000	1
	40	420	10.5	1000	1
	60	710	11.83333333	1000	1
	75	940	12.53333333	1000	1
	100	1360	13.6	1000	1
	150	2180	14.53333333	1000	1
Average			12		
CFL, Spiral shape	5	300	60	4000	4
	8	500	62.5	4000	4
	12	725	60.41666667	4000	4
	15	1000	66.66666667	4000	4
	20	1350	67.5	4000	4
	23	1550	67.39130435	4000	4
Average			64.07910628		
Energy Savings (%)			81.27314706		
Cool White LED			47	50000	50
			64	50000	50
Warm White LED			25	50000	50
			44	50000	50
Average			45		
Energy Savings (%)			73.33333333		

Price per CO_2e Reduction

The reductions per region in kWh are normalized by eGrid data that generalizes emissions by region based on the portfolio of energy production. The amount of CO2e per dollar reduced is a factor of what zone of California is being studied. Due to the low cost and huge energy savings from CFLs, saving emissions will save money at the same time.

Data Sets Necessary

- eGrid kWh to CO_2e Conversion Factors by Region

Possible Synergistic or Overlapping Strategies

- CFLs overlap with the LED lights, competing for the total number of light sockets in the city
- Increased efficiency from CFLs and other efficient household appliances can lower energy demand and therefore decrease necessary volume of solar/PV installation or other onsite renewable energy production.

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GHG Reduction Strategy: Cool Roofs

Category: Electricity

Implementing (Coordinating) Agency: Citizens, Municipality

Synopsis of Strategy

Cool roofs represent a set of alternative roofing materials with properties of high reflectance and emissivity. Installing specially crafted reflective roofing materials reflects incoming solar energy in varying amounts from the ultraviolet, visible, and infrared wavelengths.[1] The main purpose is to absorb less solar energy through rooftops during months of direct sunlight and therefore lower the cooling requirements of those buildings. This can translate to lower energy bills, lower peak electricity demands, lessen cooling equipment infrastructure needed, and even cool city temperatures (urban heat island).

This strategy is very region dependent and is based on 16 climate zones defined by the California Energy Commission.[2] Regions with higher monthly average temperatures or higher electricity costs and clearer skies represent ideal candidates for cool roofs.

A potential tradeoff for cool roofs is due to the high albedo properties themselves. While reflecting more solar energy during warmer months is beneficial, the same properties are usually associated with higher heating requirements in cooler months. More kilowatt-hours are saved over the summer while more therms of natural gas may be necessary during the winter. Where cool roofs are beneficial, the positives outweigh the negatives.

Cost per Unit Implemented

The price of implementing this strategy is based on a composite of estimated labor and materials in California for both residential and commercial instulations. These costs do vary and have trended downward in recent years.

This study uses numbers from the EPA that estimate the following cost range per square foot of installed cool roof material:

[1] "Cool Roofs | Heat Island Effect | US EPA," http://www.epa.gov/heatisland/mitigation/coolroofs.htm.

[2] "Energy Maps of California," http://www.energy.ca.gov/maps/building_climate_zones.html.

- $0.75 - $1.50 per sq. ft. Installed[3]

Maintenance of the rooftops will vary but this study assumes that a newly implemented cool roof needs to be replaced every 20 years based on EPA data.

- Cool Roof needs replacement once every 20 years[4]

Achievable Energy Reduction

Table 1 below separates achievable energy reductions and therm increases and was part of a study comissioned by Pacific Gas and Electric in 2006 for generalizing energy savings that prescriptive regulation of cool roofs could bring. PG&E lowering energy requirements would mean less additional infrastructure they would need to build. The California Energy Comission's 16 climate zones (shown in Figure 1) were used as the basis for region dependant factors.

Table: Estimated costs and benefits of cool roofs averaged by region of California[5]

California Climate Zone	Roof R-Value	Annual Energy/1000 ft²			Peak Power/1000 ft²		Net Present Value (NPV)/1000 ft²			
		kWh	therm	Source MBTU	kW	$equip	$kWh	$therm	$energy	$total
1	19	115	-8.3	0.3	0.13	67	157	-62	95	162
2	19	295	-5.9	2.4	0.20	100	405	-43	362	462
3	19	184	-4.9	1.4	0.15	76	253	-35	218	294
4	19	246	-4.2	2.1	0.18	90	337	-31	306	396
5	19	193	-4.7	1.5	0.17	83	265	-35	230	313
6	11	388	-4.1	3.6	0.22	111	532	-29	503	614
7	11	313	-2.6	2.9	0.25	125	428	-20	408	533
8	11	413	-3.7	3.9	0.25	125	565	-28	537	662
9	11	402	-4.5	3.7	0.20	101	552	-33	519	620
10	19	340	-3.6	3.1	0.18	89	467	-26	441	530
11	19	268	-4.9	2.3	0.15	75	368	-37	331	406
12	19	286	-5.3	2.4	0.19	95	392	-39	353	448
13	19	351	-5.1	3.1	0.19	96	480	-37	443	539
14	19	352	-4.7	3.1	0.21	105	483	-33	450	555
15	19	380	-1.7	3.7	0.16	82	520	-13	507	589
16	19	233	-10.6	1.3	0.18	90	319	-78	242	332
min		115	-10.6	0.3	0.13	67	157	-78	95	162
max		413	-1.7	3.9	0.25	125	565	-13	537	662
avg		297	-4.9	2.6	0.19	94	408	-36	372	466

[3] Eva Wong, "Reducing Urban Heat Islands: Compendium of Strategies" (EPA: Climate Protection Partnership Division, 2008).

[4] Ibid.

[5] Ibid.

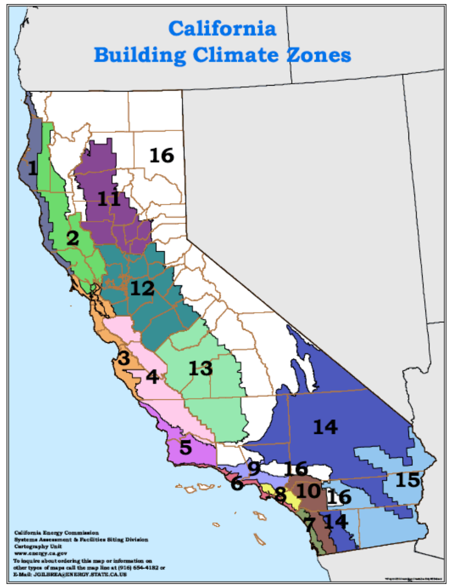

Figure 1. California Energy Commission's 16 delineated climate zones[6]

Price per CO_2e Reduction

The reductions per region in kWh are normalized by eGrid data that generalizes emissions by region based on the portfolio of energy production. The amount of CO2e per dollar reduced is a factor of what zone of California is being studied.

Data Sets Necessary

- California Climate Zones: 16 (California Energy Comission)[7]
- California Climate Zones by Zip Code (California Energy Comission)
- eGrid kWh to CO_2e Conversion Factors by Region[8]
- Square Feet of Roof Space in Target City

Possible Synergistic or Overlapping Strategies

- Tree Planting
- Green Roofs
- Increased Building Insulation
- Rooftop Solar Photovoltaic Panels

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[6] "Energy Maps of California."

[7] Ibid.

[8] "eGRIDweb | Clean Energy | US EPA," *eGRIDweb*, November 2, 2009, http://cfpub.epa.gov/egridweb/ghg.cfm.

GHG Reduction Strategy: Landfill Methane Capture & Energy Generation

Category: Waste and Electricity

Implementing (Coordinating) Agency: City or Waste Agency

Synopsis of Strategy

Landfills give off large amounts of methane, which can be captured for the purpose of electriciy generation, heat generation or bio-fuel creation.

This strategy is an excellent means to efficiently deal with the problems of GHG emissions, waste and energy generation. However, identifying quantitative values for the costs and benefits of the strategy is extremely difficult based on the high levels of variation amoung landfills and the needs of communities contributing to the landfills. A California document has identified the variations as too vast to attempt cost estimates (SCS Engineers 2008). Even with the large amount of variations this project attempts to make generalizations that are accurate enough to legitamately compare the strategy of Landfill Methane Capture & Energy Generation to other known GHG reduction strategies.

Assumptions

Electric generation is the most common form of energy generation from this strategy (U.S. EPA). Therefore electric is the one type of energy generation considered in SAFEGUARD assuming that if a community were to chose another form of energy generation it would be due to the fact that it was more economically feasibile to them.

Several variations on cost exist due to the large level of variation on the strategy (U.S. EPA 2008). The default levels of this strategy were averaged from these variations to best represent the actual cost of the strategy. In order to more specifically identify costs the user should refer to the EPA document Clean Energy Strategies for Local Governments: Ch 7.4 Landfill Methane Utilization: Draft.

Benefits are assumed to exist based on predictions of electric generation as well as the assumed price of the electricity.

The energy and subsequent emissions produced by this strategy will be assumed to directly replace energy and subsequent emissions produced by the utility company of a given area. Therefore the emissions reduction will come solely from the predicted methane captured. This assumption is likely to calculate emissions reductions that are slightly lower than than actual reductions. This was decided due to the difficulty in determining which entity involved in the landfill was credited for the electric generation.

Defaults are set for the following inputs as follows:

Cost of Feasibility Study - $25,000

(A feasibility study costs from $10,000-$25,000 with a possible additional $10,000)

Cost of System - $2,900,000

(Systems cost an initial $18,000/acre if no collection and flaring system exist. Landfills can range greatly in size. A typical range is 10-350 acres. 50 acres was chosen for this assumption. Other system prices can range from $970-$5,400/ KW potenial. In this range $2,000 was chosen for this assumption. The KW potential is highly variable. 1,000 KW was chosen for this assumption)

Annual Maintenance Cost - $202,000

(Maintenance for the collection and flaring system is $4,000/acre. 50 acres was chosen again for this assumption. The maintenance on the system can range from $110-$350/ KW potential. $200 was chosen for this assumption and again 1,000 KW.)

Generation Potential – 1,000 *KW*

(Same choice in other parts of default assumptions)

Predicted Methane Capture – 75%

(A range of 60%-90% in Methane Capture is common. 75% was chosen for this assumption)

These defaults were all selected due to the average or median standard that each number held in the ranges presented. The variablility of the strategy should encourage users to alter the defaults to localized specifications, however if unaltered the defaults offer an average or median of typical costs. All numbers were derived from the following sources (U.S. EPA 2008) (CalRecycle).

Cost/Savings per Unit Implemented (capital + annual maintenance)

The Captial Cost are all initial or start up costs.

The Annual savings come from subtracting the price of the energy generated multiplied by the amound of energy generated from the annual maintenance cost. The potential energy generated is assumed to be actualized and generated consistantly over a years time. There are 8,760 hours in a year.

Achievable Emissions Reduction

This strategy can capture 60-90% of the methane released from the landfill and utilize it for the purpose of energy generation (U.S. EPA 2008). Methane produced by landfills accounted for about 23% of manmade methane in the U.S. in 2007 (U.S. EPA).

The methane captured is utilized to produce energy, which would otherwise come from another source. The methane captured is counted as an emissions reduction, however the offset provided by the energy generation is highly variable and often negligable because the production of energy using the captured methane will give off a select amount of emissions. Therefore, the achievable emissions reduction is roughly equal to the level of emissions captured.

Data Sets Necessary

- Landfill emissions baseline
- Optional inputs
    - Cost of Feasibility Study
    - Cost of System
    - Annual Maintenance Cost
    - Generation Potential
    - Predicted Methan Capture

Possible Synergistic or Overlapping Strategies

- Recycling programs and emissions from other forms of energy generation have the possibility to alter the efficiency of the strategy, however these changes are specific and subtle to a point where they will not alter SAFEGUARD. Furthermore, if this overlap were to exist it is likely that GHG emissions may no longer be an eminent threat.

Ventura - Specific Example Calculations

The landfill utilized by the City of Ventura has already implemented this strategy, which captures 90% of the methane emissions (Yahner 2009). The initial costs of the strategy will be set to zero. The maintenance costs and energy production will be set at the default values and the methane captured will be set at 90%.

Barriers to Implementation

Various institutions own landfills, which makes initial implementation difficult. Furthermore, after simple criterion are considered a feasibility study, costing at minimum $10,000, must be conducted before choice in project can be made and then begun. If the study is approved further extensive capital cost must be accrued (U.S. EPA 2008).

Even with these barriers this strategy is still highly valuable, which is why an attempt to include it in SAFEGUARD was made. The EPA has created programs as well as multiple tools and fact sheets that help remove these barriers. This information is found at

Additional Information/Images

Capital and O&M Costs of LFGE Electricity Generation Projects			
Technology	**Optimal Project Size (capacity)**	**Typical Capital Cost ($/kW capacity)**	**Typical Annual O&M Costs ($/kW capacity)**
Microturbine	< 1 MW	$5,400	$350
Small Internal Combustion Engine	< 1 MW	$1,700	$180
Reciprocating Engine	> 800 kW	$1,300	$160
Gas Turbine	> 3 MW	$970	$110

Data from U.S. EPA 2008

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GHG Reduction Strategy: Light Emitting Diodes (LEDs)

Category: Electricity

Implementing (Coordinating) Agency: End User

Synopsis of Strategy

Light-emitting diodes (LEDs) are small light sources that create light by the movement of electrons through a semiconductor material (DOE, 2010). Home LED lighting is an extremely efficient way to produce light, and is still somewhat of an emerging commonplace technology. Famous for their long lifetime, LED lights are a sustainable lighting alternative that can last for decades. High capital costs inhibit many consumers from investing in LEDs, but many stand behind their long lifetime as more sustainable and convenient than other bulbs.

Conventional incandescent bulbs produce light by passing electricity through a filament until it is so hot it glows. A great deal of energy is wasted in this process—up to 90% of energy used goes to producing heat rather than light. Only a tiny amount of heat is produced in LED bulbs, and in newer products is directed backward into a heat sink. Therefore, a well-made LED bulb is nearly cool to the touch (DOE, 2010).

While more expensive than a conventional bulb or a CFL, an LED light has some distinct advantages. LEDs deliver their full light output instantly when turned on (the delay in CFL bulbs is a common complaint). Additionally, LEDs contain no mercury.

Cost per Unit Implemented

Assumed price premium for ENERGY STAR Qualified CFL Unit: $50

This is a conservatively high estimate, as prices for LEDs have been dropping. This price is fully ajustable within SAFEGUARD. If the user wishes to install a particular bulb, she may enter the most up-to-date wattage and price information.

Achievable Energy Reduction

Assuming that someone installing LED lighting in their home will keep the lights on for the same amount of time as before the retrofit, LEDs can serve the exact purpose of their predecessors while using, on average, 73% less electricity to do so. LEDs produce about 45 lumens per watt, while incandescent bulbs produce only about 12 lumens per watt.

$$\text{Electricity Saved} = \left(1 - \frac{12\ {}^{lumens}\!/_{watt}}{45\ {}^{lumens}\!/_{watt}}\right) \times \left(\text{original watts}\right) \times \left(\text{hours of use}\right) = \textit{kWh saved}$$

Lightbulb Comparison Chart

Description	Wattage	Light Output (lumens)	lumens/watt	Lifetime (hours)	lifetime (years)
Incandescent, Soft Output	25	225	9	1000	1
	40	420	10.5	1000	1
	60	710	11.83333333	1000	1
	75	940	12.53333333	1000	1
	100	1360	13.6	1000	1
	150	2180	14.53333333	1000	1
Average			12		
CFL, Spiral shape	5	300	60	4000	4
	8	500	62.5	4000	4
	12	725	60.41666667	4000	4
	15	1000	66.66666667	4000	4
	20	1350	67.5	4000	4
	23	1550	67.39130435	4000	4
Average			64.07910628		
Energy Savings (%)			81.27314706		
Cool White LED			47	50000	50
			64	50000	50
Warm White LED			25	50000	50
			44	50000	50
Average			45		
Energy Savings (%)			73.33333333		

Price per CO_2e Reduction

The reductions per region in kWh are normalized by eGrid data that generalizes emissions by region based on the portfolio of energy production. The amount of CO2e saved and its reduction-per-dollar ratio is a factor of what zone of California is being studied.

Data Sets Necessary

- eGrid kWh to CO_2e Conversion Factors by Region

Possible Synergistic or Overlapping Strategies

- LED lights overlap with CFL lamps, competing for the total number of light sockets in the city.
- Increased efficiency from LEDs and other efficient household appliances can lower energy demand and therefore decrease necessary volume of solar/PV installation or other onsite renewable energy production.

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GHG Reduction Strategy: LED Street Lights

Category: Electricity

Implementing Agency: City (utility if street lights are owned by the utility)

Synopsis of Strategy

Street lighting costs represent one of the largest components of a city government's utility bill, often accounting for 10 percent to 38 percent of the total bill (Clinton Climate Initiative 2009). Replacing current street lights with light-emitting diodes (LEDs) will result in up to 80% reduction in electricity (kWh) and replace the yellow, discoloring illumination caused by conventional street lights with a warm, white glow.

Current street light types include: incandescent, mercury vapor, metal halide, and high pressure sodium (HPS). While this variety of lamps complicates energy savings estimates, it is a testament to Cities' consistent attention to lighting efficiency. More efficient lighting options are readily available with induction and LEDs as the most efficient and economical options. LEDs were chosen as the preferred substitute because there have been many studies of the monetary costs and benefits along with the additional benefit of being mercury-free. Another specific advantage of LEDs is that they produce directional light, allowing greater control of what is illuminated (street versus sky), in turn reducing light pollution and wasted energy.

LEDs have been around since the 1960s, but until recently have largely been used for small applications such as indicator lights. Although they cost more upfront, LEDs have a life span of 10-12 years (compared to the 2-3 years of current lights) and use 40-80% less energy, depending on the type of light being replaced. A pilot project in Ann Arbor, Michigan, a city with nearly the same population as Ventura, replaced "Globe" style lights downtown and found a $962 savings over 10 years, with a payback period of 4.4 years (City of Ann Arbor 2006). Additionally, the test installations had signs requesting public input and 81 of the 83 respondents were in favor of the new lights. Those in favor cited lack of light spillover and improved light color.

Another case study, conducted jointly by the City of Los Angeles and the Clinton Climate Initiative found that replacing 140,000 street lights would result annual savings of $10 million, 68,640,000 kWh, and 40,500 tons of CO_2 with a payback period of 7 years (Clinton Foundation 2009).

The City of San Francisco and the Department of Energy (DOE) conducted a thorough test of LED streetlights from four different manufacturers (Bryan 2008). This study is the source of the default costs and wattages in the SAFEGUARD software. The default numbers used are for the bulb that was both most efficient and lowest priced. LED technology improves and costs decrease annually, so the best option in 2008 is likely to be standard, if not outdated, by 2010.

Assumptions

- Streelights on 4100 hours per year (Bryan 2008)
- Standard electricty rate per kWh equal to residential rate, but this is editable
- Wattage, initial costs, and maintenance costs from SF/DOE study (Bryan 2008)

HPS

- 100W bulb = 138W with ballast
- 3 year life span

LEDs

- 11 year life span
  - Based on 10-12 year life span
- Best performing LED from DOE/San Francisco study used.

Achievable Energy Reduction

- Difference in kilowatt demand of old bulb and LED replacement times 4100 hours/year = kWh saved
- GHG reduction = CO_2e per kWh from utility times energy reduction (in kWh)

Payback Period

9 years in Ventura, may change depending on electricity prices and technology used.

Data Sets Necessary

- Number and types of current fixtures in community

- If unknown, the number 100W-equivalent can be estimated if the annual kWh used for street lights is known; see Ventura-specific calculations below.

- Altrnatively, one can assume 70% reduction in energy usage (DOE/SF). Costs will be more difficult to calculate, but can assume 7-10 year payback on retrofit (DOE/SF, Michigan, others).

Possible Synergistic or Overlapping Strategies

- LED traffic lights, parking lot illumination
- Renewable portfolio standard

Ventura - Specific Example Calculations

Total kWh for streetlights supplied in Ventura's CCAR inventory report.

Barriers to Implementation

- City does not own streetlights and utility is not interested in retrofit
- Upfront cost

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GHG Reduction Strategy: California Low Carbon Fuel Standard

Category: Transportation

Implementing (Coordinating) Agency: CARB

Synopsis of Strategy

To reduce the carbon intensity of transportation fuels, ARB is developing a Low Carbon Fuel Standard (LCFS), which would reduce the carbon intensity of California's transportation fuels by at least ten percent by 2020 as called for by Governor Schwarzenegger in Executive Order S-01-07 (California Air Resources Board 2008).

The Final Rulemaking Package was filed with the Office of Administrative Law on November 25, 2009 and OAL apprived the rulemaking and filed it with the Secretary of State on January 12, 2010. The regulation became effective on the same day (California Air Resources Board 2009).

Fuel providers will have at least three different option with which to comply on an annual basis:

- Blend or sell an increasing amount of low-carbon fuels
- Use previously banked credits
- Purchase credits from fuel providers who have earned credits by exceeding the performance standard (Crane, David and Prusnek, Brian 2007)

Assumptions

The LCFS is a statewide strategy, so the first assumption is that the state does indeed follow through on the regulation. Also, the 10% reduction is assumed to be uniform across the state; in reality, some areas may have access to more low carbon fuels while others do not. The availability of fuel providers to purchase and bank credits further increases the non-uniform reduction.

In ARB's AB 32 Scoping Plan, the report estimates a 16.5 MMTCO2E from LCFS, but due to overlapping with the Pavley regulation of GHG emissions from vehicles, the estimate was reduced by approximately 10% to 15 MMTCO2E (California Air Resources Board 2008). This assumption has been carried through in these calculations (i.e. a 9% reduction in emissions from transportation fuels was used).

This target is only a reduction by the year 2020, for these calculations we assumed that the reductions would take place gradually from year to year leading up to the 2020 target with no further reductions from the LCFS after 2020.

Cost/Savings per Unit Implemented (capital + annual maintenance)

Because this is a mandated State strategy, we assume the capital cost to be zero for Ventura. There for the net present value is only a function of the annual savings, which is dependent on the amount of fuel saved each year.

Achievable Energy Reduction

- 15 MMTCO2E statewide in 2020
- 9% reduction from transportation fuels

Data Sets Necessary

- Total emissions from tranportation fuels

Possible Synergistic or Overlapping Strategies

- CAFÉ standards, Pavley GHG emissions from motor vehicles, public transit, bike infrastructure

Ventura - Specific Example Calculations

- Total emissions from transportation fuels in 2007: 403,811 metric tonnes CO_2e
- Total emissions from transportation fuels in 2020 (assuming 1% increase annually): $403{,}811*(1+0.01)^{13} = 459{,}575$ metric tonnes CO_2e
- 459,575 * .09 = 41,361 metric tons CO2e reduction in 2020.

Barriers to Implementation

- State efforts to enforce regulation, reporting and verification.
- Availability of alternative fuels

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AECOM

GHG Reduction Strategy: Low Flow Showerheads

Category:	Electric/Gas through Water Flow
Implementing (Coordinating) Agency:	City, Non-profits or Residences

Synopsis of Strategy

Water conservation has historically been a goal of California due to constrained water resources and highly contentious water rights issues. With the advent of climate change and the obligation cities have to reduce GHG emissions there is more reason than ever to conserve water.

The pumping and treatment of water require a large amount of energy, which converts directly to GHG emissions. This two-step conversion varies based on where a city gets its water, how the water gets pumped and the specific electric utilities used within the city. Installing low flow water fixtures such as showerheads will reduce the water demand as well as energy. Additionally, showerheads offer an energy reduction due to less water having to be heated.

Assumptions

It is assumed that the city can produce a water to energy conversion. It is recommended that a city begin this proccess by establishing the amount of energy used to distribute and treat water.

The caluclations made by Flex Your Power on water and energy saved are used in SAFEGUARD. It is assumed that all households not utilizing low flow showers currently use showerheads with a flow of 2.5 GPM. Fixtures with varying flow rates exist. The two most common flow rates for low flow fixtures, 2.2 GPM and 1.5 GPM, are used in SAFEGUARD. The default is set to use the most efficiet of the two (Flex Your Power).

It is additionally assumed that the only other energy used for water is that of heating. According to California's Flex Your Power campaign about 73% of the water flow from showerheads is hot water. Reducing the flow of hot water also reduces the energy used to heat the water (Flex Your Power).

The cost of a low flow showerhead is very low compared to a standard model showerhead. A quick glance around the local hardware store, or one's preferred showerhead supplier, will provides a wide range of showerhead options ranging in price from a few dollars to over $300 (CostHelper). The wide range of options prompts us to set SAFEGUARD's default intial cost at $10 for installing this technology in order to account for those that replace standard working models for low flow models. The preference in showerhead model depends heavily on the consumer. When the low flow model is inevitably replaced in the future SAFEGUARD will allocate zero cost as there is no real price premium for this product.

The savings achieved comes from the price of the water saved as well as the price of the energy saved. The data Flex Your Power uses for cost savings was not used in SAFEGUARD. Instead the data on water and energy reductions were used and costs are calculated separately based on city-by-city pricing.

Prices are set based on the cities initial inputs. In order to account for the difference among households that use gas as opposed to electric to heat water a slider option is implemented. The percent of the city assumed to use gas and electric is set and taken into account in the cost equation. The average ratio for California is 32.54% electricity, 64.5% gas and 2.96% LPG (U.S. Energy Information Administration 2004). Given LPG's similarity to gas emissions the two were added together for SAFEGUARD's default. This sets the default at 32.54% for electricity and 67.46% for gas.

All costs and savings are attached to the number of fixtures expected to be installed within the community. The default on this setting is one fixture per household within the community, installing the fixture in 80% of those houses. The default of one fixture per home is set because reductions on water and energy are assumed to be per household. Larger numbers can be selected, however the result is very similar to increasing the number of households the strategy will be applied.

Cost/Savings per Unit Implemented (capital + annual maintenance)

- The Captial Cost are all initial or start up costs.
- The Annual Savings come from the price of the water saved multipled by the amount of water saved. In addition to this savings is the price of energy times the energy saved from not having to heat water.

Achievable Emissions Reduction

It is estimated that 80,000 tons of GHG emissions could be avoided if only one out of every 100 American homes were retrofitted with low flow water fixtures (U.S. EPA).

The pumping and treatment of water require a large amount of energy, which converts directly to GHG emissions. This two-step conversion varies based on where a city gets its water, how the water gets pumped and the specific electric utilities used within the city. Installing low flow water fixtures such as showerheads will reduce the water demand as well as energy.

The achievable energy reduction depends heavily on the city's water provider. Some cities in California obtain water from the state water project, while others acquire water from local sources. Various water distribution systems also exist altering the water to energy conversion.

There are an incredible number of variables that exist creating the conversion from water flow to energy (Cheng 2002). Establishing the most accurate conversion will produce the most accurate results in SAFEGUARD, however best estimates will allow for sufficient comparison to other reduction strategies.

Included in the reduced water flow of efficient showerheads is a reduction in energy used for water heating. Depending on the method of water heating each household has an added energy reduction of up to 830 kWh/fixture if electric heated or 37 therms/fixture if gas heated. With the low, to zero, cost of technologies that reduce flows by half of standard fixtures this strategy has the potential to decrease total city emissions by a significant margin (Flex Your Power).

Price per CO_2e

The payback peiod on this strategy is almost instant. Once the standard fixture is replaced water savings and water heating savings will occur. The emissions reduction will not change over time.

Data Sets Necessary

- Water to energy conversion
- Electric to CO_2e conversion
- Gas to CO_2e conversion
- Percent of city using gas verse electric
- Number of households in the city
- Residential price per gallon of water
- Optional inputs
    - Number of households with the potential to switch to low flow
    - Average number of fixtures per household
    - Cost of Fixture
    - Fixture with flow rate of 2.2 GPM or 1.5 LPG

Possible Synergistic or Overlapping Strategies

- The water to energy conversion can change if more efficient means of moving water are achieved.
- If standard waterheaters are replaced with efficient ones then the reduction from the heated water will overlap.

Ventura - Specific Example Calculations

The city of Ventura owns and operates it's own water services and obtains its water from local water sources decreasing the overall emissions associated with water flow.

For water distribution in the city of Ventura the energy used is approximately 3,800 kWh/million gallons. For Ventura's wastewater plant the energy used is approximately 2,800 kWh/million gallons (Yahner 2009). The energy in both cases was added then converted to produce the water to energy conversion of 0.66 kWh/gallon.

The price of water was taken from the 2009-2010 Ventura City water rates and established at about $0.08 per gallon. This price was derived from selecting the price at the lowest tier for residential use of water and adding it to the lowest tier of wastewater treatment (City of Ventura).

Conversions from electricity emissions as well as gas to emissions are taken from the utility companies supplying to Ventura. The ratio of gas to electric in heating water as well as specific prices of gas and electricity are also unique to the city of Ventura.

All of the energy reduced through a citywide decrease in water flow is seen in the municipal emissions inventory where water represents approximately 50% of total emissions.

Barriers to Implementation

There are two barriers to implementation. First, if most of city residences have already made the change no reduction will be seen. Second, changing the behavior of individuals can be difficult, however studies in social behavior and household conservation show that it is possible (Abrahamse et al. 2005).

Additional Information: Data from Flex Your Power

Cost-Effectiveness Showerheads			
Performance	Base Model	Recommended Level	Best Available
Water Use Only			
Gallons per minute/ cycle	2.5 GPM	2.2 GPM	1.5 GPM
Annual Water Use	18,250 gallons	16,060 gallons	10,950 gallons
Annual Water Cost	$73	$64	$44
Lifetime Water Cost	$590	$520	$350
Electric Water Heating			
Annual Energy Use	2,370 kWh	2,120 kWh	1,540 kWh
Annual Energy Cost	$142	$127	$92
Lifetime Energy Cost	$1,070	$960	$690
Lifetime Energy and Water Cost Savings	-	$200	$600
Gas Water Heating			
Annual Energy Use	131 therms	120 therms	94 therms
Annual Energy Cost	$53	$48	$38
Lifetime Energy and Water Cost Savings	-	$100	$350

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Abrahamse, Wokje, Linda Steg, Charles Vlek, and Talib Rothengatter. 2005. A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology* 25, no. 3 (September): 273-291. doi:doi: DOI: 10.1016/ j.jenvp.2005.08.002.

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GHG Reduction Strategy: Low-flow Toilets

Category: Electric/Gas through Water Flow

Implementing (Coordinating) Agency: City, Non-profits or Residences

Synopsis of Strategy

Water conservation has historically been a goal of California due to constrained water resources and highly contentious water rights issues. With the advent of climate change and the obligation cities have to reduce GHG emissions there is more reason than ever to conserve water.

The pumping and treatment of water require a large amount of energy, which converts directly to GHG emissions. This two-step conversion varies based on where a city gets its water, how the water gets pumped and the specific electric utilities used within the city. Installing low flow water fixtures such as toilets will reduce the water demand as well as energy.

Assumptions

It is assumed that the city can produce a water to energy conversion. It is recommended that a city begin this proccess by establishing the amount of energy used to distribute and treat water.

The caluclations made by Flex Your Power on water saved are used in SAFEGUARD. It is assumed that all households not utilizing low flow toilets currently use toilets with a flow of 3.5 GPF. Fixtures with varying flow rates exist. The two most common flow rates for low flow fixtures, 1.6 GPF and 1.0 GPF, are used in SAFEGUARD. The default is set to use the most efficiet of the two (Flex Your Power).

The cost of a low flow toilet is next to nothing in comparison to a standard model toilet. A quick glance around the local hardware store, or one's preferred toilet supplier, will provide one with a wide range of toilet options ranging in price of a $50 dollars to over $3000. Additional costs of installation can also be assumed to exist ranging in price from $50 to $150 (CostHelper). The wide range of options prompts us to set SAFEGUARD's default intial cost at $250 for installing this technology in order to account for those that replace standard working models for low flow models. The preference in toilet model depends heavily on the consumer, and when the low flow model is inevitably replaced in the future SAFEGUARD will allocate zero cost as there is no real price premium for this product.

The savings achieved comes from the price of the water saved. The data Flex Your Power uses for cost savings was not used in SAFEGUARD. Instead the data on water reductions was used and costs were calculated separately based on city-by-city pricing.

Prices are set based on the cities initial inputs.

All costs and savings are attached to the number of fixtures expected to be installed within the community. The default on this setting is assumed to be one fixture per household within the community, installing the fixture in 80% of those houses. The default of one fixture per home is set because reductions on water and energy are assumed to be per household. Larger numbers can be selected, however the result is very similar to increasing the number of households the strategy will be applied.

Cost/Savings per Unit Implemented (capital + annual maintenance)

The Captial Cost are all initial or start up costs.The Annual Savings come from the price of the water saved multipled by the amount of water saved.

Achievable Emissions Reduction

It is estimated that 80,000 tons of GHG emissions could be avoided if only one out of every 100 American homes were retrofitted with low flow water fixtures (U.S. EPA).

The pumping and treatment of water require a large amount of energy, which converts directly to GHG emissions. This two-step conversion varies based on where a city gets its water, how the water gets pumped and the specific electric utilities used within the city.

The achievable energy reduction depends heavily on the city's water provider. Some cities in California obtain water from the state water project, while others acquire water from local sources. Various water distribution systems also exist altering the water to energy conversion.

There are an incredible number of variables that exist creating the conversion from water flow to energy (Cheng 2002). Establishing the most accurate conversion will produce the most accurate results in SAFEGUARD, however best estimates will allow for sufficient comparison to other reduction strategies.

Payback Period

The payback period on this strategy is almost instant. Once the standard fixture is replaced water savings will occur. The emissions reduction will not change over time.

Data Sets Necessary

- Water to energy conversion
- Number of households in the city
- Residential price per gallon of water
- Optional inputs
  - Number of households with the potential to switch to low flow
  - Average number of fixtures per household
  - Cost of Fixture
  - Fixture with flow rate of 1.6 GPF or 1.0 GPF

Possible Synergistic or Overlapping Strategies

- The water to energy conversion can change if more efficient means of moving water are achieved.

Ventura - Specific Example Calculations

The city of Ventura owns and operates its own water services and obtains its water from local water sources decreasing the overall emissions associated with water flow.

For water distribution in the city of Ventura the energy used is approximately 3,800 kWh/million gallons. For Ventura's wastewater plant the energy used is approximately 2,800 kWh/million gallons (Yahner 2009). The energy in both cases was added then converted to produce the water to energy conversion of 0.66 kWh/gallon.

The price of water was taken from the 2009-2010 Ventura City water rates and established at about $0.08 per gallon. This price was derived from selecting the price at the lowest tier for residential use of water and adding it to the lowest tier of wastewater treatment (City of Ventura).

All of the energy reduced through a citywide decrease in water flow is seen in the municipal emissions inventory where water represents approximately 50% of total emissions.

Barriers to Implementation

There are two barriers to implementation. First, if most of city residences have already made the change no reduction will be seen. Second, changing the behavior of individuals can be difficult, however studies in social behavior and household conservation show that it is possible (Abrahamse et al. 2005).

Additional Information/Images

Cost-Effectiveness Toilets			
Performance	Typical Existing Unit	New Standard Unit	Best Available Unit
Gallons Per Flush	3.5 GPF	1.6 GPF	1.0 GPF
Annual Water Use	27,300	12,500	7,800
Annual Water Cost	$110	$50	$30
Lifetime Water Cost	$880	$400	$250

Data from Flex Your Power

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Abrahamse, Wokje, Linda Steg, Charles Vlek, and Talib Rothengatter. 2005. A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology* 25, no. 3 (September): 273-291. doi:doi: DOI: 10.1016/ j.jenvp.2005.08.002.

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AECOM

GHG Reduction Strategy: Planting Trees

Category: Other: Carbon Sequestration

Implementing (Coordinating) Agency: City, Non-profits or Residences

Synopsis of Strategy

Tree planting is part of a long tradition of environmental works. Trees provide multiple environmental benefits including pollution control and runoff control. With climate change as the most pressing environmental problem today trees have become valued to a greater extent for carbon storing qualities. Planting a tree within a city provides the benefit of carbon sequestration as well as other non-use values including; pollution reductions, water run-off control and aesthetic appeal.

Assumptions

The sequestration of a tree differs depending on species, age and natural variation. Sequestration variations were taken into account for the Center for Urban Forest Research (CUFR) Tree Carbon Calculator (CTCC), but some error is still expected (USDA). SAFEGUARD uses an average sequestration among all species within a given region, selected from the CTCC, in order to give managers and planners a rough estimate of the reductions possible. If tree species with high sequestration rates are selected for planting (i.e. eucalyptus) the potential carbon sink will be greatly increased. Selecting the appropriate tree is important as each species has its own pros and cons outside the realm of pure carbon reductions.

Along with natural sequestraion, trees offer an additional CO_2 reduction through shading to reduce heating and cooling in buildings. The calculations of these reductions are highly dependant on not only age and species of tree, but also distance from a given building and variations on building structure i.e. age, insulation and height. Due to the large number of variation on buildings SAFEGAURD excludes the calculations on this CO_2 reduction making actual CO_2 reductions slightly higher than the output.

The high variation among trees requires variable initial costs as well as rates of maintenance for specific trees. Based on information from Ventura's Urban Forest Coordinator, Nathan Slack, generalized initial costs of $300/tree as well as a maintenance cost of $100/tree are set as defaults in SAFEGAURD. Furthermore, a generalized scheduled maintenance is set in the model at the 3rd and 6th year with every 5 years following (Slack 2009).

Trees offer multiple benefits to a community aside from the sequestration of CO_2. These benefits include heating and cooling reductions, pollution reductions, water run-off control, aesthetic appeal, etc. SAFEGAURD attempts to capture the value of these benefits with the inclusion of non-use values. If non-use values are included the maintenance costs mentioned above will be automatically disabled. It is assumed that the non-use values occur on an averaged annual basis and the default values are a cost of $28.77/tree as well as a benefit of $54.33/tree, taken from a study done in Modesto, CA (McPherson et al. 1999). The option to include non-use values is set as the default.

The space available limits how many trees can be planted. The default setting assumes that there is enough space to plant one tree per resident within the city.

Cost/Savings per Unit Implemented (capital + annual maintenance)

The Capital Cost is the initial cost of planting the tree

The Annual Savings in this strategy only exist if non-use values are enabled. If enabled the savings are the difference between the benefits and costs entered.

Achievable CO_2e Reduction

The achievable CO_2 sequestration rate varies by age, species and natural variation. Research indicates that 22.8 million tCO_2/yr are sequestered across the United States. On a city level net sequestration rates vary from 600 tCO2/yr to 32,200 tCO_2/yr (Nowak and Crane).

For SAFEGAURD the CTCC was used to estimate CO_2 sequestration rates in California. In August of 2008 the CTCC was approved by the California Climate Action Registry (CCAR) Board of Directors for use in the California Air Resources Board (CARB) protocol for measuring and verifying carbon reductions from urban forest (CARB).

The CTCC requires specific inputs to accurately calculate the CO_2 stored in an individual tree as well as inputs to determine heating and cooling energy saved from tree shading. Direct sequestration of a tree species is obtained through inputs of region and tree age. SAFEGAURD only utilizes the information on direct sequestration of an individual tree within CTCC. The average sequestration rate was calculated for each tree species at age 5, 10 and 40 in each region.

Region Example: North and Central Coast

- Average sequestration/tree @ year 5 = 0.009 tCO_2
- Average sequestration/tree @ year 10 = 0.025 tCO_2
- Average sequestration/tree @ year 40 = 0.135 tCO_2

- A regression or best fit line was run through these points and the following equation emerged: tCO_2=(0.0036 * year)-0.0102
- In SAFEGAURD each of the seven regions located in California is associated with a rate of sequestration derived from the same method.

Payback Period

Excluding non-use values creates a scenario where there is never a payback on planting trees. However, if non-use values are taken into account a payback for trees will occur. Often the ratio of benefit to cost is estimated near 2:1 within a brief timeframe (Nowak and Crane 2002) (McPherson et al. 1999).

Data Sets Necessary

- Tree species climate region
- Number of residents within the city
- Optional inputs
    - Inclusion of non-use values
    - Regional cost of planting and maintaining a tree
    - Desired values for Costs and Benefits

Possible Synergistic or Overlapping Strategies

- If heating and cooling reductions were taken into account all building efficiency measures have the potential to overlap reduction rates from tree shading.
- There is not infinite space within a city; therefore any space used to plant a tree takes away from another potential value.

Ventura - Specific Example Calculations

North and Central Coast region was selected for Ventura. It was decided that 5,000 trees would be planted. Initial planting cost is $300.00. Non-use values would be used and set at cost of $14.38/tree as well as a benefit of $54.33/tree.

Barriers to Implementation

Funding and space available are the two largest barriers to implementing this strategy.

Additional Information/Images

Urban Forest Project Reporting Protocol

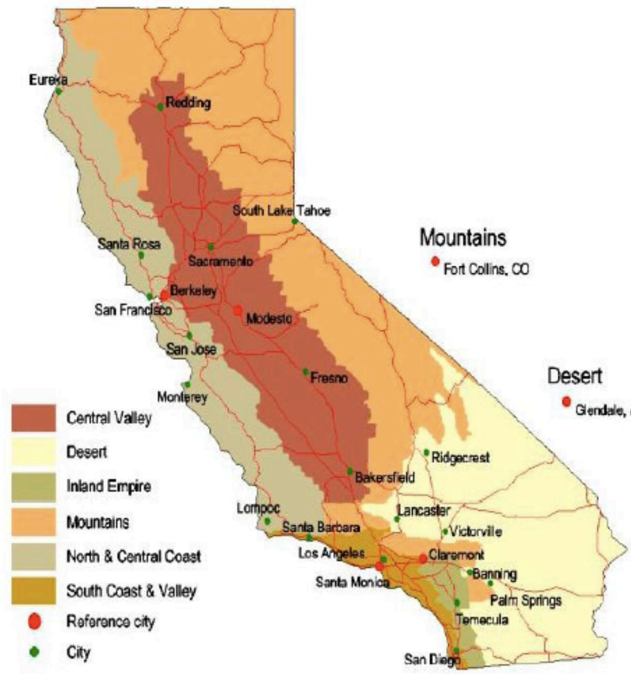

Figure D.2. California climate zones.

Image from CCAR, 2008

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GHG Reduction Strategy: Shift from private auto to using public transportation

Category: Transportation
Implementing (Coordinating) Agency: Local Transportation Agency

Synopsis of Strategy

Only 1 percent of the power in a gallon of gasoline is actually used to move a single person in the automobile (Lovins 2009). While it is impossible to acurately generalize the costs and benefits of increased use of public transportation for any given community, some rigourous studies have generated defensible numbers. This strategy applies these nation-wide averages to communities based on the current number of passenger-miles spent in a private vehicle. This strategy only considers shifting from driving or riding in a private vehicle to using a mix of bus and rail options. Alternative-fuel vehicles, shift in driving times ("peak-shifting"), ridesharing, biking, walking, and telecommuting could be individual or combined strategies of their own.

While reduced private auto VMT results in reduced gasoline use, diesel and electric use will increase due to additional diesel, electric and hybrid buses and trains.

Individuals will save an average of $0.25 per passenger-mile (PM) by using an even mix of bus and rail instead of a private vehicle for transportation purposes (Litman and Doherty 2009). The cost savings per PM calculted from Litman and Doherty's table assumes a 60-40 peak-off peak trip time and averages across all trip types. The monetary benefits include both market and non-market values: $0.02/PM and $0.23/PM, respectively.

The average cost of building, maintaining, and operating a combination of buses and rail is $0.81/PM (Mallinckrodt 2007). This is the gross cost; the net to the government, or subsidy, after subtracting user fees, totals $0.62/PM with $0.53/PM of operation and maintenance. These costs vary across transportation modes and regions, so a thorough community-specific assesment of costs is strongly recommended.

An exemplinary cost analysis for rail, the "Santa Barbara Commuter Rail Study" prepared for Santa Barbara County Association of Governments, projected detailed capital costs, operating costs, and ridership under several scenarios (Wilbur Smith Associates and PB Transit & Rail Systems 2005).

For community-specific customization, employing the SAFEGUARD model and average U.S. costs, the number of single-occupancy automobile passenger-miles, average vehicle occupancy and private auto moe-share are required. These inputs are outlined below.

Passenger-miles can be found using the National Household Travel Survey (NHTS) “Transferability” page (US DOT 2007). Accurately transferring the nation-wide data to the community-level requires the knowledge of all census tracts in the community. The tract numbers for Ventura were found using GIS data from the city of Ventura. The NHTS Transferability service allows the user to select a geographic region using an in-browser map, but without knowledge of the census tract boundaries there is high potential for selection error. One try over-estimated the passenger-miles by nearly three times. Using census tracts and multiplying the weekday PM/household by the number of households in each resident number-vehicle number category, 3,420,418PM/weekday was calculated. As in the Ventura baseline methodology, the weekday number was multiplied by 260 weekdays and 0.94x105 weekend days to calculate the annual 1,212,538,131 passenger-miles of Ventura residents. Details regarding the transfering of national travel survey data are provided in the “Transferring 2001 National Household Travel Survey” documentation (Pat Hu, Reuscher, and Schmoyer 2007).

Average vehicle occupancy may not be available for all communities. The U.S. average is 1.63 (Hu and Reuscher 2004) and the Ventura County average is 1.4 (SCAG 2003).

Mode share used for the Ventura case study was the Ventura county-wide estimate from a Southern California regional transportation study (SCAG 2003). Mode shares vary widely across trip purposes and time periods, but across all trip purposes and time periods, approximately 90% of Ventura county trips were taken in a private vehicle.

Assumptions

- Only considering private vehicle drivers and passengers converting to even mix of bus and rail options.
- Nation-wide passenger-mile (PM) averages of costs and benefits and all assumptions contained within the respective studies.
    - Capital cost of $0.28/PM (Mallinckrodt 2007)
    - Annual maintenance and operation costs of $0.53/PM (Mallinckrodt 2007)
    - Cost savings to driver of $0.25/PM ($0.02/PM market benefits, $0.23/PM non-market)
- Average vehicle occupancies:
    - Private auto = user input
    - Bus = 25, Rail = 30

Achievable Energy Reduction

Passenger-Miles reduced to vehicle-miles reduced based on average vehicle occupancies.

- Decreased private auto VMT: 98.6% gasoline, 1.6% diesel
- Increased transit VMT 50% diesel, 50% electricity

Data Sets Necessary

- Number of passsenger-miles in community
- Current mode share of private vehicles
- Average Vehicle Occupancy

Possible Synergistic or Overlapping Strategies

- Alternative fuel vehicles (hybrid, electric, biodiesel, ethanol, etc.), ridesharing (carpool/vanpool), non-motorized transportation (walk/bike), telecommuting, shifting time of trip (peak to off-peak).
- CAFE standards, low carbon fuel standards.

Barriers to Implementation

- Upfront costs
- Meeting demand (coverage and frequency)
- Negative stigma attached to public transportation
- Current and future growth patterns (diffuse growth hinders public transit)

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GHG Reduction Strategy: Rainwater Harvesting for Landscaping

Category: Water, Electricity
Implementing (Coordinating) Agency: Citizens, Water District and/or Municipality

Synopsis of Strategy

Potable water is becoming incerasingly scarce and requires a substantial amount of electricty to treat and distribute. Generally, 40-60% of potable water is used outdoors. These applications, landscaping and car washing, for example, don't require potable water. Collecting rain for outdoor use can then reduce water deamand by up to 60%, depending on the average annual rainfall and the type of rainwater collection system used.

This srtategy uses the average annual rainfall and the amount of available roofspace to calculate rainwater collection potential.

Collection surface is footprint of roof, regardless of pitch, calculated by multiplying length by width, eave to eave (Krishna 2005). The potential volume of rainwater is calculated using a standard formula like this one:

Equation 1(Lee 2005)

Determine Rainwater Volume Available:

$$\underset{\text{(gals)}}{\text{Rainwater volume}} = \text{(in. of rain)} \times \underset{\text{(convert} \rightarrow \text{ft)}}{1/12} \times 1\ \text{SF} \times \underset{\text{(convert} \rightarrow \text{gals/SF)}}{7.48} \times \text{(roof SF)} \times \underset{\text{(collection \%)}}{0.90}$$

Professional installers design systems to meet quarterly demand – three months without rain (Krishna 2005; Phillips 2005). In turn, one-quarter of the annual collection potential is used as the necessary cistern size.

Installation of a large cistern, and the large expense, is unecessary in arid regions or for small collection areas. If the average three-month volume of rainfall is less than 56 gallons, a simple 55 gallon container can be used. This drum or barrel does not need to be professionally installed and does not require any accessories. SAFEGUARD will determine this, based on required city inputs, and will run this strategy based on a cost of $55 per home for the simplest rain barrel system.

If the quarterly volume of rainfall requires a larger above or underground cistern, accesseroies will be needed. A roof washer improves the quality of the collected water, generally by diverting the first bit of water during a precipitation event away from the cistern. Additionally, a small cartridge filter can be used to remove sediment and materials larger than three microns. A small electric pump will be needed to use the collected water. While some above-ground cisterns may be able to use gravity to distribute water, below ground cisterns require a pump and this strategy assumes all cisterns will need a pump.

A three-quarter horsepower pump, such as the Grundfos MQ identified in the Texas report, requires approximately 0.545 kilowatts per hour to operate. The hourly energy demand is absed on an average of .575 (Grundfos 2010), 0.5 (Ghisi and Oliveira 2007) and 0.559 (Grady and Younos 2008). The total hours needed per year is based on the volume of rainwater collected and the flow rate of the pump, 20 gallons per minute (Grundfos 2010):

Equation 2: Annual pump-hours needed

$$\frac{annual\ rainwater\ volume\ (gallons)}{20\ gallons\ per\ minute} \times \frac{60\ minutes}{1\ hour} = total\ annual\ hours$$

The total annual hours is multiplied by the kilowatts needed per hour to calculate the increase in electricity demand for distributing collected rainwater.

The amount of water collected annually, along with the corresponding electricty avoided, constitute the savings. Electricity is saved because the water provider no longer needs to treat and distribute the potable water that would be used out-of-doors. The exact amount of electricty saved and the resulting reduction in GHGs are dependent on the water-energy coefficient and the utility provider of a specific community.

<u>Assumptions</u>

- Average annual rainfall is split evenly among four three-month time periods
- Roof space is divided evenly among all single-family homes
- Capital, installation, and maintenance costs:
    - Cistern $1 per gallon capacity (Krishna 2005; Phillips 2005; Grady and Younos 2008)
    - Roof washer, Smart-Valve Rainwater Diverter Kit = $50 (Krishna 2005)
    - Pump, Grundfos MQ = $400 (Krishna 2005)
    - Installation:
        - $600 above ground (Phypers 2001)
        - $600 + $2/gallon capacity underground (Crowley 2009)
    - Maintenance = $3.50 3-micron filter every three months (Krishna 2005) = $14/year (Tank Town 2010)

    - Lifespan = 20 years (Krishna 2005)
- Electricity needed to run pump = 0.545 kW/hour

Achievable Energy Reduction

[total gallons collected in the community per year * water delivery-energy conversion factor] – [electricty needed for pump (detailed above)].

Data Sets Necessary

- Average annual rainfall
- Residential roof Space in city
- Number of homes in city
- Residential water price per gallon
- Water-energy conversion factor (excluding wastewater treatment)

Possible Synergistic or Overlapping Strategies

- None so far

Barriers to Implmentation

- Upfront cost
- Lack of knowledge
- Zoning or code regulations

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GHG Reduction Strategy: Rooftop Solar Photovoltaic Panels

Category:	Electricity
Implementing (Coordinating) Agency:	Private Contractors, Utility Company

Synopsis of Strategy

Perhaps the most recognizable and iconic symbol of sustainability, photovoltaic panels have been available for decades with constant improvements being made to the technology. Photovoltaic panels are able to convert specific wavelengths of the sun's light spectrum into usable electricity.

While photovoltaic panels have high upfront costs for the consumer, there are many benefits. Consumers are able to receive nearly free electricity for decades rather than paying the fluctuating costs of a utility provider. Grid-tied electricity systems also have the potential for owners to make a profit by selling electrons back to the grid that are not used on-site. Though PV is not without an environmental footprint, electricity generated by solar photovoltaic panels does not emit greenhouse gases to the atmosphere. Additionally, many incentives exist today to bring down the initial cost of photovoltaic panels, therefore making this strategy more accessible to a wider range of interested parties.

Assumptions

This strategy's default assumptions are based upon traditional silicon-based photovoltaic panels. NREL's PVwatts v.1 tools were used to obtain reasonable values for electricity generation potential. A number of factors are incorporated in figuring out that potential, such as the geographic location (latitude, elevation), panel efficiency, derate factors of the system (energy losses in equipment for converting from DC to AC), and climate conditions (NREL 2009).

Cost/Savings per Unit Implemented (capital + annual maintenance)

The costs of photovoltaic projects vary widely but are usually done on a per-watt-installed basis. This strategy's initial cost estimates are based on an average 3-4kW residential system. Those costs are variable in SAFEGUARD, as are the initial incentives.

Using the DC watt peak of all the system's installed and multiplying that by the achievable average AC output in kWh achieve annual savings, we figure out the total amount of electricity generated annually (EPA 2009). Using that information and the average cost of electricity within the city, we calculate the savings. All savings come from electricity costs that were avoided because of the panels installed.

An industry standard 1% of capital cost as maintenance cost annually is assumed. This is to account for small costs of repair and the temporal variability of those costs.

Achievable Energy Reduction

Rather than reducing any energy demand from the community, photovoltaic panels reduce the emissions of greenhouse gases when compared to electricity generated from fossil fuel sources. There may be additional gains by removing transmission and distribution losses.

Data Sets Necessary

- NREL PV watts v.1 Geographic Location
- eGrid kWh to CO_2e Conversion Factors by Region (EPA 2009)
- Square Feet of Roof Space in Target City

Possible Synergistic or Overlapping Strategies

- Cool Roofs (competes for roof space)

Barriers to Implementation

The most common barrier to adoption for this strategy is the upfront cost. A close second is the lack of knowledge or uncertainty on the part of the potential consumer. It is easiest to continue the same path as always and simply pay the utility company based on the electricity consumed each month. Education and more widespread adoption will slowly begin to solve these issues.

Additionally many cities have ordinances that prohibit rooftop solar photovoltaic panels due to their appearance. While appearances are certainly important and can contribute greatly to a sense of community, the local and global benefits of installing panels should certainly be reexamined in those places.

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GHG Reduction Strategy: CA State Renewable Portfolio Standard

Category: Electricity

Implementing (Coordinating) Agency: CARB, CPUC, CEC, Utilities

Synopsis of Strategy

Under AB 32, the state has a goal to achieve 33% renewable energy mix statewide by 2020. CEC estimates that about 12 percent of California's retail electric load is currently met with renewable resources. Renewable energy includes (but is not limited to) wind, solar, geothermal, small hydroelectric, biomass, anaerobic digestion, and landfill gas. California's current Renewables Portfolio Standard (RPS) is intended to increase that share to 20 percent by 2010. Increased use of renewables will decrease
California's reliance on fossil fuels, thus reducing emissions of greenhouse gases from the Electricity sector. (California Air Resources Board 2008)

It is unclear what costs from this strategy will be passed on to cities in California. For this study, none of the costs are not passed onto the cities.

Cost/Savings per Unit Implemented (capital + annual maintenance)

$54.2 billion state expenditures (California Public Utilities Commission 2009)

Achievable Energy Reduction

21.3 MMTCO2E statewide from current 12% level to 33% renewables (California Air Resources Board 2008)

Price per CO_2e

$133/ton CO2e (California Air Resources Board 2008)

Payback Period

N/A

Data Sets Necessary

- Percent of Renewables at Inventory Year
- Total electricity consumption

Possible Synergistic or Overlapping Strategies

- Feed-in tariff

Ventura - Specific Example Calculations

Year	% Renewable Energy	CO_2e Coefficient (metric tonnes CO_2e/kWh)	CO_2e (metric tonnes)
2010	20.0%	0.000291399	186,041
2011	21.3%	0.000287611	183,623
2012	22.6%	0.00028381	181,196
2013	23.9%	0.000279997	178,761
2014	25.2%	0.00027617	176,318
2015	26.5%	0.00027233	173,867
2016	27.8%	0.000268477	171,407
2017	29.1%	0.00026461	168,938
2018	30.4%	0.000260728	166,460
2019	31.7%	0.000256832	163,972
2020	33.0%	0.000252921	161,475

Barriers to Implementation

- Transmission line infrastructure
- System changes for integration of large-scale wind and solar energy
- State funding
- Coordination among many agencies

Works Cited

California Air Resources Board. 2008. Climate Change Proposed Scoping Plan, a Framework for Change. October.

California Public Utilities Commission. 2009. 33% Renewables Portfolio Standard Implementation Analysis Preliminary Results. June.

GHG Reduction Strategy: Tire Pressure Program

Category: Transportation

Implementing (Coordinating) Agency: CARB

Synopsis of Strategy

Air Resources Board adopted a regulation that will require California's automotive maintenance industry to check the tire pressure of every vehicle they service. The 40,000 service providers subject to the regulation include smog check stations, engine repair facilities and oil service providers. Those not included are car wash, body and paint, and glass repair businesses.

The program, beginning July 1, 2010 will annually:

- Eliminate 700,000 metric tons of greenhouse gas emissions;
- Reduce the state's fuel consumption by 75 million gallons; and,
- Extend the average tire's useful life by 4,700 miles.

The cost of implementing the regulation balanced with the benefits from the measures will save the average Californian 12 dollars per year.

The Tire Pressure Strategy was identified as one of these Early Actions. While current Federal law requires auto manufactures to install tire pressure monitoring systems in all new vehicles beginning September 1, 2007, owners of older vehicles will lack this important tool to help them reduce their climate change emissions. ARB staff is currently investigating various options to ensure that tire pressures in older vehicles are also properly maintained.(California Air Resources Board 2008)

Achievable Energy Reduction

75 million gallons (statewide)

Data Sets Necessary

- Percentage of California's total vehicles in the City

Possible Synergistic or Overlapping Strategies

- Fuel Efficiency Standards
- Low Carbon Fuel Standard

- Increased Public Transit
- Increased Bicycle Infrastructure

Ventura - Specific Example Calculations

- 700,000 metric tons statewide
- 75 million gallons of fuel statewide

Total fuel use in California (2007):

15,672,334,029 (total) - 27,801,567 (aviation gasoline) = 15,644,532,462 gallons gasoline (83.5%)
3,082,740,281 gallons diesel fuel (16.5%)
= 18,727,272,743 (State of California 2009)
75,000,000 gallons reduced = 0.4% fuel use statewide (0.33% gasoline, 0.07% diesel)

Total fuel use in Ventura (2007 Inventory):

40,353,596 gallons gasoline (91%)
3,947,121 gallons diesel fuel (9%)
= 44,300,717 total gallons of fuel

Reductions:

0.36% x 40,353,596 = 133,166 gallons gasoline saved
0.04% x 3,947,121 = 2,762 gallons diesel saved

CO2 Equivalent
133,166 gallons gasoline x 0.009 tonnes/gallon = 1198.5 tonnes CO2e
2,762 gallons diesel x 0.010 tonnes/gallon = 27.6 tonnes CO2e

Cost Savings based on fuel saving
133,166 gallons of gas x $2.50 = $332,915
2762 gallons of diesel x $3.00 = $8286
Total savings: $332,915 + $8286 = $341,201
$341,201 / 103,219 (population) = $3.31 per person

Barriers to Implementation

- Successful state coordination and implementation efforts with local automobile services.

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GHG Reduction Strategy: Traffic Signal Timing

Category:	Transportation
Implementing (Coordinating) Agency:	City Government, County Government, CalTrans

Synopsis of Strategy

Coordinating traffic signals increase traffic flow, reduces idling, decreases air pollution, saves on fuel use and decreases GHG emissions. Coordination is ideal for signals on major arterials to allow for fewer delays in traffic on these major roads. Many cities and regions have already implemented these programs.

San Bernardino Associated Governments Board of Directors approved a plan for coordinating signals in the San Bernardino Valley. The program involved approximately 800 traffic signals and cost a total of $15 million. This cost includes necessary communication links, computer hardware and software, and development of plans.(Chu 2010)

Assumptions

- City has large arterials that are viable candidates for coordinated signals

Cost/Savings per Unit Implemented (capital + annual maintenance)

- $1,091 per signal (Skabardonis, Alexander 2001)
- Cost per intersection: $1091 * 4 = $4,364 per intersection
- Fuel savings: 7835 gallons * cost of fuel ($3.50) = $27,422.50 per signal

Achievable Energy Reduction

7835 Gallons per intersection per year (Silva-Send, Nilmini 2009)

Data Sets Necessary

- Number of uncoordinated traffic signals in jurisdiction

Possible Synergistic or Overlapping Strategies

- Fuel Efficiency Standard
- Low Carbon Fuel Standard

- Increased Public Transit
- Bicycle Infrastructure
- Tire Pressure Program

Barriers to Implementation

This strategy does have a high upfront cost for implementation. Additionally, the costs all lie with the city government, while the benefits are distributed across the entire community.

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GHG Reduction Strategy: Water Heating

Category: Electricity • Natural Gas

Implementing (Coordinating) Agency: Property owner

Synopsis of Strategy

Water heating can account for 14%–25% of the energy consumed in your home (U.S. Department of Energy 2009a). Water heaters currently use either electricity or natural gas. Solar water heaters are not common, but have the potential for the greatest greenhouse gas reduction. The GHG reduction potential depends on the current type of water heater and the chosen replacement.

Conventional, or storage tank, water heaters keep a quantity of water at a consistent temperature that is available when hot water is needed. Energy is lost because the storage tank is never perfectly insulated, resulting in loss of heat to the ambient air. The most efficient technology currently on the market is tankless, or on-demand, water heaters. Tankless water heaters heat ambient water to the desired temperature only when hot water is demanded by an appliance or tap. While gas-fired tankless heaters are suitable for whole-house applications, electric tankless heaters are only sufficient for smaller households or remote appliances (such as a hot tub or isolated bathroom). Electric storage heaters can easily and affordably be made more efficient with the addition of an insulating insulation blanket and a timer. Increased insulation decreased heat lost to the ambient air and a timer ensures that water is only heated at needed times and when electricity demand and costs are lower during off-peak hours. Insulation blankets for gas or oil-fired water heaters generally require professional installation and timers are not effective due to the pilot light.

The greatest reduction in GHGs is achieved by installing a solar water heater with an electric or natural gas back-up. The solar option aside, switching from conventional gas to tankless gas and adding an insulation blanket and a timer to electric storage results in the greatest GHG reduction. All water heaters should be set at approximately 120°F, which will save an additional 3-5% in energy usage and costs (U.S. Department of Energy 2009b).

The GHG savings also depend on the temperature of the ambient water and air as well as the fuel source of electricity produced by the local utility. The upfront cost of switching from gas to electric or vice versa can be prohibitive and complicated. Additionally, the low level of renewable energy in the vast majority of electricity providers' portfolios currently makes natural gas water heating less carbon intensive. As renewable energy portfolios increase, this strategy will need to be revisited.

Currently, this strategy assumes that water heater owners will retain their current fuel, natural gas or electric (heating oil, wood, coal, LPG, etc. can be added for regions beyond CA). The current mix of water heating fuels can be obtained from the Residential Energy Consumption Survey, based on census region (Berry 2008).

Assumptions

- Retain current water heating source (i.e. gas or electric)
    - Switch from gas to tankless gas
    - Add water insulation blanket and to electric storage tank
    - Current gas/electric ratios based on census regions from "Residential Energy Consumption Survey", Water Heating data table .
- Solar market penetration is evenly distributed between current gas and electric users
- Ambient air assumed to be constant due to improved home and water heater insulation.
- Low estimate of 3% savings from temperature adjustment due to overlap with other efficiency gains.

Cost/Savings per Unit Implemented (capital + annual maintenance)

Fuel Savings (U.S. Department of Energy 2009c):
For gas water heaters
You need to know the unit cost of fuel by therm. (1 therm = 100,000 Btu for oil)

For conventional electric water heaters to more efficient or solar with electric backup
You need to know the unit cost of fuel by therm. (1 therm = 100,000 Btu for oil)

0.1: Water heater options

Water Heater Type	Energy Factor	Installed Cost	Lifespan (years)
Conventional Gas Storage	0.6	$850	13
Tankless (Instant) Gas	0.82	$1,600	20
Solar with Gas Backup	2	$6,000	20
Conventional Electric Storage	0.92	$820	13
Electric + Insulation & Timer	N/A‡	$15 + $60 = $75	13*
Solar with Electric Backup	3	$5,000	20

Source: (California Center for Sustainable Energy 2008) except insulation blanket and timer (U.S. Department of Energy 2009a)
‡Combination will save an average of 15% in electricity use (average of 4-9% for blanket & 5-12% for timer)
*Blanket and timer can be reused so the incremental cost is applied every other heater replacement period

Data Sets Necessary

- Ratio or numbers of gas/electric water heaters from EIA breakdown by census region (Berry 2008).

Possible Synergistic or Overlapping Strategies

- Low flow [shower and faucet] fixtures. Less water used means less water that needs to be heated.
- Roof top solar, cool roofs and other physical space conflicts for solar water heaters

Barriers to Implementation

- Up front cost
- Lack of incentives
- Space, building codes, available sunlight for solar
- GHG reduction of gas versus electric will change as RPSs increase

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