Investigating the Feasibility of Greenhouse Gas Mitigation in Santa Barbara County

A Group Project submitted in partial satisfaction of the requirements for the degree of Master of Environmental Science and Management

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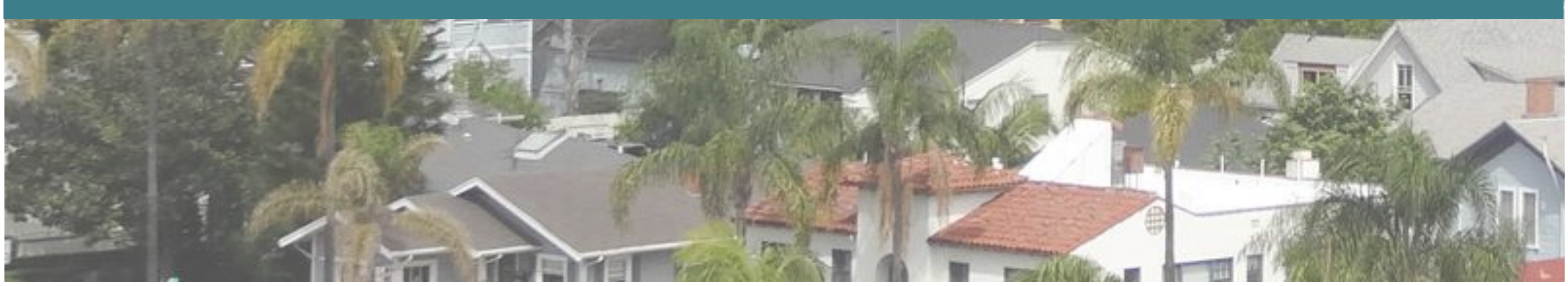

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The mission of the Bren School of Environmental Science & Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principal of the School is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions.

The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. The project 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 Group Project Final Report is authored by MESM students and has been reviewed and approved by:

Sangwon Suh

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Acronyms

AB 32	-	Assembly Bill 32, the California Global Warming Solutions Act of 2006
ARB	-	California Air and Resources Board
CAPCOA	-	California Air Pollution Control Officers Association
CEC	-	California Energy Commission
CEQA	-	California Environmental Quality Act
CFCs	-	Chlorofluorocarbons
CH_4	-	Methane
CPUC	-	California Public Utilities Commission
CO	-	Carbon Monoxide
CO_2	-	Carbon Dioxide
CO_2e	-	Carbon Dioxide Equivalent
DOE	-	United States Department of Energy
E3	-	Energy and Environmental Economics, Inc.
EIA	-	Energy Information Administration
EMFAC	-	Emissions Factor Model
EPA	-	United States Environmental Protection Agency
EVs	-	Electric Vehicles
GHG	-	Greenhouse Gases
HFCs	-	Hydrofluorocarbons
HVAC	-	Heating, Ventilation, and Air Conditioning
kWh	-	Kilowatt Hours
NCTR	-	National Center for Transit Research
NOx	-	Nitrogen Oxides
N_2O	-	Nitrous Oxide
NREL	-	National Renewable Energy Laboratory
O_3	-	Ozone
PFCs	-	Perfluorocarbons
PG&E	-	Pacific Gas & Electric
PV	-	Photovoltaic
RPS	-	Renewable Portfolio Standard
RTPA	-	Regional Transportation Planning Agency
SBCAG	-	Santa Barbara County Association of Governments
SCE	-	Southern California Edison
SF_6	-	Sulfur Hexafluoride
VMT	-	Vehicle Miles Traveled
VOCs	-	Volatile Organic Compounds

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1 Executive Summary

In California, there are a number of policies in place that require governments, businesses, and agencies to mitigate GHG emissions. Two of the state-level initiatives are the California Global Warming Solutions Act of 2006 (AB 32) and the 2010 California Environmental Quality Act (CEQA) Guideline Amendments. AB 32 requires California to reduce GHG emissions to 1990 levels by 2020, while CEQA directs state and local agencies to avoid or mitigate any significant GHG emissions associated with public projects.

Over the next several years, Santa Barbara County's annual GHG emissions are projected to increase and, in order to comply with California's regulations, these emissions must be mitigated or offset. Although GHG mitigation targets can be met by purchasing carbon offset credits from a national or international exchange, county residents and decision-makers alike would prefer to reduce GHG emissions through local mitigation projects. Local GHG reduction projects are preferred because they can generate co-benefits for the county, such as economic growth and reduced air pollution.

The objective of this project was to determine which mitigation strategies would be the most cost-effective and easily implemented in Santa Barbara County given the county's unique characteristics. The first step of the project was the construction a GHG emissions forecast. The forecast revealed the relative contribution of different sectors to the county's economy to GHG output allowing us to prioritize analysis of mitigation options in the highest emitting, and therefore highest reduction potential, sectors. In addition, the forecast served as a baseline from which the impact of GHG mitigation efforts could be calculated. The GHG emissions forecast included select sources from the transportation, residential, commercial, agricultural, oil and gas, and waste sectors and revealed that the transportation, residential, and commercial sectors emit significantly more GHGs than the other examined sectors. Consequently, the GHG mitigation strategies that we chose to analyze were within these high emitting sectors.

The GHG mitigation strategies that we selected for analysis were energy efficiency retrofits, solar photovoltaics, electric vehicles, commuter benefits programs, and alternative work schedules. In order to determine the cost-effectiveness of these strategies, we calculated the net present value of the cost and the total GHG reduction potential over our selected time horizon from 2015 to 2040. We then summarized the results in a GHG abatement cost curve, which is a visual tool commonly used to display the cost-effectiveness of GHG mitigation strategies. Our results indicate that Santa Barbara County can mitigate nearly 18,000 kilotons of GHGs over the next 25 years and nearly 10,000 kilotons of reduction can be achieved at a negative cost.

In addition to determining the cost-effectiveness of each mitigation option, it was necessary to investigate the feasibility of implementing these GHG mitigation strategies in Santa Barbara County. For each strategy, we explored current incentive programs and policies that could facilitate or hinder GHG mitigation project implementation. We found that there are a number of local, state, and federal programs in place that minimize barriers to strategy implementation. Most of these programs offer financial incentives, educate the public, assist customers with paperwork, connect customers with providers, or provide some combination of these services.

The results of our GHG abatement cost curve for the county, combined with our review of existing opportunities and barriers to implementing the GHG mitigation strategies, indicate that Santa Barbara County should prioritize lighting retrofits, heating, ventilation, and cooling (HVAC) retrofits, solar photovoltaics (PV), electric vehicles (EVs), commuter benefits programs, and alternative work schedules to mitigate GHGs locally.

2 Project Objectives

1. Create a GHG emissions forecast for select sources in sectors of interest in Santa Barbara County.

2. Determine the cost-effectiveness of GHG mitigation strategies and visualize results in a GHG abatement cost curve.

3. Analyze the opportunities and barriers to implementing GHG mitigation strategies

4. Provide recommendations to the county regarding which GHG mitigation strategies should be pursued based on cost-effectiveness and ease of implementation.

3 Project Significance

While climate change is a global issue, many of the factors that influence GHG emissions, such as transportation infrastructure, land use, and waste disposal, are controlled by local governments. Consequently, local action to mitigate GHGs is critical to combating climate change and will be essential to California's success in meeting state-wide reduction targets. By identifying the most cost-effective and easily implemented GHG mitigation strategies, this project will help Santa Barbara County choose the best strategies to reduce GHG emissions and meet state reduction goals.

4 Background

4.1 Climate Change and GHG Emissions

Climate change is caused by the amplification of the greenhouse effect, which describes how greenhouse gases (GHGs) trap heat in Earth's atmosphere by absorbing and emitting infrared radiation. Since the industrial revolution, human activity, mainly the combustion of fossil fuels, has significantly increased the concentration of GHGs in the atmosphere. As a result, global mean temperatures have been rising over the past century with the ten warmest years on record occurring within the past sixteen year (Kahn, 2015). The effects of a warming planet include sea level rise, changes in precipitation, a decline in biodiversity, and an increase in extreme weather events (IPCC, 2013).

Three gases account for the majority of GHG emissions: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (Figure 1). The largest sources of anthropogenic CO_2 emissions are fossil fuel combustion and land use change, while the largest sources of CH_4 emissions are fossil fuel mining, livestock emissions, and waste decomposition. The majority of N_2O emissions are due to agricultural activities, particularly the use of nitrogen-based fertilizers. Other GHGs include ozone (O_3) and water vapor, as well as the fluorinated gases (F-gases), such as sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), chlorofluorocarbons (CFCs), and perfluorocarbons (PFCs), which are emitted mainly by industrial processes. Climate change policy focuses primarily on CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6, and not on CFCs or water vapor as CFCs were phased out of large-scale manufacturing under the Montreal Protocol, and water vapor is naturally occurring.

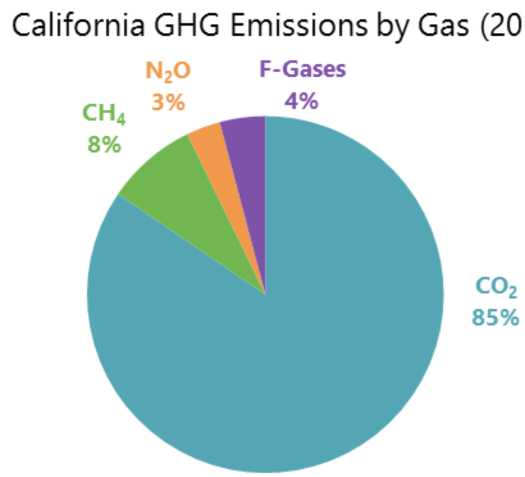

Figure 1. Breakdown of 2012 GHG emissions in California by gas.
Source: ARB, 2014

4.2 California's GHG Policies

Strategies to address climate change take two forms: mitigation and adaptation. Mitigation strategies are focused on reducing GHG emissions in order to slow the progress and lessen the ultimate impact of climate change. Adaptation strategies are focused on instituting changes, such as relocating coastal populations or building sea walls, in order to avoid climate change-related damages. While a certain level of climate change is unavoidable, failure to reduce global GHG emissions will likely lead to more severe, potentially irreversible, damage to the climate system. Consequently, both adaptation and mitigation strategies are necessary to properly address climate change. This report, however, is focused solely on mitigation strategies.
As the largest economy and most populous state in the United States, California's contribution to national GHG emissions is significant, totaling to 6.7% of the nation's annual output in 2011

(EPA, 2013). Transportation, industrial activities, and electricity generation account for the majority of the state's GHG emissions (Figure 2).

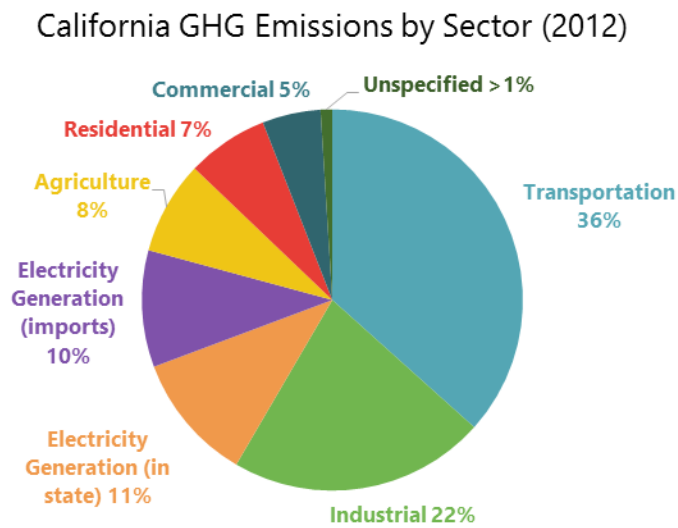

Figure 2. California's GHG emissions by sector in 2012.
Source: ARB (2014)

Two key pieces of California's climate legislation are the California Global Warming Solutions Act of 2006 (AB 32) and the 2010 California Environmental Quality Act (CEQA) Guideline Amendments. AB 32 requires California to reduce its GHG emissions to 1990 levels by 2020. The bill covers the six major GHGs, CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, as well as nitrogen trifluoride (NF_3), and applies to nearly all sectors of California's economy. Pursuant to this goal, the California Air Resources Board (ARB) drafted the AB 32 Scoping Plan, which outlines the most cost-effective and realistic ways for California to reduce GHG emissions (ARB, 2008). These strategies include direct regulations, market approaches, incentives, and voluntary efforts. One of the main contributions of the AB 32 Scoping Plan was the formation of the market-based cap-and-trade system for GHG emissions in California (ARB, 2013).

The CEQA Guideline Amendments of 2010 require state and local public agencies to quantify GHG emissions from new projects, determine if emissions are significant and, if significant, determine ways to mitigate, reduce, and/or avoid emissions if possible (State of California, 2014). With the exception of most single-family residences and smaller infill projects, almost all physical building projects in California are subject to CEQA provisions (State of California, 2014).

In addition to AB-32 and CEQA, California has several other policies related to GHG emissions. These include:

Assembly Bill 1493 (Pavley Bill) – Passed in 2009, the Pavley Bill requires California to develop and adopt regulations that achieve the maximum feasible reduction of GHGs emitted by passenger vehicles and light-duty trucks.

Sustainable Communities Sustainable Communities & Climate Protection Act (SB 375) – SB 372 requires ARB to develop regional GHG emission reduction targets for passenger vehicles for 2020 and 2035.

Renewables Portfolio Standard (Senate Bill X1-2) – The Renewable Portfolio Standard (RPS) requires investor owned utilities, electric service providers, and community choice aggregators to procure 33% of their electricity from renewable energy by 2020. The RPS is jointly administered by the California Public Utilities Commission (CPUC) and the California Energy Commission (CEC).

4.3 Mitigating GHG Emissions

As a result of AB 32, CEQA, and other existing policies, governments, businesses, and agencies are often encouraged or required to mitigate their GHG emissions. The Intergovernmental Panel on Climate Change defines a GHG mitigation option as "a technology, practice, or policy that reduces or limits the emissions of GHGs or increases their sequestration" (Adler et al., 1995). GHG mitigation can be achieved by:

- Avoiding the operation or activity;
- Changing the operation or activity;
- Adding emissions control technologies; and
- Sequestering emissions that have been released (CAPCOA, 2010).

Instead of mitigating, an entity that is required to reduce GHG emissions can purchase offsets on an exchange from a party that generates GHG emission credits through voluntarily mitigation. In order for voluntary mitigation offset credits to be accepted onto the exchange, the mitigation project must be:

- **Additional** - The reduction in GHG emissions must exceed, i.e. be in addition to, GHG emission reductions or removals that would have otherwise occurred;
- **Real and Quantifiable** - The reduction in GHG emissions must represent actual emissions reductions. This requires the amount of GHG emissions reduced to be accurately quantified;

- **Verifiable** - The reduction in GHG emissions should be monitored and confirmed by an independent third party; and
- **Permanent** - The reduction in GHG emissions must endure for the foreseeable future, e.g. at least 100 years (Offset Quality Initiative, 2008).

These requirements are in place to ensure that businesses, organization, and agencies do not receive GHG mitigation credit for efforts they would have pursued under a business-as-usual scenario or that do not truly reduce GHG emissions.

4.4 GHG Abatement Cost Curves

A GHG abatement cost curve is a commonly used economic tool that outlines the cost-effectiveness of a selection of GHG mitigation measures over a specified time period. The purpose of a GHG abatement cost curve is to provide policy-makers with the information required to implement cost-effective GHG reduction measures. Since a number of states have passed legislation setting emissions reduction targets, GHG abatement cost curves can also be used to help policy-makers meet statewide emissions goals.

In a GHG abatement cost curve, mitigation measures are arranged along the horizontal axis from left to right in order of increasing cost. Each measure is displayed as a bar, with the width of the bar indicating the magnitude of GHG abatement achievable over the timeframe and the height of the bar indicating the cost of abatement per ton of CO_2 equivalence (CO_2e). An abatement option is displayed as having a negative cost when its long-term savings (due to lower operating costs, lower energy use, etc.) outweigh its upfront costs (Figure 3).

How to Read GHG Abatement Cost Curve

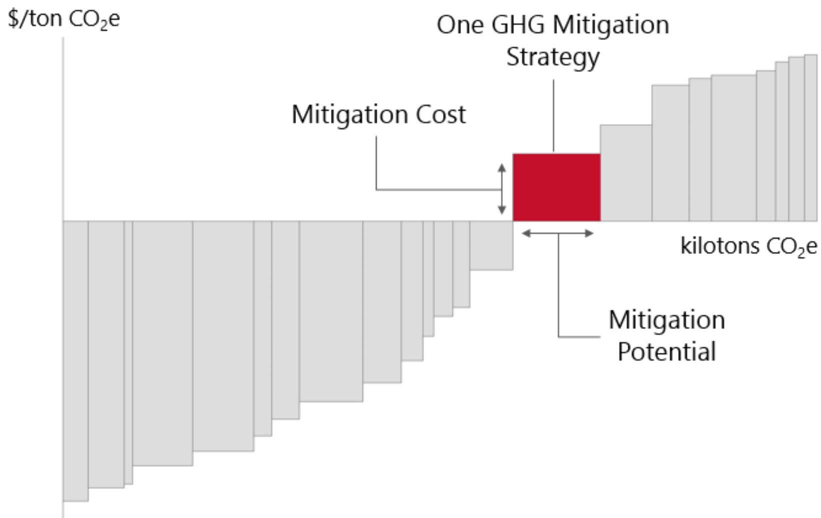

Figure 3. How to read a GHG abatement cost curve.

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GHG abatement cost curves require a considerable amount of data collection and analysis to generate. When they are completed, they are typically presented as part of a detailed report that explains and provides context for each GHG mitigation option included in the curve. The process for developing a GHG abatement cost curve typically involves the following basic steps:

1. **Determine the type of emissions reduction measures that will be included in the cost curve.** This depends on the scope of the project, data availability, and whether the cost and GHG emission reduction potential of the measure can be quantified.

2. **Establish a GHG emissions forecast.** This makes it possible to quantify the reduction in GHG emissions that can be achieved through the abatement measures.

3. **Quantify the relevant costs of the abatement measures**. The cost of abatement is calculated as the difference between the cost of the baseline scenario and the costs of the GHG mitigation scenario. In other words, the costs are calculated as those additional to the baseline. The amount of emissions avoided is calculated in the same way, i.e. as the difference between the emissions of the baseline scenario and the emissions of the abatement scenario.

Beyond these key steps, the methodology for generating cost curves can vary considerably depending on the application; cost curves can be developed for singular industries, like agriculture, entire economies, or on state, national, and global geographic scales.

4.4.1 Existing GHG Abatement Cost Curves

One of the best known GHG abatement cost curves, the North America McKinsey Cost Curve developed by McKinsey & Company, is often cited as evidence that significant reductions in GHGs can be achieved at a relatively low cost (McKinsey & Company, 2007). McKinsey & Company examined 250 different abatement options and conclude that the United States could reduce GHG emissions by 3.0 to 4.5 gigatons of CO_2e by 2030 using various, currently available technologies and strategies, each at a cost of less than $50 per ton of CO_2e (Figure 4).

McKinsey & Company GHG Abatement Cost Curve for the U.S.

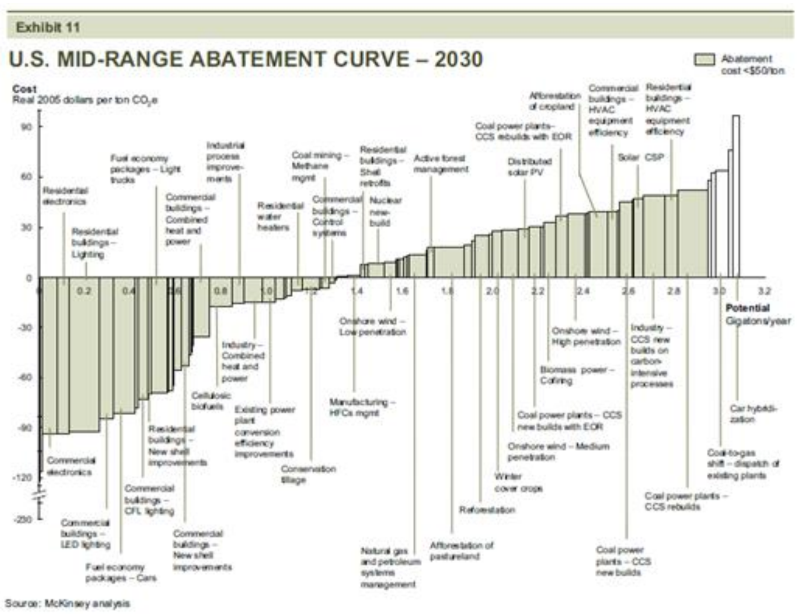

Figure 4. McKinsey & Company's GHG abatement cost curve for North America.
Source: McKinsey & Company (2007)

Other GHG abatement cost curves relevant to the U.S. include those generated by Sweeney & Weyant (2008) and Lutsey and Sperling (2009). Sweeney & Weyant (2008) examine over 40 GHG abatement options for their California-specific GHG abatement cost curve, which they created as a tool to guide policy makers implementing AB 32. Like, McKinsey & Company (2007), Sweeney & Weyant (2008) analyze GHG mitigation options across several sectors, including commercial and residential energy use, transportation, electricity generation, industrial processes, and land-use. The GHG abatement cost curve created by Lutsey and Sperling (2009) focuses on the transportation sector. Specifically, they examine mitigation strategies related to improving the efficiency of light-duty vehicles and commercial trucks, increasing the use of hybrid gas-electric vehicles, using alternative refrigerant for vehicle air conditioning, and replacing traditional fuels with low carbon alternatives. Similarly to McKinsey & Company (2007), Sweeney & Weyant (2008) and Lutsey and Sperling (2009) conclude that many abatement options will have a negative cost. Sweeney & Weyant (2008), however, find many abatement measures with positive costs that exceed $50 per ton of CO_2e, concluding that the cost of implementing AB 32 may exceed $100 per ton CO_2e.

In constructing their GHG abatement cost curves, McKinsey & Company (2007), Sweeney & Weyant (2008), and Lutsey and Sperling (2009) all use a bottom-up approach. They rely primarily on government sources, such as the U.S. Environmental Protection Agency (EPA), the U.S. Energy Information Association (EIA), and the U.S. Department of Energy (DOE) for national and state data on GHG sources and sinks. Thus, they accept many of the assumptions made by these sources, which they outline briefly in their reports. As is typically included in the quantification of GHG emissions, both McKinsey & Company (2007) and Sweeney & Weyant (2008) included CO_2, CH_4, N_2O, SF_6, HFCs, and PFCs in their analysis, and standardized all GHG sources and sinks by converting them into units of CO_2e.

4.4.2 Limitations of GHG Abatement Cost Curves

GHG abatement cost curves forecast into the future, which requires cost curve developers to make a number of assumptions. As a result, GHG abatement cost curves are inherently uncertain. In addition, GHG abatement cost curves are limited by the fact that there are many factors that can affect the viability of a given GHG mitigation measure that cannot easily be accounted for, such as equity implications and administrative efforts (Sweeney & Weyant, 2008). GHG abatement cost curves are also often sensitive to baseline assumptions and therefore are limited where these assumptions lack precision. Other shortcomings of GHG abatement cost curves include their inability to account for:

- Interactions between GHG abatement options;
- Future development of new technologies and improvements to existing technologies;
- Future regulations or policies that may influence some of the measures; and
- Co-benefits of GHG mitigation, such as improved human health.

GHG abatement cost curves are also limited to GHG mitigation strategies with quantifiable costs and impacts. This often results in a focus on technological strategies to reduce GHGs, such as cleaner energy sources and increased energy efficiency, as behavioral interventions can be difficult to quantify. For example, the abatement options covered by McKinsey & Company and Sweeney & Weyant (2008) included:

- Building and appliance energy efficiency;
- Improvements in vehicle fuel economy;
- Greater reliance on low-carbon fuels and renewable energy
- Improvements in industrial processes; and
- Land-use and forestry and expanding and enhancing carbon sinks.

4.5 GHG Mitigation Assessments

Quantifications of GHG mitigation cost and potential begin by establishing a GHG emissions inventory. A GHG emissions inventory helps (1) identify the sectors and activities that emit GHGs; (2) understand GHG emission trends; and (3) create goals and strategies for reducing GHG emissions (EPA, 2014). For local and community GHG inventories, transportation and energy use in the residential and commercial sectors are likely to be among the biggest contributors to GHG emissions (EPA, 2014).

Once an inventory has been established, a GHG emissions baseline scenario is created so that the impacts of GHG mitigation projects can be calculated. ARB defines a baseline as "the scenario that reflects a conservative estimate of the business-as-usual performance or activities for the relevant type of activity or practice" (ARB, 2009). Simply put, the baseline is meant to capture the GHG emissions that would occur in the absence of the mitigation or offset project(s) under consideration.

To enable the evaluation of specific mitigation projects, the baseline must include sufficient detail about the relevant GHG emitting factors and activities, such as future energy use patterns, fuel production systems, and technology choices (Lazarus et al., 1995). Selecting a base year and time horizon are also crucial to establishing a baseline. Since the projection of economic variables and the characterization of technologies can become quite uncertain when looking 50-

100 years into the future (Lazarus et al., 1995), the time horizon for mitigation assessments is usually around 20-40 years (Adler et al., 1995). Because establishing a baseline is not an exact science, a baseline should be conservatively defined (Goodward & Kelly, 2010).

To quantify GHG emissions, data on the GHG emissions of the activity in question are collected and summarized. Then, individual GHGs are converted to CO_2e by multiplying the emissions values (generally expressed in terms of metric tons per year) by their global warming potential (GWP). The general equation for emissions quantifications is:

GHG Emissions = [source metric] x [emissions factor] x [GWP]

The "source metric" is the quantity of the source of the GHG emissions (for example, gallons of diesel fuel) and the "emissions factor" is the rate at which emissions are generated per unit of source metric (for example, kilograms of CO_2 per gallon of diesel fuel) (CAPCOA, 2010). The total GHGs emitted from an individual source is the sum of emissions from each GHG.

4.6 GHG Emissions in Santa Barbara County

As part of the Energy and Climate Action Plan, the County of Santa Barbara completed a GHG emissions inventory for unincorporated Santa Barbara County for 2007. The inventory does not include incorporated cities, UC Santa Barbara, state and federal lands, or offshore oil and gas facilities. This inventory found that transportation was the largest source of GHG emissions in unincorporated Santa Barbara County, accounting for roughly 521,160 metric tons (MT) of CO_2e. Residential and commercial energy use were the second and third highest sources of GHG emissions, accounting for 195,490 MT CO_2e and 121,580 MT CO_2e, respectively. Other sources of GHG emissions include off-road equipment, solid waste disposal, agriculture, water and wastewater, industrial energy, and aircraft operations. The county's Energy and Climate Action Plan excludes sources of emissions that could not be quantified as well as those over which the county lacks jurisdictional control. In terms of forecasting GHG emissions, the county estimates that, under a business-as-usual scenario, community-wide emissions will grow by approximately 14% by 2020 and by approximately 29% by 2035 (County of Santa Barbara, 2013).

4.7 GHG Mitigation Strategies for Santa Barbara County

While the GHG emissions inventory created for Santa Barbara County's Energy and Climate Action Plan is restricted to unincorporated Santa Barbara County, it, along with existing GHG emissions inventories for California, suggests that transportation and energy use in the commercial and residential sectors have significant potential for GHG reduction. In the following section, we will review various strategies used to mitigate GHG emissions in these sectors, as well as other strategies that are particularly relevant to Santa Barbara County.

4.7.1 Energy Efficiency Retrofits

Energy efficiency retrofits (also referred to as energy retrofits) describe a variety of strategies, such as installing better insulating windows or replacing old light bulbs with more efficient ones, that are aimed at decreasing the overall energy use of a building. Energy efficiency retrofits to residential and commercial buildings have the potential to save a significant amount of energy, usually at a negative cost as the initial investment in new appliances is paid off by utility bill savings over the lifetime of the retrofit. For example, residential retrofits have been found to reduce total household energy use anywhere from 10% to 33% (Brook et al. 2012; Jackson et al., 2012; Cohen et al., 1991). Given that over 80% of the homes in Santa Barbara County were built over 25 years ago, energy efficiency retrofits are likely an appropriate and effective method for reducing energy use in the county (emPower Santa Barbara County, 2013).

Types of energy efficiency retrofits include:

- Improving roof, ceiling, attic, secondary wall, and floor insulation;
- Replacing inefficient appliances with new, efficient models;
- Installing smart or programmable thermostats;
- Installing better insulation windows; and
- Switching to compact fluorescent or LED light bulbs.

In California, lighting is the largest end-use of electricity in the commercial and residential sectors, while other significant end-uses include refrigerators, heating and cooling, TVs, PCs, and Office Equipment (Figure 5).

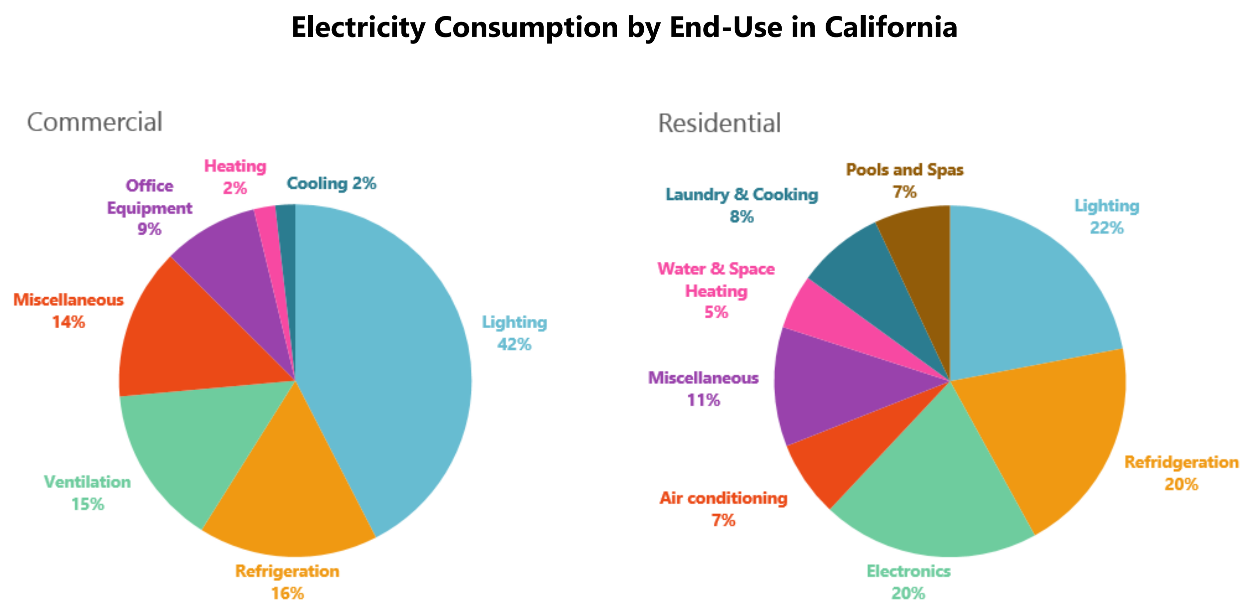

Figure 5. Household electricity consumption by end-use in California.
Source: CEC (2010); CEC (2006)

4.7.2 Solar Power

Over 50% of California's electricity comes from natural gas, which is a significant source of GHG emissions (CEC, 2011). Switching to less carbon intensive energy sources is essential to reducing emissions and since California has substantial solar resources, solar power is an essential component of California's GHG reduction strategy (Figure 6). The CEC estimates that Santa Barbara County has a 297,137 MW potential for solar photovoltaics (PV), with commercial PV having a technical potential of 3,258,365 kW and new residential PV having a technical potential of 1396 kW (Simons & McCabe, 2005).

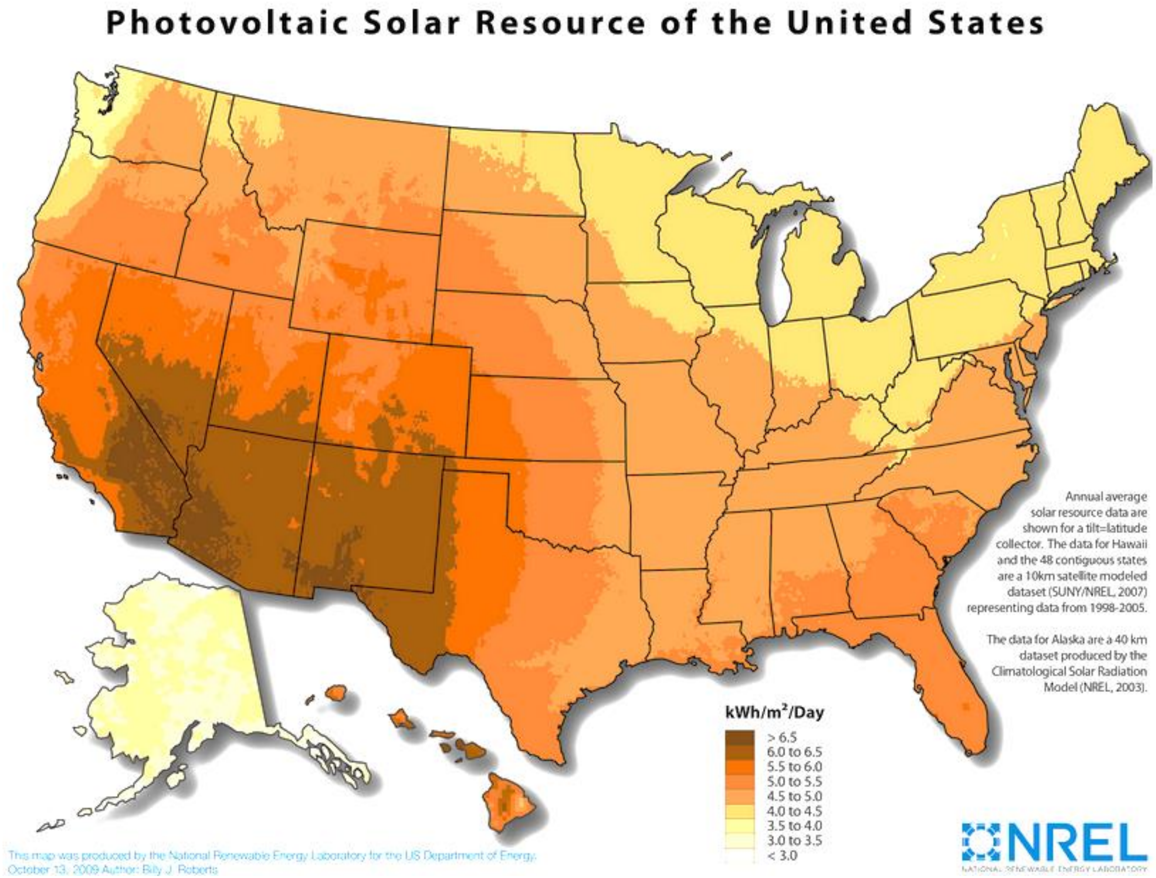

Figure 6. Solar photovoltaics (PV) resource potential of the United States in kWh/m^2/day.
Source: NREL, Billy J. Roberts (2009)

Although the cost of solar panels has been declining, the upfront costs of installing rooftop solar panels remain high (NREL, 2012). In order to incentivize solar development, the state established the California Solar Initiative (CSI). CSI is a rebate program for customers of California's three investor owned utilities: Pacific Gas and Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E) that subsidizes grid-connected solar energy systems for residential and commercial buildings. The incentive amount varies based on utility provider, system size, performance capacity, and other installation factors.

There are a number of alternatives to purchasing a solar energy system upfront including loans, leases, and power purchase agreements, all of which are typically administered by solar contractors. Customers who sign loan agreements usually pay no or little upfront cost and receive a low interest rate (usually around 4-5%), which is based on their monthly electricity generation (Khouri, 2014). Alternatively, customers who lease a solar energy system pay via monthly payments based on their electricity generation, while customers who sign Power Purchase Agreements (PPA) pay the solar provider for the energy generated by the system rather than paying for the system itself (Gordon, 2013). Homeowners interested in purchasing rooftop solar can also take out a home equity loan. Home equity loans vary case by case, but typically charge a low interest rate because they use the home as collateral.

4.7.3 Electric Vehicles

Electric vehicles have significant GHG reduction potential in California. All-electric vehicles (EVs), are powered solely by an electric battery and thus have no tailpipe emissions. Any emissions from EVs are indirect emissions due to electricity generation. Because they are more efficient at converting energy, EVs also have a higher fuel economy than conventional fuel vehicles. Given that roughly 37% of GHG emissions in California come from transportation, EVs are a significant component of the state's strategy to reduce GHG emissions. In 2012, California Governor Edmund G. Brown Jr. issued an Executive Order calling for over 1.5 million EVs on California roads by 2025 (Governor's Interagency Working Group on Zero-emission Vehicles, 2013). Pursuant to this goal, the California's Zero-Emission Vehicle (ZEV) Action Plan identifies specific strategies and actions that agencies can take to promote the adoption of EVs and plug-in hybrid electric vehicles (PHEVs) in a variety of sectors. Strategies recommended by the plan include continuing consumer rebates for the purchase or lease of ZEVs, development of interoperability standards for electric vehicle charging stations, raising consumer awareness of ZEVs, and expanding ZEVs within public and private bus fleets (Governor's Interagency Working Group on Zero-emission Vehicles, 2013).

Although they have higher upfront costs than conventional fuel vehicles, some studies suggest that EVs may be cheaper over their lifetime due to lower maintenance and fuel costs (Atkins, et al. 2013; Griffith, 1995). In their analysis of electrifying Florida's transit buses, Atkins, et al. (2013) find that the total lifetime cost for an electric bus is lower than that of a diesel bus. Aguirre et al. (2012), however, find that the lifetime cost of an EV is slightly higher than that of a conventional vehicle. In addition to reduced emissions, Atkins, et al. (2013) find that electrifying public transit may result in co-benefits such as increased economic activity due to an increased demand for electricity. Griffith (1995) likewise found that Santa Barbara's Metropolitan Transit District's electric buses reduce aggregate emissions of nitrous oxides (NOx), particulate matter, and carbon monoxide (CO) by roughly 95% in comparison to diesel buses.

4.7.4 Commuter Benefit Programs and Alternative Work Schedules

Commuter benefit programs are employer-administered tax-based incentive programs built into the federal tax code (IRS code 132(f)). The code provides for a commuter benefit account that employees can place earned wages into a commuter benefit account that can be used to pay for alternative modes of transportation is not subject to payroll or income taxes.

There are two possible structures for a commuter benefits program:

1. An employee-paid, pre-tax benefit; or
2. An employer-paid subsidy program.

The pre-tax benefit program requires employees to divert money from their paycheck into in an untaxed account that is then re-administered to employees in the form of travel vouchers or transportation-limited debit cards (Commute Smart, 2014). For an employer-paid subsidy program, the employer administers subsidies in the form of untaxed vouchers or transit debit cards. Employers can administer their own commuter benefits program or hire a benefit vendor. Benefit vendors usually charge approximately $3 to $5 per month per participant (Commute Smart, 2014).

Commuter benefit account funds can be used to pay for public transit, vanpool, biking, and parking costs. The amount of money that employees are allowed to place in commuter benefit accounts is capped and varies depending on the transportation mode (Table 1). These caps are subject to change annually.

Table 1. Monthly commuter benefits incentive caps for 2015.

Transportation Mode	Incentive Limit
Public Transit	$130
Vanpool	$130
Qualified Parking	$250
Bicycle Reimbursement	$20

Source: NCTR (2013)

Not typically implemented under commuting benefits, alternative work schedules, which are workweek schedules that differ from the standard 8-hour day, 5-day workweek, are another way that GHG emissions from commuting can be reduced. For example, a 9/80 work schedule, which describes a work scheduled in which employees work 9-hour days and receive one day off every other week, eliminates roughly two commute days from every month. By eliminating the number of days employees are required to come into work, such schedules can reduce VMT from commuting and thus reduce transportation related GHG emissions.

4.7.5 Agricultural Engine Electrification

Agriculture engines, which are frequently diesel-powered, impact local air pollution and GHG emissions. Currently, California regulations require agricultural diesel engines exceeding a rating of 50 brake horsepower to be registered with the local Air Pollution Control District. Agriculture engines are also regulated under ARB's Airborne Toxic Control Measure for Stationary Diesel Engines, which requires engines to meet certain emission standards. To incentivize the adoption of low emissions agriculture engines, state and local programs provide funding for engine electrification. The Santa Barbara County APCD, for example, offers funding of up to 80% of the cost of the new equipment for cleaner off-road equipment, including large spark ignition engines, agricultural tractors, and construction equipment (APCD, 2013).

4.7.6 Flare Gas Recapture

Flaring is the process by which untreated natural gas, primarily composed of CH_4, is converted into CO_2 via open-air combustion and released into the atmosphere (Bott, 2007). Although flaring is wasteful and contributes to GHG emissions, it is preferable to venting untreated natural gas directly into the atmosphere since CH_4 is a more potent GHG than CO_2. According to a 2007 study conducted by the ARB, flares from California's oil and gas industry emit approximately 260 kilotons of CO_2 equivalent annually (Lee, 2011).

Gas flaring is standard in the oil and gas industry for safety, economic, and practical reasons. Emergency flares are necessary to alleviate dangerous pressure build-ups that occur in wells during the extraction process. Flares are also used to dispose of gas when the volume generated is too small or the gas is too impure to make sale viable. (Bott, 2007).

Alternatives to flaring include selling the gas or using it to generate electricity on-site. Before sale, natural gas must be processed in order to remove impurities and proper gas transportation infrastructure must be in place. The cost, however, is often prohibitive and outweighs the financial benefits of selling small volumes of gas at a low market price. The use of on-site electricity generation technologies, such as microturbines, can be a more financially viable option for waste gas. Microturbines typically are between 30kW to 250kW with a combined capital and installation cost of approximately $2,500/kW, which is recuperated within a few years through electricity bill savings (McAvoy, 2011; Energy and Environmental Analysis, 2008). Although microturbines can operate on variety of fuel types, including unprocessed natural gas, there is concern that impurities, like sulfur, which is typically present in high amounts in untreated gas, have the potential to generate acidic byproducts that could corrode system components (Energy and Environmental Analysis, 2008). Other potential problems with microturbines include reduced efficiencies at low gas loads and suboptimal ambient temperatures as well as part degradation (Energy and Environmental Analysis, 2008).

4.7.7 Rangeland Composting

Rangeland, which is defined here as "land on which plant cover is composed principally of grasses, grass-like plants, forbs, or shrubs suitable for grazing," stores approximately 20-30% of the world's soil organic carbon (SOC) (DeLonge, 2014; Haden et al., 2014). SOC storage in rangelands occurs when plants assimilate atmospheric carbon or carbon from manure deposition (DeLonge, 2014). The capacity of rangelands to serve as a carbon sink depends on climatic variables, disturbance frequency, and management practices. Phenomena such as drought, overgrazing, and soil degradation can lead to plant death and increases in microbial decomposition which, depending on the magnitude, can turn a rangeland from a carbon sink into a carbon source (DeLonge, 2014).

California, which is approximately 40-50% rangeland, could achieve significant GHG reduction through rangeland management practices that maximize carbon sequestration. To this end, scientists in the state have been researching a number of land management practices, including rangeland composting. Rangeland composting directly increases SOC because the applied organic matter integrates with the rangeland soil, is sequestered in plants, and enhances plant growth by adding nutrients. Additionally, rangeland composting prevents CH_4 emissions that would have otherwise occurred had the compost decomposed in anaerobic conditions in a landfill (Haden et al., 2014). In January of 2015, rangeland composting was accepted as GHG offset method that can be used to generate credits for sale on voluntary carbon markets (CAPCOA, 2015).

5 Santa Barbara County GHG Emissions Forecast

5.1 Methods

Developing a baseline GHG emissions forecast was the first phase of our project. The sectors and sources of GHG emissions included in the forecast include:

- Residential Energy Use;
- Commercial Energy Use;
- On-Road Transportation;
- Oil & Gas Flares;
- Organic Waste; and
- Agriculture Engines.

These sectors were chosen either because they are known to be high emitting sectors or were of interest to our client and team. The GHG emissions forecast we created for Santa Barbara County projects GHG emissions from these sectors and sources from 2015 to 2040 given that:

- Economic and demographic trends continue;
- No new legislation is passed; and
- No new projects are undertaken.

Our GHG emissions forecast accounts for relevant measures and projects that have been approved, but not yet implemented or completed, including the RPS, the Pavley Bill, and the Low Carbon Fuel Standard (LCFS). The GHG emissions forecast serves as an emissions baseline scenario for Santa Barbara County, and any reduction in GHG emissions below this baseline is considered GHG mitigation.

The first step required to generate our GHG emissions forecast was to determine the GHG emissions of the selected sectors in 2015. This was accomplished by obtaining the most current GHG emissions data available and adjusting the values to reflect the changes expected to occur between the date the data were collected and 2015. Once the GHG emissions inventory for 2015 was completed, it was grown annually to 2040 according to assumptions about the annual growth and development of each sector. The specific calculations and assumptions used to create our GHG emissions forecast for Santa Barbara County are outlined in the following sections.

5.1.1 Household and Employment Projections

The Santa Barbara County Association of Government's (SBCAG) Regional Growth Forecast provided household and sector-specific employment data that were used to calculate the GHG emissions associated with residential and commercial energy use. In the SBCAG report, the figures are projected from 2010 and estimated for 2020, 2035, and 2040 by region. To obtain annual values, linear growth was assumed between the time points.

5.1.2 Utility Emissions Factors

The emissions factors used to calculate the GHG emissions associated with electricity use were obtained from Pacific Gas and Electric (PG&E) and Southern California Edison (SCE), the two investor owned electric utilities that serve Santa Barbara County, and from projections generated by Energy and Environmental Economics, Inc. (E3). The electricity emissions factor projections created by E3 rely on an accelerated policy case, which assumes that:

- Currently projected energy efficiency savings double by 2020;
- The 33% RPS is met by 2020;
- The state installs 3000 MW of rooftop solar PV by 2020;
- The state installs 4000MW of new combined heat and power by 2020; and
- Peak demand reduces by 5%.

Table 2. Electricity emissions factors for electricity for PG&E and SCE projected by E3

Emissions Factors for Electricity (tons CO_2e/MWh)		
	PG&E	**SCE**
2008	0.24	0.31
2012	0.21	0.27
2013	0.20	0.27
2014	0.19	0.26
2015	0.18	0.25
2016	0.17	0.24
2017	0.16	0.23
2018	0.15	0.23
2019	0.14	0.22
2020	0.13	0.21

GHG emissions from electricity use were calculated by utility service territory so that the appropriate emissions factors could be applied. Unlike electricity emissions factors, which are dependent on the fuel and technology utilized by electricity generators, the emissions factor for natural gas is constant. The emissions factor for natural gas was obtained from the Local Government Operating Protocol Version 1.1 (Table 3).

Table 3. Natural Gas Emissions Factor

Natural Gas Emissions Factor (CO_2e/Therm)
0.00546

5.1.3 Residential Energy Use and Emissions

Santa Barbara County residential electricity and natural gas use were figures were obtained from the CEC's database, which was last updated in 2012. All values were projected to 2040 using the assumption that electricity and natural gas use per household will remain constant from 2012 to 2040. Because per capita energy consumption in California has remained relatively stable for the past 30 years, we felt this was a valid assumption. As a result, residential electricity and natural gas use increase as a function of the increase in the number of households expected from 2015 to 2040. The GHG emissions associated with electricity use also changes from 2015 to 2040 due to the expected change in California's electricity emission factors.

Average annual electricity use per household for 2012 was determined by dividing the total residential electricity use by the total number of households in the county.

Average Annual Electricity Use per Household =
[Total Residential Electricity Use] ÷ [Total Households]

To calculate the total annual residential electricity use from 2015-2040, we assumed that the annual electricity use per household is constant across the time horizon.

Average annual natural gas use per household for 2012 was determined by dividing the total residential natural gas use by the total number of households in the county. To calculate the total annual natural gas use from 2015-2040, we assume the annual natural gas use per household is constant across the time horizon.

5.1.4 Commercial Energy Use and Emissions

Commercial electricity and natural gas data were also obtained from the CEC's database, which was last updated in 2012. Our commercial GHG emissions forecast included office buildings, government buildings, and hotels and motels. Other commercial building types were omitted because recommendations for energy use reductions for specialized buildings, like industrial plants and hospitals, are complicated and site-specific. Unlike residential energy use, we could not assume that all commercial buildings have the same basic energy use profile and thus could not calculate average energy use by dividing total commercial energy use by the number of commercial buildings. Additionally, there is no data available on the total number of commercial buildings in Santa Barbara County. Instead, a bottom-up approach was utilized to estimate the energy use emissions from the commercial sector.

Employment and employee density data were used to estimate the square footage of each type of commercial building which was then used to determine the total energy use by employment sector. The general methodology utilized was as follows:

Total Energy Use by Building Type/Employment Sector =
[Number of Employees in Sector] x [SQF per Employee] x [Annual Energy Use per SQF]

The SBCAG Regional Growth Forecast provided employment by sector data. Estimates for the number of square feet per employee typical for office buildings, government buildings, and hotels and motels were obtained from a Southern California Association of Governments (SCAG) employee density study. Finally, Energy IQ, an interactive database that utilizes data from the California Commercial End-Use Survey, was used to estimate the average annual energy use per square foot of each building type.

Commercial sector GHG emissions for 2015 were calculated by applying the appropriate emissions factors to the total commercial energy use. To accomplish this, we assumed that the commercial sector is homogenous throughout the county.

The total GHG emissions by building type were grown annually holding the employee density and energy use values constant across the time horizon. Therefore, changes in annual GHG emissions are a function of the expected change in the number of employees per industry between 2015 and 2040.

5.1.5 On-Road Transportation

On-road vehicle population, vehicle miles traveled (VMT), and emissions data for Santa Barbara County were obtained from SBCAG. SBCAG utilized ARB's Emissions Factor (EMFAC) emissions estimator model to generate the data. EMFAC2011, the latest in a series of EMFAC models, is utilized by SBCAG, and other Regional Transportation Planning Agencies (RTPAs) in California, to generate the transportation forecasts required for government-mandated planning reports.

EMFAC2011

EMFAC2011 is composed of two different modules, EMFAC2011-LDV and EMFAC2011-HD, which address different vehicle types and rely on two different methods. EMFAC2011-LDV addresses light duty (less than 14,000 pounds gross vehicle weight rating) gasoline and diesel passenger vehicles and urban transit buses. In this module, vehicle population data is estimated using a combination of 2009 vehicle registration data from the Department of Motor Vehicles, Smog Check data, and Vehicle Identification Number (VIN) decoders. VMT estimates come from RTPA estimates, when supplied, or are based on default speed distributions and mileage accrual rates. SBCAG did not supply VMT data for the EMFAC2011-LDV model. The methodology for the emissions calculations can be found in the EMFAC2011 technical documentation and other supporting documents.

EMFAC2011-HD addresses commercial heavy-duty (exceeding 14,000 pounds gross vehicle weight rating) gasoline and diesel trucks and buses. The vehicle population, VMT estimates, and emissions factors utilized are from the 2010 Statewide Truck and Bus Rule amendments (EMFAC Technical Documentation).

The EMFAC output utilized in this report is from EMFAC2011-SG, which is a synthesis of the EMFAC2011-LDV and EMFAC2011-HD modules. The GHG emissions estimates from this model incorporate the emissions reductions expected from the Low Carbon Fuel Standard (LCFS) and Pavley Bill (Figure 7). The effects of the LCSF and Pavley Bill are applied to the emissions predictions in the form of "correction factors" that reduce the carbon dioxide emissions from the baseline expectations (Appendix D). Assumptions about the penetration of zero-emissions vehicles are also integrated into EMFAC2011.

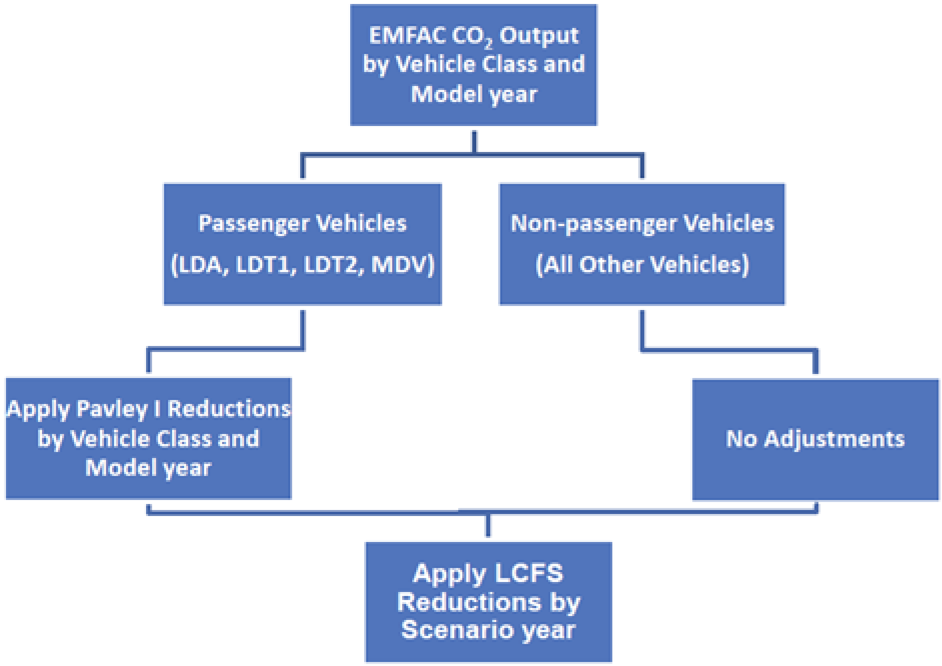

Figure 7. Outline of the method applied in EMFAC2011-SG to calculate emissions reductions due to the Low Carbon Fuel Standard (LCFS) and the Pavley Bill.
Source: EMFAC2011 Technical Documentation.

The SBCAG output forecasts emissions and VMT by vehicle type out from 2011, the most current year that accurate county-level VMT data exists, to 2020 and 2035. In order to generate annual projections, linear growth was assumed between the time points. To project data out to 2040, the rate of linear growth between 2020 and 2035 was assumed to continue between 2035 and 2040.

Commuter Baseline

The EMFAC data was utilized to generate a commuter baseline that was used to calculate the impact of commuter benefit-related mitigation strategies. In order to generate this baseline, VMT and emissions data from vehicles that could be used to commute to work, defined as passenger vehicles and light-duty trucks, were separated from the other data. The VMT and emissions attributable to workers commuting alone to work was calculated as a percentage of the figures in the EMFAC baseline.

5.1.6 Oil and Gas Industry Flares

The flare emissions data utilized in this report are 2011 values from the Santa Barbara County APCD emissions database. There are 70 operational oil and gas flares in the county and seven of these flares were included in the forecast. The flares included operate continuously and emit at least 500 metric tons of CO_2e annually. These characteristics indicate that there could be a sufficient volume and flow rate of gas for distributed generation technology to be viable (Appendix G).

The GHG emissions from existing flares were held constant across the time horizon. It was assumed that no new flares would come online and no existing flares would be decommissioned over the time horizon.

5.1.7 Organic Waste

The annual GHG emissions attributable to organic waste disposed in Santa Barbara County was estimated through the use of the California Department of Resources Recycling and Recovery's (CalRecycle) waste disposal data and the California ARB's emissions calculator model. CalRecycle maintains a database that contains annual waste disposal data from 1990 to 2013 for all active landfills in Santa Barbara County. These data show that waste disposal trends are not dependent on fluctuations in household or population numbers, but rather are more strongly correlated to other economic trends.

Since prediction of economic trends is out of the scope of this project, and because the annual fluctuations in the amount of waste disposed from year to year are small, the average amount of waste disposed from 1990 to 2013 was assumed constant over the time horizon.

According to the 2008 Waste Characterization Study from the California Environmental Protection Agency (CalEPA), approximately 32% of waste disposed in California is organic the majority of which is food waste (Figure 8). The California-wide estimates were assumed to be the same for Santa Barbara County and held constant from 2015 to 2040.

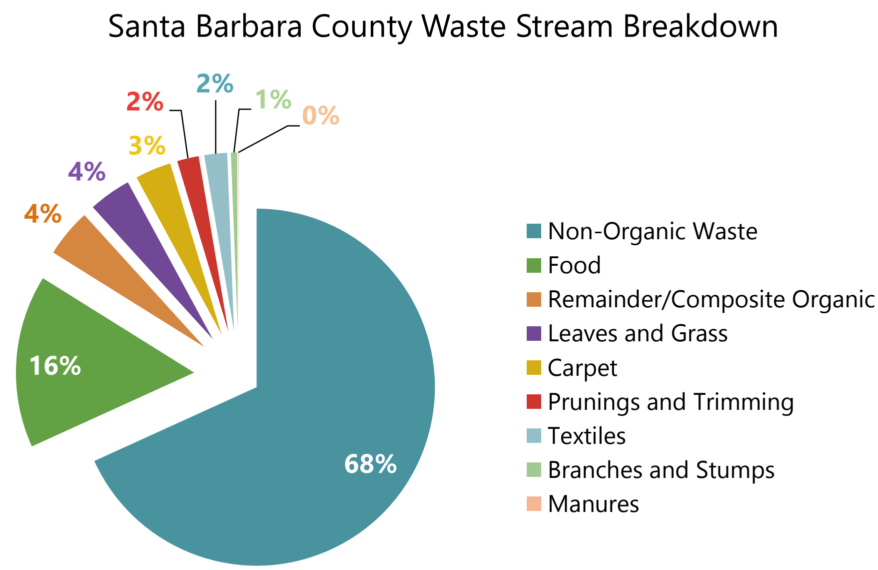

Figure 8. Composition of organic waste disposed in Santa Barbara County from 2015 to 2040.
Source: CalEPA (2008)

ARB's Landfill Emissions Tool Version 1.3 was used to determine the emissions attributable to organic waste disposed. The default organic waste percentages of the model were altered to reflect the data from the CalEPA's Waste Characterization Study and the total annual waste disposed in Santa Barbara County. Although organic waste disposed in the 2015 to 2040 time interval will continue to emit GHGs for years into the future, only emissions that occur within the time interval are included in the forecast.

5.1.8 Agriculture Engines

Agriculture engine emissions data for 2014 was obtained from the Santa Barbara County APCD. Information utilized in the emissions calculations were obtained from engine permit applications. The annual emissions value for agriculture engines in 2014 was assumed constant over the time horizon.

5.2 Results

Our GHG emissions forecast for Santa Barbara County between 2015 and 2040 reveals that the transportation sector is the largest source of emissions among the sectors and sources we examined, followed by the residential and commercial sectors (Figure 9). The emissions in these three sectors are significantly higher than the emissions attributable to agriculture engines, organic waste, and flares. As a result, we focused the remainder of our analysis on GHG mitigation strategies within the transportation, residential, and commercial sectors only.

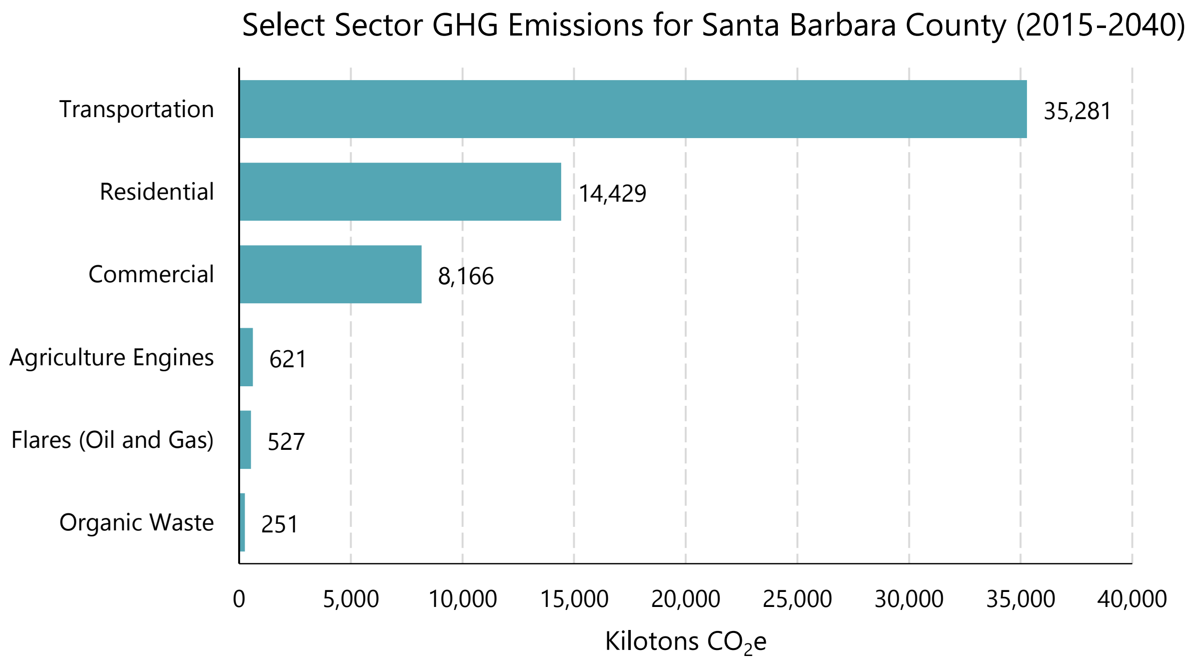

Figure 9. Santa Barbara County's GHG emissions inventory for select sectors for 2015 to 2040 in kilotons CO_2e.

6 Santa Barbara County GHG Abatement Cost Curve

6.1 Methods

6.1.1 Selection of GHG Mitigation Strategies

We focused on mitigation strategies within the transportation, residential, and commercial sectors because they are the highest emitting sectors in our forecast. In order to get select the best strategies in these sectors, we conducted an extensive literature review and generated a list of potential GHG mitigation strategies (Appendix H). We excluded strategies that:

1. Were infeasible given the characteristics of Santa Barbara County;
2. Lacked sufficient data to credibly establish a baseline, cost, and/or effectiveness; or
3. Were already in place at the state or county level.

From this list, we chose strategies that had high GHG reduction potential, were of interest to our client and team, and were feasible to investigate given the timeframe and scope of this project. The strategies included in this analysis are:

- **Energy Efficiency Retrofits**
    - Upgrades to lighting, heating, ventilation, and air conditioning (HVAC), water heating, and refrigerating
- **Solar PV**
    - Installation of solar PV systems to residential buildings
    - Installation of solar PV systems to commercial buildings
- **Electric Vehicles**
    - Electric Passenger Cars
    - Electric Light Duty Trucks
    - Electric Transit Buses
- **Commuter Benefits Programs and Alternative Work Schedules**
    - Vanpooling
    - 9/80 Work Schedules

In the following section, we will review the methodology used to calculate the cost and GHG reduction potential of each of these strategies over the 2015-2040 time period.

6.1.2 GHG Abatement Cost Curve

McKinsey & Company and Lutsey and Sperling (2009) use a discount rate of 7% in their GHG mitigation supply curve for the U.S., which is consistent with federal policy making guidelines. Sweeney & Weyant (2008), however, use a 5% discount rate for their California-specific GHG abatement cost curve. Lower discount rates of 3-5% are typical for government or low risk projects (Libecap, 2014). Therefore, we use a 5% discount rate to calculate the net present value (NPV) of all costs associated with each GHG reduction strategy.

The GHG mitigation potential of each mitigation strategy was calculated as if all mitigation strategies were implemented simultaneously. Therefore, the final GHG abatement cost curve represents the collective GHG mitigation potential of all strategies together, rather than if only one measure was implemented at a time.

For each GHG mitigation option, annual total costs were discounted and then summed over the time horizon to get the NPV of the total cost. NPV was calculated as follows:

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1-r)^t} - C_o$$

Where:

C_t = Net cash inflow during the time period

C_o= initial investment

r = discount rate

t = number of time periods

All cost data were converted into 2014 real dollars using the U.S. Bureau of Labor Statistics' Consumer Price Index inflation calculator.

Total GHG emissions mitigated were also calculated annually and summed over the time horizon to get the total GHG mitigation potential of each strategy. Annual values for GHG mitigation potential, however, were not discounted.

6.1.3 Electricity Price Assumptions

All cost calculations that depend on the price of electricity use the average price of electricity paid by residential and commercial customers (Table 3). These averages were calculated using data from Electricity Local, which provides the average electricity price paid by residential and commercial customers in Carpinteria, Buellton, Guadalupe, Goleta, Lompoc, Santa Barbara, Santa Maria, and Solvang, the eight major cities that make up Santa Barbara County.

Table 4. Average Price of Electricity in Santa Barbara County.

Sector	Price ($/kWh)
Residential	0.16
Commercial	0.14

EIA's 2013 Annual Energy Outlook projects that electricity prices in the U.S. will increase by 1.9-3.4% per year from 2013 to 2040 while E3 projects that prices will increase by 3.5-6.3% per year from 2008 to 2020 (Cook, 2013). To calculate the average cost of mitigation measures dependent on electricity prices, we assumed the price of electricity grows 3.4% annually.

6.1.4 Gas Price Assumptions

For 2015 fuel prices, we used the current average fuel price for diesel and gasoline in California (Table 5). For fuel prices between 2016 and 2040, we used the fuel price projections given by EIA's 2014 Annual Energy Outlook (Table 6).

Table 5. California retail price for diesel and gasoline fuel in March, 2015

California Retail Fuel ($/gallon)	
Gasoline (Regular)	$3.36
Diesel (Southern California)	$3.10

Source: CEC (2015)

Table 6. Fuel price projections for diesel and gasoline to 2040

Fuel Price (2014 Dollars) ($/gallon)		
	Diesel	Gas
2020	$3.18	$3.78
2025	$3.39	$4.10
2030	$3.54	$4.33
2035	$3.79	$4.61
2040	$4.02	$4.88

Source: EIA (2014)

6.1.5 Energy Efficiency Retrofits

For the residential and commercial energy efficiency retrofits calculations, we assumed that all households and all government and office buildings in the county in 2015 are retrofitted and that all households and all government and office buildings added to the county in subsequent years are outfitted with the same retrofits immediately. Data on the average cost and average energy savings associated with each type of retrofit were taken from the National Renewable Energy Laboratory (NREL), Energy Star, and the Santa Barbara County Better Buildings Program. Data on the lifetime of each retrofit and the number of each retrofit needed per household came from the Santa Barbara County Better Buildings Program. Data for the number of households and the expected growth in households in the county came from SBCAG. We used E3's emissions factor projections for electricity in California to calculate GHG emissions avoided per kWh of electricity saved.

In the residential sector, we calculated the cost and GHG mitigation potential of replacing all light bulbs in all homes in the county with LED light bulbs, and of installing more efficient HVAC units, water heaters, and refrigerators. For the commercial sector, we examined the same retrofits, with the exception of water heaters. Our baseline scenario for measuring GHG mitigation potential of LEDs assumes that all households and all office buildings currently use incandescent light bulbs, but that once the price of LED light bulbs becomes competitive with incandescent light bulbs, households switch over to LEDs. For upgrading HVAC units, water heaters, and refrigerators, which range in cost and energy use based on type and model, we calculated the average cost and average energy use for each type of retrofit based on Energy Star data and used those averages to calculate the cost and mitigation potential of each.

Annual cost for each type of retrofit was calculated as follows:

Annual Cost =
[Purchase Cost x Units per Home - Energy Bill Savings per Home] x [Retrofitted Homes]

Our calculation of annual cost took into account replacement cost based on the lifetime of each retrofit. We also assumed that incentives and rebates that are currently available for lighting, HVAC, water heater, and refrigerator upgrades are utilized.

Annual GHG emission reductions were calculated using the average annual electricity savings per household for the given retrofit along with the emissions factor for electricity generated in California as follows.

Annual GHG Reductions =
[Emissions Factor] x [Average Annual Energy Savings] x [Retrofitted Homes]

6.1.6 Residential and Commercial Solar PV

For the residential and commercial solar PV calculations, we assume that all households and government, office, and hotel and motel buildings in the county install solar PV systems. It is also assumed that all additional households and included commercial buildings constructed in subsequent years install solar PV systems immediately. To account for the baseline growth in solar PV installations amongst commercial and residential buildings, we assumed that solar installations grew by 7.5% per year, as this is the baseline growth in solar PV predicted by EIA (U.S. Energy Information Administration, 2014).

Solar costs were calculated using cost per watt. Annual data on the cost per watt for solar PV was obtained from NREL (Appendix C). Data on the average number of sun-hours in a day and the average number of sun-days in a year were obtained from the National Climatic Data Center. We used the average sun-days per year (286) and average sun-hours per day (5.94) for Santa Maria as the county averages.

We calculated average system size by dividing the average annual electricity use per building by the number of sun-hours in a year as follows:

Average System Size = [kWh per Year] ÷ [Sun-hours per Day x Sun-days per Year]

To get the average purchase price of the system, average system size was then converted to watts and then multiplied by the cost per watt:

Purchase Price = [System Size] x [Cost per Watt]

To calculate the amount of electricity offset by the solar energy system, we subtracted efficiency losses from the system size then multiplied by the number of sun-hours in a year as follows:

kWh Delivered by System Annually =
[System Size - Efficiency Losses] x [Sun-hours per Day] x [Sun-days per Year]

Annual costs were calculated as the sum of purchase cost, annual maintenance cost, and electricity bill savings:

Annual Cost = [Capital Cost per Home - Energy Bill Savings per Home] x [Number of Homes]

Annual GHG emissions were calculated using the average annual electricity use per household in Santa Barbara County along with the emissions factors for electricity generated in California as supplied by E3:

Annual GHG Savings = [Emissions Factor] x [Average Annual Energy Use] x [Number of Buildings]

6.1.7 Electric Vehicles

The calculations pertaining to electrifying the county's transit bus fleet and electrifying all new passenger cars and light duty trucks in the county used the emissions outputs, number of vehicles, and VMT per year as given by the EMFAC model. EMFAC divides light duty trucks into two categories: light duty trucks with a gross vehicle weight rating (GVWR) of less than 3750 lbs. (LDT-1), and light duty trucks with a GVWR of 3751 to 5750 pounds (LDT-2). All vehicle categories included in the EMFAC model output are divided into diesel-fueled and gas-fueled vehicle sub categories. To account for differences in purchase cost, vehicle population, GHG emissions, VMT, etc., separate calculations were completed for each vehicle category and each vehicle type.

Our estimate of the cost of electrifying the county's transit bus fleet assumes that all buses have a lifespan of 12 years, as this assumption is common in the literature (Clark et al., 2007; Griffith 1995; Lajunen 2014). We assume that electric transit buses have an average fuel economy of 1.92 kWh/mile, as stated by electric bus manufacturers, and that this fuel economy improves by 0.5% per year, as estimated by Li et al. (2013).

We assume passenger cars and light duty trucks have a lifespan of 11 years as this is the average lifespan of modern vehicles (Seng, 2013). We also assume that electric light duty vehicles have an average fuel economy of 0.33 kWh/mile in 2015. This average was calculated using data from fueleconomy.gov on the fuel economy of all commercially available EVs in the U.S. We assumed that the fuel economy for light duty EVs also improves by 0.5% annually.

Annual costs for the baseline scenario and for the electric bus scenario were calculated using the following equation:

Total Annual Cost = [Annual Fuel Costs] + [Annual Purchase Cost] + [Annual Maintenance Costs]

Annual fuel costs were calculated using the following equation:

Annual Fuel Cost = [Fuel Economy] x [Annual VMT] x [Price of Fuel]

The fuel economy for the baseline scenario was derived from EMFAC emissions and VMT data using the relevant emissions factor for fuel as follows:

Miles per gallon = [Tons CO_2e] ÷ [Tons CO_2e/gallon Fuel] x [VMT]

Annual purchase cost data for 2015 to 2040 for light duty vehicles was taken from national averages as given by EIA.

Annual GHG emissions for the electric bus scenario and electric light duty vehicles scenarios were calculated using the following equation:

Annual GHG Emissions = [Fuel Economy] x [Annual VMT] x [Electricity Emissions Factor]

To calculate the total GHG mitigation for each scenario, annual GHG emissions were summed over the time horizon and then subtracted from the total GHG emissions of the relevant baseline.

In addition to calculating the cost and GHG mitigation potential of EVs, we also calculated the air pollution reduction potential. Air pollution reductions were calculated by multiplying the annual VMT of the relevant baseline scenario by the emissions factor for the given air pollutant and then summing annual values over the time horizon. Air pollution emissions factors for each type of vehicle were obtained from Argonne National Laboratory's GHG, Regulated Emissions, and Energy use in Transportation (GREET) Model (Cai et al., 2013). The air pollutants included were volatile organic compounds (VOCs), carbon monoxide (CO), nitrous oxides (NOx), sulfur dioxide (SO_2), particulate matter with a diameter of 10 micrometers or less (PM_{10}) and of 2.5 micrometers or less ($PM_{2.5}$), CH_4, and N_2O.

6.1.8 Commuter Benefits and Alternative Work Schedules

In order to calculate the GHG reduction potential of alternative 9/80 work schedules and of vanpooling, it was necessary to generate a commuting emissions baseline. The baseline was limited to emissions attributable to people commuting alone to work by gas or diesel-powered vehicles. It was assumed that passenger cars and light-duty trucks were the only vehicle types used to commute to work.

According to the SBCAG 2007 Commute Profile, the average daily commute in Santa Barbara County is 28 miles. We multiplied this value by the average number of workdays in a year to get the annual commute VMT per commuter:

VMT Annually per Commuter= [28 VMT Daily] x [250 Workdays]

Approximately 71% of people commute alone via passenger vehicle as their primary mode of transportation to work (SBCAG, 2007). We assumed there was no secondary mode of transportation and used this percentage to determine the total number of people commuting alone to work in the county:

Number Solitary Commuters=
[Annual Employment Projection] x [0.71 Percent Solitary Commuters]

In order to determine the annual VMT attributable to solitary commuters, the number of solitary commuters was multiplied by the annual VMT attributable to solitary commuting to work. Then, the value was adjusted to reflect the gas and diesel-powered reduction in VMT due to the EV replacement mitigation strategy outlined in the prior section:

Annual Solitary Commute VMT=
[Number Solitary Commuters] x [7000 VMT per Worker Annually] - [VMT Reduced by EVs]

The annual solitary commute VMT number was calculated as a percentage of total VMT expended in the county by vehicles in the commuter vehicle categories (passenger cars and light-duty trucks). Then, this value was multiplied by the annual emissions of those vehicle categories to get the total annual emissions due to solitary commuting:

Percentage Annual VMT Attributable to Solitary Commuting =
[VMT Solitary Commuters] ÷ [Annual VMT in Passenger and Light - Duty Truck Categories]

Annual Emissions Attributable Solitary Commuting =
[Percentage Annual VMT Attributable to Solitary Commuting]
x [Annual Emissions in Passenger and Light-Duty Truck Categories]

Emissions reductions due to vanpooling and 9/80 work schedules were calculated as a reduction from this emissions baseline. The GHG reduction due to 9/80 schedules was calculated first as a reduction in the number of VMT traveled due to people commuting to work fewer days annually. The 9/80 work schedules calculation followed the same structure outlined above, except the number of annual workdays spent commuting is 224 days instead of 250, which results in an annual VMT attributable to each solitary commuter of 6,272 instead of 7,000 VMT. It was assumed that all employed people in Santa Barbara County work 9/80 schedules. Subtracting the 9/80 commuting emissions from the solitary commuting baseline gives the total amount of emissions reductions due to 9/80 schedules.

Emissions Reductions from 9/80 Schedules=
[Annual Emissions from Solitary Commuting] –
[Annual Emissions 9/80 Schedule Solitary Commuting]

Emission reductions due to vanpooling were calculated assuming every employed person in the county uses a vanpool to commute to work with two people per vanpool. This emissions calculation was completed by dividing the emissions from the total 9/80 schedule emissions by two:

Emissions Reductions from Vanpooling=
[Annual Emissions 9/80 Schedule Solitary Commuting] ÷ [2]

There are no positive costs associated with switching to 9/80 schedules, but there are negative costs in the form of fuel savings. There are also negative costs associated with fuel savings for vanpooling. In order to calculate fuel savings, it was necessary to calculate the amount of money spent on gasoline by solitary commuters annually. This was achieved by multiplying the annual VMT expended by solitary commuters by the average fuel economy and the price of fuel in that year.

Annual $ Spent on Fuel for Solitary Commuting =
[Annual Solitary Commute VMT] x [Average Fuel Economy (Gal/Mile)] x [Fuel Price ($/Gal]

The total fuel savings for 9/80 schedules and vanpooling were calculated as a function of the number of gallons of fuel reduced due to reduced VMT.

Vanpooling has the additional positive cost of vanpool fees and negative cost of commuter account tax savings. The typical cost to belong to a vanpool is approximately $2,000 per year. This value multiplied by the total number of people participating in the program, which is the total number of people commuting to work solitarily, gives the total annual costs due to vanpooling:

Annual Costs Vanpooling=
[Annual Costs Vanpooling] x [Number Solitary Commuters]

The negative cost of commuter account tax savings is a function of the total amount of income tax savings for employees, payroll tax savings for employers, and the number of people receiving the savings. In order to calculate tax savings, it was necessary to calculate the annual taxes paid. It was assumed that every employee in the county receives the median Santa Barbara County income of $62,000 and pays an income tax of 25% (SBCAG, 2007). It was also assumed that every employee places the maximum of $130 per month in the untaxed commuter account. These inputs were inserted into a commuter benefit tax savings model in order to obtain the total income tax savings per employee annually (Benefit Resource Inc., 2014). The annual income tax savings are $509 per employee participating in the program (Table 7).

The payroll taxes per employee, consisting of Federal Social Security and Medicare Taxes and State Taxes, paid on the employee wage amount of $62,000, was determined to be 11.5% per employee. It is estimated that the payroll tax savings from establishing a commuter benefits account is at least 7.65%, which is the value we used for our calculations (NCTR, 2013). The annual payroll tax savings per employee is $384 for each employee participating in the program (Table 7).

Table 7. Commuter benefit program tax savings

Tax Savings	
Income Tax Savings	$509
Payroll Tax Savings	$384

6.2 Results

6.2.1 Santa Barbara County GHG Abatement Cost Curve

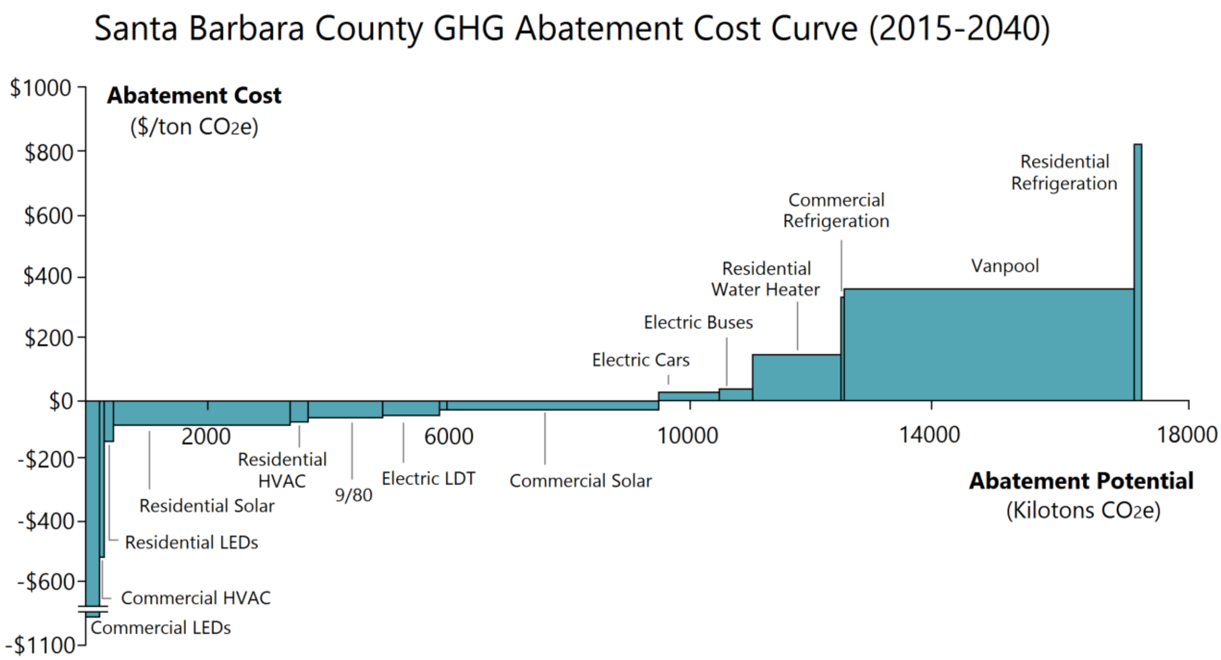

Figure 10. GHG abatement cost curve for Santa Barbara County from 2015 to 2040. Abatement costs are in real $2014 per ton of CO2e. Abatement potential per year is in kilotons of CO2e.

Our results indicate that Santa Barbara County can mitigate nearly 10,000 kilotons of CO_2e from 2015 to 2040 at a negative cost and nearly 18,000 kilotons of CO_2e overall. Solar PV and most energy efficiency retrofits have a negative cost over the time horizon, while most of the strategies targeted at the transportation sector have a positive cost. Solar PV, vanpooling, and EVs are among the strategies with highest GHG mitigation potential. In the following sections, we will review the results for each mitigation option presented in this curve in detail.

6.2.2 Energy Efficiency Retrofits

Table 8. Abatement cost and GHG reduction potential of residential energy efficiency retrofits in Santa Barbara County from 2015-2040.

Residential Energy Retrofit Measures				
	Lights	**Refrigerators**	**HVAC**	**Water Heater**
$/ton CO_2e	-$121	$779	-$64	$140
kiloton CO_2e	166	114	299	1,487

Table 9. Abatement cost and GHG reduction potential of commercial office building energy efficiency retrofits in Santa Barbara County from 2015-2040.

Commercial Energy Efficiency Measures			
	Lights	**Refrigerators**	**HVAC**
$/ton CO_2e	-$1,066	$311	-$475
kiloton CO_2e	229	16	71

Our results for residential energy efficiency retrofits reveal that GHG savings can be achieved at a negative cost when replacing light bulbs, HVAC units, and water heaters with more efficient options. The most cost-effective measure studied for residential retrofits was light bulb replacement from incandescent light bulbs to LED light bulbs. This retrofit, however, did not have the largest GHG reducing potential at 229 kiloton CO_2e, as less cost-effective measures such as HVAC or water heater retrofits have a higher potential to mitigate GHG emissions overall. In commercial office buildings, however, lighting retrofits did have the largest GHG reduction potential by a significant margin.

Our results are sensitive to purchase price and electricity price assumptions. Additionally, for many retrofits, there is a range of costs and savings, therefore sensitivity analyses for the discount rate, annual growth in electricity prices, purchase cost, and energy savings potential were performed for lighting replacement, HVAC, water heater, and refrigerator replacements, where relevant, for both residential and commercial office building retrofits (Figure 11).

Sensitivity Analysis of Abatement Cost of Energy Efficiency Retrofits

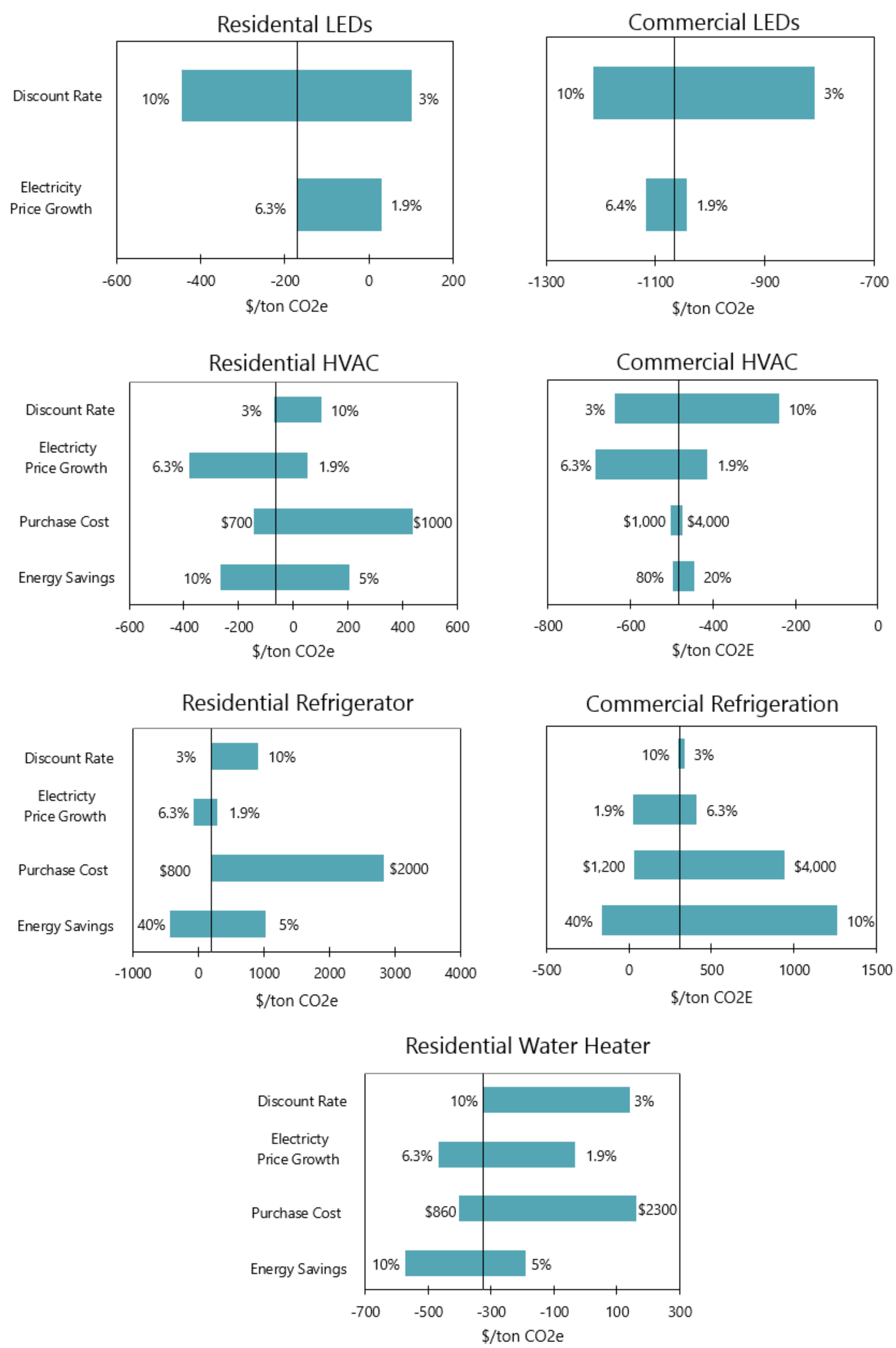

Figure 11. Sensitivity analyses of the lifetime cost per ton of GHG abated for refrigerator, HVAC, and LEDs, for residential and commercial office buildings. Data labels indicate the range of the input parameter.

As Figure 11 illustrates, the GHG abatement cost of most of the energy efficiency retrofits we examined are sensitive to assumptions about the discount rate, electricity prices, and the purchase cost. This indicates that the GHG abatement cost of energy efficiency retrofits is primarily controlled by utility bill savings rather than purchase cost. This is not the case for refrigerator retrofits, however, as the insensitivity of cost to the discount rate and electricity prices indicates that purchase costs primarily control the total cost.

Because the energy use associated with a particular type of light bulb is constant, we looked at the sensitivity of LED costs to the discount rate and the price of electricity only, finding that lighting costs are more sensitive to the discount rate than to the change in electricity price. This is due to the fact that LEDs are projected to become cost competitive with traditional light bulbs by 2020, and thus LEDs are part of the baseline emissions past 2020. As a result, all mitigation from switching to LEDs is contained within the first five years of the time horizon.

6.2.3 Solar PV

For commercial and residential solar PV, we looked at the abatement cost of a scenario in which all residential and commercial buildings in the county install rooftop solar PV systems.

Table 10. GHG abatement cost and potential for commercial and residential solar PV in Santa Barbara County from 2015-2040.

	Residential Solar PV	Commercial Solar PV
\$/ton CO_2e	-\$71	-\$22
kiloton CO_2e	2,913	3,632

Our results for all households, office buildings, and hotels and motels in the county installing rooftop solar reveal that GHG reductions through this strategy have an overall negative cost, as the upfront cost for an average solar PV system purchased in 2015 has a payback period of roughly 20 years. Consequently, the utility bill savings over the lifetime of the solar PV system outweigh the upfront purchase cost as well as maintenance costs.

Because solar prices are projected to decrease while electricity prices are projected to increase over the timeframe we examined, solar PV systems purchased further in the future have a shorter payback period than those purchase today. For example, a solar PV system purchased in 2020 has a payback period of roughly 15 years, 5 years less than a system purchased today.

Results are sensitive to assumptions about the rate of increase in electricity prices, available incentives, and to the discount rate (Figure 12). For example, if the discount rate for either commercial or residential solar PV is 9% or greater, then the abatement cost will be positive.

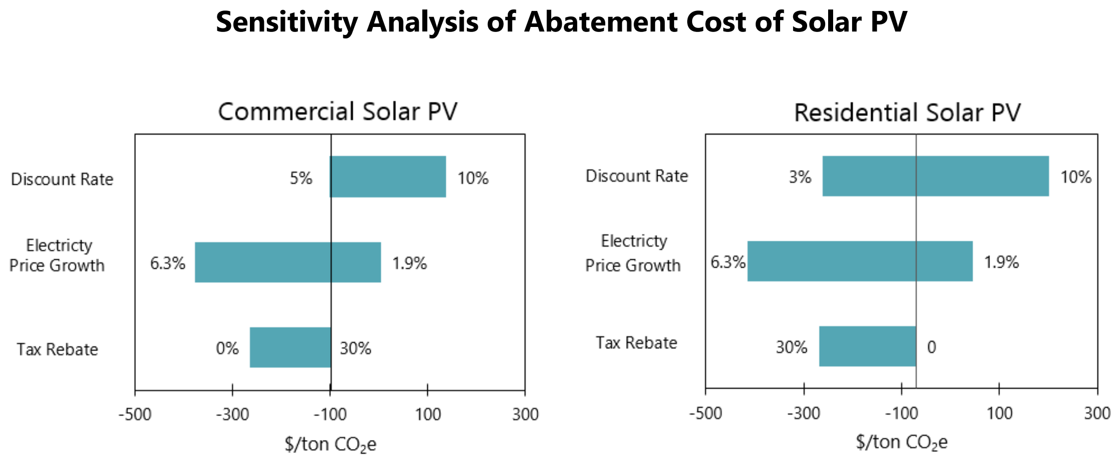

Figure 12. Sensitivity analysis of the discount rate, annual growth in electricity prices, and the availability of tax rebates for calculating the lifetime cost per ton of GHG abated for commercial and residential solar PV.

The GHG reduction potential is also dependent on the rate of solar adoption under the GHG emissions forecast baseline. The higher annual rate of solar adoption under the GHG emissions forecast baseline, the lower the GHG mitigation potential of solar PV. As a result, this analysis is limited by the validity of our assumption about the predicted rate of growth of solar PV.

6.2.4 Electric Vehicles

We determined the cost and GHG mitigation potential of replacing transit buses and all new light duty trucks and passenger cars were with EVs. The results are presented in the table below:

Table 11. GHG abatement cost and potential for EVs in Santa Barbara County from 2015-2040.

	Light Duty Trucks	Passenger Cars	Transit Buses
$/ton CO_2e	-$42	$27	$36
kiloton CO_2e	935	1,016	556

The results for replacing the county's transit bus fleet with electric buses reveals that GHG reduction through this strategy has a positive cost on average. While EVs are more fuel-efficient, lower maintenance, and are declining in purchase cost, fuel and maintenance savings over the lifetime of the vehicle are lower than the purchase price of the vehicle.

The cost of electrifying the entire transit bus fleet in Santa Barbara County is higher than electrifying all new passenger cars and light duty trucks. This is due to the fact that the cost difference between a conventional diesel or gasoline bus and an electric bus is greater than that for smaller vehicles. Unlike transit buses or passenger cars, the abatement cost for light duty trucks is negative. This is due to the greater fuel economy difference between an electric vehicle and a light duty truck, as conventional fuel light duty trucks are large and less fuel efficient than passenger cars. Consequently, the fuel cost savings of switching from a truck to an electric vehicle is greater than from switching from a passenger car, and thus the option is more cost-effective.

Cost calculations for electric cars are sensitive to assumptions in electricity prices and assumptions about available incentives (Figure 13). While the GHG abatement cost for electric passenger cars is unaffected by changes to the discount rate, the cost for light duty vehicles is affected. This disparity is due to the fact that the cost of electric light duty vehicles is more influenced by fuelling cost savings because light duty vehicles are less efficient than passenger cars. In the case of passenger cars, the total GHG abatement cost is negative if customers receive the maximum incentives currently available, take advantage of special EV rates offered by the electric utility, or if the annual growth in electricity prices is low.

The GHG abatement cost of electric buses is sensitive to assumptions about purchase and maintenance cost, but not to assumptions about electricity prices, which had almost no impact on cost (Figure 13). The abatement cost of electric buses is also somewhat sensitive to assumptions about the discount rate, indicating that purchase and maintenance cost have a greater influence than fuel savings on total cost.

Sensitivity Analysis of Abatement Cost of Electric Vehicles

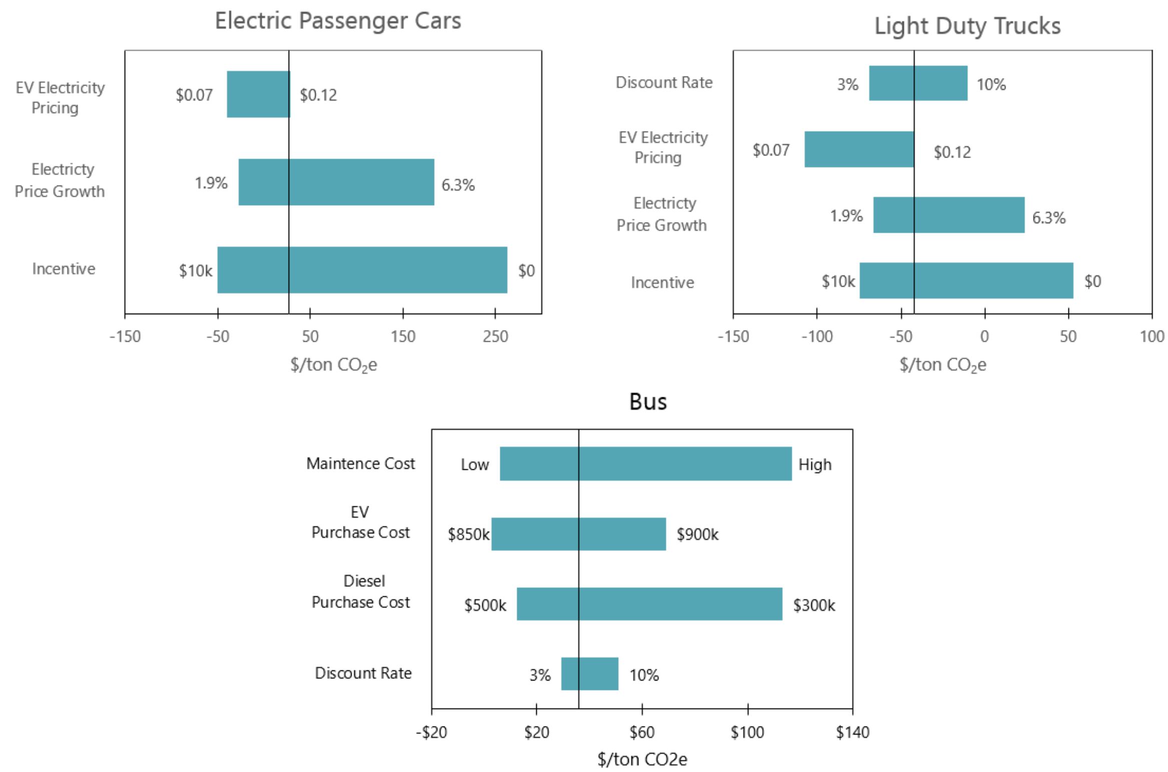

Figure 13. Sensitivity analyses for the GHG abatement cost of electric passenger cars, light duty vehicles, and transit buses.

To gauge how replacing new passenger cars, light duty trucks, and transit buses in Santa Barbara County would impact air pollution, we calculated the air pollution reduction associated with all three vehicle types (Table 12).

Table 12. Air pollution reduction (tons) from 2015-2040 associated with converting new passenger cars, light duty truck, and all transit buses in the county to EVs.

Air Pollution Reduction 2015-2040 (tons)								
	VOC	**CO**	**NO_X**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**CH_4**	**N_2O**
Electric Buses	127	2805	551	4	47	21	15	1
Electric Passenger Cars	1183	20418	861	30	237	133	86	31
Electric Light Duty Trucks	833	15215	960	17	162	96	81	24

Because EVs have no tailpipe emissions, electrifying vehicles in the county has significant potential to reduce air pollution.

6.2.5 Commuter Benefits and Alternative Work Schedules

Table 13. GHG abatement cost and potential for commuter benefits and alternative work schedules in Santa Barbara County from 2015-2040.

	Vanpooling	9/80 Scheduling
$/ton CO_2e	$339	-$52
kiloton CO_2e	4,280	1,248

Our results for vanpooling reveal that GHG savings through this strategy has a high positive cost on average as well as a high GHG mitigation potential. Alternative 9/80 schedules, on the other hand, have a negative cost on average and a moderate GHG mitigation potential. While vanpooling results in fuel savings and tax savings, these savings do not outweigh vanpool participation fees. Although the 9/80 schedule results in only modest fuel savings, 9/80 schedules are essentially cost free, and so fuel savings dominate overall cost.

The cost and GHG mitigation potential of vanpooling depends on the number of participants, with more participants resulting in greater GHG mitigation. Additionally, these strategies have the potential to reduce congestion on roads and highways, and likewise would reduce air pollution, although by a much smaller amount than EVs.

7 Opportunities and Barriers to Implementation

While cost-effectiveness is an important criterion for local governments when considering investment in GHG mitigation, cost alone does not determine the feasibility of a given GHG mitigation strategy. Existing legislation, zoning codes, and other policies have the potential to either facilitate or impede the implementation of new programs targeted at reducing GHG emissions. In the following section, we will review the current barriers and opportunities at the federal, state, and local levels for the GHG mitigation strategies examined in this analysis.

7.1 Energy Efficient Retrofits

7.1.1 Relevant Zoning Codes

Retrofitting an existing building with energy efficient upgrades does not constitute land use development and is therefore not subject to permitting and review by the Planning and Development department in Santa Barbara County. The only exception to this rule is water tanks greater than 5,000 gallons in size and/or with a diameter to height ratio of 2:1 or greater (Santa Barbara County Ordinance No. 5639).

According to the Orcutt Community Plan, buildings that produce noise greater than 45 decibels are required to have double-paned windows. The plan, though not aimed to increase energy efficiency, does encourage higher than average adoption of double-paned windows. The plan also states that "rooftop mechanical structures," like some air conditioning units, should be avoided when possible for aesthetic reasons, requiring those that cannot be avoided to be "shielded from view from surrounding roadways and residences through architectural design, camouflage housing, or other appropriate methods" (Santa Barbara County Planning & Development Comprehensive Planning Division, 2004).

7.1.2 Available Incentives and Rebates

High upfront cost is often the largest barrier to energy-saving retrofits to residential and commercial buildings. To combat this problem, the federal, state, and county governments, along with utility companies, offer financing options for energy efficient appliances.

Utility Rebates

As mandated by the CPUC, California's four investor owned utilities administer a number of programs to support energy efficiency retrofits and upgrades to residential, commercial, and industrial buildings. For residential customers, both SCE and PG&E offer individual appliance rebates for replacing outdated or energy-inefficient appliances with new, Energy Star certified appliances (Table 14).

Table 14. Residential energy retrofit rebates offered by SCE and PG&E

Retrofit	Rebate	Utility
Refrigerator Recycling Rebate (pickup and disposal)	$50	SCE, PG&E
Energy Star Refrigerator Replacement Rebate	$75	SCE, PG&E
Gas Storage Water Heater	$200	SCE, PG&E
Electric Heat Pump Water Heater	$500	SCE, PG&E
Energy Star Washing Machine	$50	SCE, PG&E
Variable Speed Pool Filtration Pump	$100-$200	SCE, PG&E

Source: PG&E (2015); SCE (2015a)

PG&E and SCE also offer On-Bill Financing (also known as the Energy Efficiency Retrofit Loan Program), to help commercial and industrial customers pay for energy efficiency upgrades. Under On-Bill Financing, customers receive zero interest loans for upgrades, including lighting, HVAC, electric motors, LED street lights, refrigerators, water pumps, and food service equipment. Additionally, businesses can borrow up to $100,000 with a five year loan term, while government agencies can borrow up to $250,000 with a 10 year loan term (CPUC, 2010). Before a loan is administered, the utility company must inspect the property and establish appropriate loan terms.

7.1.3 Relevant Programs and Legislation

Energy Upgrade California

Energy Upgrade California is a state funded program administered by the CPUC and CEC to educate businesses and homeowners about energy efficiency and help customers identify rebates and other sources of financing for energy efficiency upgrades. Energy Upgrade California helps customers participate in the Home Upgrade and Advanced Home Upgrade programs offered in conjunction with local utility providers. The Home Upgrade and Advanced

Home Upgrade programs are both whole home approaches to energy efficiency that allow customers to bundle several energy efficiency measures by connecting them with qualified energy efficiency contractors, who identify suitable energy efficiency retrofits, help customers fill out necessary paperwork (including rebate forms), and perform safety compliance checks (Energy Upgrade California, 2015).

A Home Upgrade aims to reduce a home's energy use by 10% or more while an Advanced Home Upgrade aims to reduce a home's energy use by at least 45% (Energy Upgrade California, 2015). A Home Upgrade may include simple efficiency measures such as better insulation, whole-house air sealing, duct sealing, and furnace and AC replacements, while an Advanced Home Upgrade includes deeper improvements such as a cool roof, hardwire lighting, a tankless water heater system, and energy-efficient windows (Energy Upgrade California, 2015). Customers pursuing a Home Upgrade or Advanced Home Upgrade can receive up to $2,500 and $6,500 in rebates and incentives, respectively (PG&E, 2014).

Empower Central Coast

At the county level, emPower Central Coast (formerly emPower Santa Barbara County) provides unsecured loans with low interest rates for energy efficiency retrofits from CoastHills Federal Credit Union and Ventura County Credit Union. The emPower Central Coast program partners with Energy Upgrade California to provide customized, flexible loans for the Home Upgrades package and for solar energy systems. Loans from emPower Central Coast range from $1,000 to $30,000, require no equity or collateral, have terms of up to 15 years, and have no prepayment penalties (emPower Central Coast, 2015). With their loan application, customers must submit their contractor's bid proposal, a list of the upgrades they intend to install, and a letter verifying their enrollment in the selected incentive program. Contractors fill out and submit the rebate and incentive forms, and projects must be completed within 60 days of being approved by the rebate program and emPower Central Coast (emPower Central Coast, 2015).

Santa Barbara Green Business Program

The Santa Barbara Green Business Program is a voluntary program that offers a certification for green business practices such as the use of solar energy systems or energy efficiency retrofits in their facilities. The program both credits businesses for existing practices and rewards newly adopted technology and practices. Although the program offers no cash incentives of their own, it offers Small Business Awards and certification as a means of incentivizing businesses to join the program.

7.2 Solar PV

7.2.1 Relevant Zoning Codes

Santa Barbara County's land use and development code exempts roof-mounted solar energy systems from design review and permit approval. Roof-mounted solar energy systems, however, may require building, electrical, and plumbing permits where applicable. Such permits are issued through the Santa Barbara County Planning and Development Board (Santa Barbara County Land Use & Development Code, section 35.20.160). If the solar energy system could possibly have an adverse impact on public health or safety, for example, shining a glare onto oncoming traffic on a busy street, a solar use permit is also required. A proposed rooftop solar energy system that is within a "Special Problem Area," i.e. an area that is particularly sensitive to construction and land use development, will also require additional permitting along with approval from the Special Problems Area Review Committee (SPARC) (Santa Barbara County Ordinance Code § 10-1.5). Unlike roof-mounted systems, freestanding solar energy systems do require a coastal development permit or land use permit (Santa Barbara County Land Use & Development Code, section 35.20.160).

For those who wish to go through the permitting process as quickly as possible, Santa Barbara County has developed an "Expedited Residential PV Permit Process" that promises 48 hour permit turnaround for new solar PV energy systems that:

- Are composed of four or fewer series strings per inverter;
- Have an inverter capacity with a continuous AC power output of 13.44 kW or less;
- Use an engineered mounting system;
- Have a rooftop distributed weight of less than 5lbs./ft^2 and less than 40 lbs. per attachment;
- Have a list PV modules, utility-interactive inverters, and combiner boxes as components; and
- Have an AC interconnection point on the load side of service disconnecting means (County of Santa Barbara Planning and Development, 2011).

In cases in which all these requirements are not met, processing may take up to 10 working days. All permit applicants must also submit the following documents along with their permit application:

- The Santa Barbara County permit application;
- The site plan showing the location of the solar PV system;

- The seal and signature of the architect, engineer, or electrical contractor;
- The Photovoltaic Manufacturer's Module & Inverter Specification Data Sheets;
- The electrical wiring drawings;
- The completed Questionnaire Page for the Expedited Plan Review; and
- The Signage Requirements for PV Interactive System (County of Santa Barbara Planning and Development, 2011).

7.2.2 Available Incentives and Rebates

Federal Tax Credit

Pursuant to the Federal Energy Improvement and Extension Act of 2008, homeowners and businesses that decide to invest in solar energy systems or solar-powered water heating can claim a tax credit of 30% of the installation cost of the system. This credit runs through December 31, 2016, but may be extended (IRS, 2014). In cases in which construction and costs span more than one tax year, or in which there is excess credit, the credit can be carried forward to the next tax year (IRS, 2014). Currently, there is no maximum credit that can be granted for an installed solar energy system. The solar energy system must serve a residence that is located within the United States and that is owned by the taxpayer. Eligible solar-powered water heaters must be certified by the Solar Rating Certification Corporation (SRCC) and produce at least half of the energy used to heat the residence's water.

PACE Financing

Property Assessed Clean Energy (PACE) is a voluntary program in which local governments can offer financing to residential, commercial, and industrial building owners for energy efficiency, renewable energy, and water conservation upgrades. Qualified service providers help building owners select a PACE qualified project, while the PACE program itself is responsible for processing applications, approving projects, and providing or arranging financing. Additional rebates may also be used in conjunction with PACE financing.

As an example, PACE financing may have the following requirements:

- Mortgage-related debt must not exceed 90% of property value;
- Mortgage payments must be current;
- Owners must have no more than one 30-day mortgage late payment over the past year;
- Property taxes must be current, one late payment in last three years allowed;
- No outstanding involuntary liens (tax or mechanic liens);

- No active bankruptcies within last seven years;
- For condominiums, written authorization from management is required; and
- The senior mortgage debt lender must acknowledge placement of assessment (Renovate America, 2015).

In order for property owners in Santa Barbara County to secure a PACE loan, they must find a participating regional program, such as the HERO Program in Lompoc, California. The borrower can then submit a project proposal, a project plan, and a letter of acknowledgement from the principal lender in order to negotiate the terms of the loan. Once the financials are agreed upon, the loan is paid back yearly as part of a special line item on the property's tax statement. The interest rate on each loan is determined by the term period of the loan itself, be it five, 10, or 20 years. This property tax is transferable if the property is subsequently sold, making the new owner responsible for paying back the remainder of the loan.

Advantages of offering PACE financing include increased economic activity and job creation and increased energy and water conservation. For example, a 2011 study of four cities, which included the City of Santa Barbara, found that every $1 million in PACE spending generated $10 million in gross economic output, 60 jobs, and $1 million in combined federal, state, and local tax revenue on average (Pozdena and Josephson, 2011). In Santa Barbara specifically, they found that for every $1 million in project purchases, solar PV generated 6 new jobs and had a state and local fiscal impact of $34,686, while energy efficiency programs also generated 6 new jobs and had a state and local fiscal impact of $34,973 (Pozdena and Josephson, 2011).

Although PACE saw initial success, the seniority of the PACE lien to a property's principal mortgage caused the Federal Housing Finance Agency to advise lending firms Fannie Mae and Freddie Mac to deny backing mortgages on properties with senior PACE liens (Hsu, 2010). Since that time, residential enrollment has fallen, but certain measures have been taken to make borrowing under PACE more secure, including loan loss reserve funds and appropriate disclosure agreements. California Governor Jerry Brown has also proposed a state-run reserve fund of $10 million to back PACE financing (Baker, 2013).

Utility Company Incentives

SCE and PG&E both offer incentives to customers for installing solar energy systems. Time of Use billing plans can make electricity less expensive for solar energy-generating customers who primarily only need to rely on utility generated electricity during off-peak hours (i.e. at night) when electricity is cheapest, as their solar energy system can provide their electricity during peak daytime hours.

In addition to Time of Use billing, Net Energy Metering is available to solar energy system users. Net Energy Metering rewards customers for surplus energy provided back into the electricity grid. When the solar energy system produces more electricity than is used by the customer, the excess can be used to relieve peak demand, and the customer is rewarded at a rate equal to that of the cost of the electricity provided. Under a Net Energy Metering agreement, residential customers are billed yearly while commercial customers are billed monthly. For multi-tenant homes, Virtual Net Energy Metering accomplishes the same goals as Net Energy Metering, but breaks up the energy bill of the entire building into manageable accounts for individual tenants. (SCE, 2015b). Finally, SCE's Multi-Family Affordable Solar Housing (MASH) Virtual NEM subsidizes solar energy systems at a lower rate for low income, multi-family housing units.

7.2.3 Relevant Programs

The Santa Barbara County Million Solar Roofs program aims to popularize renewable energy through the installation and use of personal solar power with an auxiliary purpose of job creation in the clean energy sector. Through a partnership with Santa Barbara County, the Million Solar Roofs initiative helps to lighten the design review process for solar energy systems. Consequently, design review for solar energy systems has been relegated to project proposals with "significant visual or historical impacts" (City of Santa Barbara, 2006). In place of restrictive legislation, guidelines for solar development have been passed to prevent traditional community aesthetic standards from obstructing solar installation. Additionally, the City of Santa Barbara established the Solar Energy System Guidelines and Recognition Program to further incentivize the installation of aesthetically pleasing solar energy systems (Community Development Department City of Santa Barbara, 2006). The guide describes strategies for installing systems that maintain aesthetic quality while maximizing efficiency. The program also established the Solar Recognition Awards, which are presented to citizens that install high quality solar energy systems that are hidden from public view, were a challenge to design, and are maximally efficient.

7.3 Electric Vehicles

Despite their environmental benefits and greater fuel economy, there are many barriers to greater adoption of EVs, including:

- **Lack of infrastructure** - EV charging infrastructure is not widespread in comparison to infrastructure for conventional fuel vehicles. Part of California's ZEV Action Plan called for the expansion of charging stations, with the goal of developing sufficient EV infrastructure to support one million EVs in California by 2020. Local governments can address this barrier by investing in EV charging stations in their communities and streamlining the permitting processes for EV infrastructure.

- **High upfront cost** - While federal and state incentives are available, they are not always able to cover the entire cost difference between an EV and a conventional vehicle, and applying for incentives, which are not received until after the purchase/leasing of the vehicle, might be prohibitive for some customers.

- **Limited range** - While EVs can cover the majority of household trips, they are less practical for long distance driving than conventional fuel vehicles. EVs typically have a range of 50 to 100 miles on a single charge. Electric buses, because of their larger battery, can go up to 150 miles on a single charge. Although a 50-100 mile range is enough to cover the majority of all household vehicle trips in the United States, EVs can take several hours to recharge and so are inconvenient for longer trips (NREL, 2011). The time required to recharge an EV depends on the size and type of the batteries as well as the type of charging equipment used.

- **Fewer vehicle options** - Currently, an EV option is not available for all vehicle types. Most commercially available EVs are small passenger cars.

- **Low consumer awareness** - Many customers are not aware of the benefits or incentives available for EVs. Detail about incentives and rebates currently available for EVs at the state and federal level is provided in the section below.

7.3.1 Available Incentives and Rebates

To address cost differential between EVs and conventional vehicles, there are a number of incentives at the federal, state, and even local level designed to make EVs affordable. A summary of all available incentives and sources of funding for EVs is provided in Table 15.

Table 15. Summary of available incentives for EVs.

Incentive	Description
Plug in Electric Vehicle Tax Credit	Tax credit for the purchase or lease of a new qualified electric vehicle. This credit begins to phase out for a manufacturer's vehicles once they have sold at least 200,000 qualifying vehicles in the U.S.
Tax Exemption for Electricity used to Fuel Buses	Exempts electricity used by local agencies or public transit operators to fuel vehicles from applicable user taxes
Alternative Fuel Vehicle Refueling Property Credit	A 30% tax credit for any qualified alternative fuel vehicle refueling property
Clean Vehicle Rebate Project	A $900 - $2,500 rebate for eligible EVs in California. The rebate is available on a first-come, first-served basis to individuals, business owners, and government entities in the state.
California Hybrid and Zero Emissions Truck and Bus Voucher Incentive Project	Vouchers to help fleets reduce the initial cost of electrifying fleets
PLACE program	Loans for private fleets of less than 500 vehicles for fleet modernization
Alternative and Renewable Fuel and Vehicle Technology program	Encourages the establishment of alternative transportation fuels infrastructure

Source: Rubin et al. (2013)

7.3.2 Relevant Programs and Legislation

California has adopted a number of policies and programs to address barriers to adoption of EVs, including:

- **Electric Vehicle Charging Stations Open Access Act** (Senate Bill 454) - Makes plug-in EV charging stations both easier to locate and useable by all EV drivers regardless of network subscription.

- **EV Equipment Tax Exemption** (Senate Bill 71) - Authorizes certain sale and tax use exemptions on manufacturing equipment for EVs through 2020

- **Assembly Bill 2502** - Inclusions of charging equipment in vehicle cost - Allows car dealers to include the cost of EV charging equipment within EV purchase financing, facilitating electric vehicle owners to get in-home charger installations

- **Homeowners associations and charging stations** (Senate Bill 880) - Outlines the rights and responsibilities of homeowner associations and EV owners for charging in common-interest developments to ensure that electric vehicle owners are not unreasonably prohibited from installing charging equipment

- **Assembly Bill 1092** - Requires the California Building Standards Commission and the Department of Housing and Community Development to develop standards for PEV charging infrastructure in multi-unit dwellings and non-residential developments

- **Renewable Fuel Standard** - The federal Renewable Fuel Standard requires that 36 billion gallons of totally renewable fuel be used as transportation fuel by 2022 in the U.S.

- **Electric Vehicle Everywhere Workplace Charging Challeng**e - The Department of Energy initiated a program in early 2013 that encourages employers to place EV chargers in their workplaces. Many businesses, including national and international companies, have already signed on to this program.

Utility Incentives for Electric Vehicles

In addition to high upfront cost, recently declining gasoline prices and increasing electricity prices in California may disincentivize EV adoption. However, investor owned utilities, including PG&E and SCE, offer alternate rate options that can reduce the cost of vehicle charging, namely Time of Use plans and Electric Vehicle plans.

Time of Use plans are opt-in rate structures that reward customers for using electricity during off-peak hours (usually between 9:00pm and 12:00pm) by charging a low rate (around $0.12/kWh) for electricity used during off-peak hours and a higher rate (around $0.20/kWh to $0.30/kWh) for electricity used during peak hours. Because many EV owners charge their vehicles overnight during off-peak hours, this plan facilitates low cost vehicle charging.

Electric Vehicle Plans use a separate meter to bill the electricity used to charge an EV at a lower rate. This plan also utilizes Time of Use pricing; lower rates apply during off-peak hours. This type of plan requires a separate meter or in-home charging station to be installed.

Although no formal policies have been proposed or put in place, the CPUC has been considering other alternative-fueled vehicle programs and policies to encourage the adoption of cleaner vehicles, and has been asked by the CA ZEV Action Plan to explore how electric rates can be used to support the adoption of EVs in public transit (Gallo et al., 2014).

Finally, the federal Transit Investments for Greenhouse Gas and Energy Reduction (TIGGER) program provides capital grants to public transit agencies for the purpose of reducing energy use or GHG emissions associated with public transit. TIGGER selects projects based on:

- Total projected GHG/energy savings;
- Project innovation;
- National applicability;
- Project readiness;
- Project management; and
- Return on investment.

7.4 Commuter Benefits and Alternative Work Schedules

7.4.1 Relevant United States Code

In order for a business or organization to establish an alternate work schedule, such as a 9/80 work schedule, certain steps must be taken. If the business or organization's workforce is part of a union, the provisions of the work schedule must be in the initial employment contract, and negotiated with a representative agent of that union. For non-union workforces, an agency may unilaterally install an alternative work schedule. In both cases, the head of the employing agency must approve the schedules, and has the power to veto such a schedule if the schedule might have adverse impacts on the agency, such as:

- A reduction in agent productivity;
- A diminished level of service; or
- An increase in operating costs, excluding administrative cost of establishing such a program (U.S. Office of Personnel Management, 1996).

7.4.2 Relevant Programs

Established by the U.S. EPA and the U.S. Department of Transportation, the Best Workplaces for Commuters program recognizes employers that provide their employees with outstanding commuter benefits programs. The program also offers toolkits and information on benefits to employers who are interested in commuter benefit programs for their business. In 2007, management responsibilities shifted to the National Center for Transit Research within the Center for Urban Transportation Research.

In order to become a member of the Best Workplaces for Commuters program, employers must abide by the Best Workplaces for Commuters program's stated National Standards of Excellence. Under the National Standards of Excellence, employers must offer their employees one "primary benefit," such as employer-paid vanpooling or bus passes, in addition to three "secondary benefits" such as ridesharing or carpool matching (which are often free), preferred parking, or compressed work schedules. Employers must also offer Emergency Ride Home services, which provide low or no cost transport in the case of an emergency.

If these Standards of Excellence are met, employers must then prove that they have a central point of contact for commuter benefits within their organization, keep their information on commuter benefits in a centralized location, actively promote commuter benefits to their employees, agree to use the Best Workplaces for Commuters name and logo to promote themselves, and ensure that within 18 months of acceptance into the program, at least 14% of employees use the commuter benefit services. Lastly, employers must pay a $230 annual membership fee to the Best Workplaces for Commuters (Bond, 2013).

Some of the benefits of membership into the Best Workplaces for Commuters include national branding and recognition, technical assistance in implementing improvements to their commuter benefit programs, staff training for managing commuter benefit programs, web-based tools for tracking program analytics, and forums for information exchange between members. These benefits are all in addition to the conventional benefits of commuter benefit programs, including employee attraction and retention, tax and cost savings, reputation benefits, and reduction in GHG emissions as well as other environmental benefits.

Best Workplaces for Commuters Commuter Benefit Program Implementation Guidelines

For employers to establish a pre-tax commuter benefits program, the following steps should be taken:

1. Determine whether administration of the program will take place in-house or via a third party administrator. Small employers may find in-house staffing to be favorable, and may reach out to local transit agencies for specifics on acquiring and distributing transit passes and other benefits. Larger employers, on the other hand, may find third party administrators favorable because of their larger range of options and economies of scale.

2. Identify key departments and managers in which to nest their commuter benefits program. The most likely choices are human resources, payroll/accounting, tax/legal, or departments created specifically for this duty.

3. Determine the specific commuter benefits to be offered. Some options include subsidized parking or transit fares, a subsidized highway transit vehicle, or bicycle travel reimbursements. Any combination of these benefits may be offered up to the federally established tax free limit.

4. Consult with its accounting department to establish a specific deduction code for the benefit.

5. Create and distribute program information on how to sign up, how to choose benefits, and how to claim them.

6. Market their program to employees with orientations, benefit fairs, and special events, etc. (Baker, 2012).

7.5 Success Stories

7.5.1 Solar Energy and Energy Efficiency

Local governments can promote solar energy by providing local lending and tax incentives, passing solar friendly legislation, setting clean energy goals, and installing solar energy systems on government buildings (Burr et al., 2014). Partnerships with local utility companies can also facilitate adoption of solar energy, as utility companies can offer incentives and set goals for clean energy grid mixes. For example, Seattle City Light, the public electricity utility that serves the City of Seattle, allows customers to invest in community run, large-scale solar projects that, although not directly on customer property, generate savings that are reflected in their electricity bills.

Berkeley FIRST

The City of Berkeley Financing Initiative for Renewable and Solar Technology (FIRST) was the pilot program for what now has become PACE financing. Founded in 2008, FIRST aimed to "catalyze the transition to a more sustainable use of energy and also deliver benefits beyond emission reductions, including a new source of job growth, reduced strain on the electric power system, and more comfortable and well-maintained buildings" (Fuller et al., 2009). Like PACE financing, FIRST provided funds for the installation of electric and thermal solar energy systems, repaid through an additional property tax line item on the property, with tax-deductible interest. The finances for the program were originally borrowed from the city's newly formed Sustainable Energy Financing District, which itself was funded by the issuance of a special tax bond to be paid back semi-annually over 20 years with money accrued from the new property taxes (Fuller et al., 2009).

Once a plan was approved, the city would issue the property owner a reimbursement check following project completion. Like PACE financing, the new property tax line item was transferable to any new owner of the property. The program proved to be popular as all $1.5 million in available funds were applied for within 10 minutes of the program applications becoming available. While not all applicants followed through to project installation, FIRST still managed to directly finance 13 solar energy systems and inspire an additional 40 projects to be developed by other means (City of Berkeley, 2010). According to the project's Final Evaluation report, 50% of survey respondents said that a lack of financing options was a major reason why they did not install a personal solar energy system sooner. Additionally, 90% of respondents that did participate in the FIRST program were satisfied with the program, and another 70% said that the application process was easy. There were, however, certain areas that needed improvement, including more flexible payment options, better upfront communication of additional property tax costs, and a lower loan interest rate.

Energy Independence Program

The Energy Independence Program in Palm Springs, California was successful enough to warrant three separate rounds of fully distributed funding. In this example of PACE-like funding, the city's general fund provided $7.5 million to fund 200 projects, each averaging $36,000 in cost. Of these funded projects, 70% were for energy efficiency retrofits and the other 30% were for solar energy system installation. The program boasted a first year consumer savings of $20 million, and seven new clean energy startups have credited their inception to the opportunities presented by the program (Mattson et al., 2009)

Green Finance SF

Green Finance SF, a PACE financing program in San Francisco, uses the free market to set terms in which property owners identify their own project lenders and negotiate financing terms with them. The city then collects the increased property tax and reimburses the principal project lender. This structure is designed to provide security to the lenders to enable them to provide competitive financing terms to the borrower. To be eligible, property owners must own property within the San Francisco city limits and must have a professional water and energy audit done to their property prior to beginning the project (CEC, 2013). This project is particularly successful because it secures financing by requiring written consent from all lenders with outstanding liens on the proposed property stating that they allow a senior PACE loan to supersede their own (Burr et al., 2014).

Solar America Cities Program

Portland, Oregon was initially chosen by the Federal government to participate in its Solar America Cities program, providing funding and support for solar energy system initiatives. This, combined with efforts to collaborate with local nonprofits to educate the public, led to the establishment of a collective purchasing model for solar energy systems that spread throughout the city. Educating the public about where they could find incentives to install solar energy systems led to a lowering of costs for suppliers that subsequently obtained a large volume of business. As a result of these programs, Portland installed 7.1 MW of solar power on 560 homes. The success of this program inspired multiple "solarize" campaigns throughout the country, including one in California. Since then, Portland has begun to streamline its permitting process with an online permitting system, which further decreases soft costs to consumers and solar installation firms alike. All efforts have been supplemented with state-enacted policies granting tax credits for residential and commercial solar energy systems (Burr et al., 2014).

7.5.2 Electric Vehicles

Many local governments in California have already adopted policies and programs aimed at increasing adoption of EVs. For example, the City of Berkeley offers a simple permitting process to approve EV chargers in homes, only requiring an inexpensive over-the-counter electrical permit, while the City of Thousand Oaks partnered with a third party company and the Ventura County Air Pollution Control District to fund and install a DC Fast Charging station at the Thousand Oaks Transportation Center.

Los Angeles Department of Water and Power's Charge Up L.A.!, program offers rebates to residential and commercial customers who purchase charging equipment for EVs. Residential customers can receive a rebate of up to $750 towards the purchase of an EV charger as well as a discount on their electricity bill if they install a Time of Use meter, while commercial customers can receive up to $750 for hardwired wall-mounted EV chargers and up to $1,000 for stand-alone pedestal chargers (LADWP, 2013).

The City of Riverside's Alternative Fuel Vehicle Rebate Program offers a rebate of up $500 for the purchase of new EVs to residents of Riverside. Similarly, the City of Corona's Alternative Fuel Vehicle REBATE Program offers a rebate to Corona residents of up to $2,000 for the purchase of a new qualified Alternative Fuel Vehicle or $1,000 for a qualified used vehicle (City of Corona, 2015). Due to the popularity of the program, however, funds have been exhausted for the 2014-2015 fiscal year. Rather than offering rebates, the cities of Hermosa Beach and Santa Monica incentive EVs by offering free metered parking for EVs.

7.5.3 Commuter Benefits and Alternative Work Schedules

BART Citywide Pre-Tax Commuter Benefits

In 2009, the Bay Area Rapid Transit (BART) conducted a survey on their citywide pre-tax commuter benefits program and found that nearly half (46%) of San Francisco daily riders take advantage of pre-tax commuter benefits offered by their employer, and that a total of 68% of all BART fares were pre-tax (BART, 2009). Of all the survey respondents, 96% found it easy to sign up for the program and 90% reported that claiming their benefits was also easy. This success is derived from the relatively high number of employers (58%) in the Bay Area that offer transit benefits as well as the high rate of employee interest (78%). High rates of employee interest are also expressed by the amount of employees whose employer does not offer benefits but that would be interested in such a program (90%). Employers largely utilized third party benefit organizers such as Commuter Check and Wageworks to administer and manage their transit benefits programs, as only 6% administered their own benefits to employees. There were, however, several critical comments directed at the program, such as long lines, limited hours of regional office operation, and that the program sometimes runs out of tickets. BART replied that an entirely online system could be the answer to these problems, and it is moving forward with implementation of such a program (BART, 2009).

Denver Federal Workers Compressed Workweek Experiment

In an experiment involving federal employees in Denver, Colorado, a compressed workweek of four days and 10 hours per day found that this workweek had no adverse effects on the use of commuter benefit measures, such as ride-sharing, and reduced employee VMT by 15% (FTA, 1992). The study also found that compressed work schedules are most applicable to employees with office and administrative work functions, particularly government agencies, as well as assembly line manufacturing workers.

Finally, the study found that in order to ensure that compressed work schedules would have no extra cost to the employer, state policies and legislation may need to be revised to allow certain compressed work schedules without the requirement of overtime pay (FTA, 1992).

Texas Instruments Ad-Hoc Flexibility Policy

Texas Instruments (TI) experimented with what it called an "ad-hoc flexibility" work schedule in which most, but not all, employees were allowed to make changes to their work schedules. This included occasional telecommuting and compressed work schedules for the purpose of allowing time for employees' personal business, such as doctors' appointments, child care, or late-night work commitments. As a result of the ad-hoc flexibility program, TI noted higher employee retention rates, lower stress levels, and higher efficiency as well as increased development of employee skills due to "job sharing" (Giglio, 2005).

Aflac Insurance Compressed Work Schedules

The insurance company Aflac experimented with, and has since adopted, a variety of compressed work schedules. Aflac offers both a four by 10 workweek as well as a three by 12 workweek, offering three and four days off per week, respectively. Requests for scheduling changes must be met with supervisor approval, and are employee chosen and employee driven. Feedback on these scheduling options are facilitated through employee focus group sessions, allowing employees the chance to comment on the system directly to management, as well as to allow management to gather data on program effectiveness and participation. Since the change, Aflac employees report being happier and more effective, and have an enhanced sense of pride and value of their professional lives. Aflac also reports that higher worker productivity has helped their bottom line, and has reduced costly employee turnover, stating that retention rates have risen from 87% pre-program to 94% post-program, making their decision to implement flex work good for both business and the environment (Giglio, 2005).

8 Recommendations

The results of our GHG abatement cost curve for Santa Barbara County, combined with our review of existing opportunities and barriers to implementing the GHG mitigation strategies included in this analysis, reveal that Santa Barbara County can make meaningful reductions in GHG emissions by facilitating adoption of energy efficiency, solar PV, EVs, commuter benefits programs, and alternative work schedules. In the following sections, we provide detailed recommendations regarding which GHG mitigation strategies are most worthwhile and what county decision makers can do to promote and adopt these strategies.

8.1 Energy Efficiency Retrofits

The numerous utility company rebates and facilitator programs like Energy Upgrade California and emPower Central Coast make energy efficiency retrofits to residential and commercial buildings a financially beneficial means to reduce GHG emissions. By combining high value rebates with low and zero interest loans procured through emPower Central Coast, property owners can reduce investment costs in energy efficiency measures and realize monetary savings quickly. Our analysis of GHG mitigation cost suggest that lighting and HVAC retrofits are particularly favorable as they can save property owners money and are eligible for existing rebates. These measures are also relatively easy to implement and do not require governmental approval or permitting. In particular, the use of fluorescent lighting in office buildings is expensive and widespread, so energy efficiency improvements in this particular niche can result in substantial monetary savings and as well as significant GHG reductions.

Upgrading to more efficient water heaters is also a favorable retrofit in terms of GHG mitigation potential as most standard water heaters run on natural gas. Efficient water heaters, however, have a positive cost over their lifetime, even when utility bill savings are accounted for. Because this measure has both high cost and high GHG mitigation potential, investing in higher rebates and incentives for efficient or solar powered water heaters could be worthwhile. If increasing rebates for efficient water heaters is not feasible, however, this strategy should not be pursued if cost-effectiveness takes priority over GHG mitigation.

Based on our analysis, upgrading refrigerators to more efficient models is the least favorable energy efficiency strategy as it is not only high cost, but also low in GHG reduction potential. For this measure to be cost-effective, existing rebates would need to be higher such that property owners are incentivized to choose the more expensive, more efficient models. However, even the most efficient models are unlikely to result in substantial GHG reductions, and so upgrading refrigerators in residential and commercial buildings is a low priority mitigation strategy.

8.2 Solar PV

Because of its overall negative cost, supportive state and local policies, and significant GHG reduction potential, solar energy is a highly recommendable GHG mitigation strategy for Santa Barbara County. Currently, most cities in the county do not have a PACE program, and so instituting more PACE programs could be one way to increase the adoption of solar energy in the county. Solar education programs and streamlining the permitting process can also facilitate solar adoption. Santa Barbara County has already made strides in solar permitting, as the county has already expedited the permitting process. As of 2009, however, the cities of Santa Maria, Santa Barbara, Lompoc, Solvang, and Guadalupe, have a high permitting fee for solar energy systems relative to the rest of the county, which may disincentivize solar energy in these cities (Mills et al., 2009). Lowering this permit fee could increase adoption of solar and therefore should be considered.

8.3 Electric Vehicles

While our analysis reveals that reducing GHG emissions through EVs, on average, has a positive cost, the large mitigation potential, legislative support and co-benefits of EVs make them a worthwhile means to mitigating GHG emissions. Given the right combination of incentives and fuel pricing, EVs can be cost competitive, or even cheaper, than conventional fuel vehicles over the time horizon we examined. Therefore, we suggest that local governments take action to make EV ownership more affordable in order to increase adoption rates. There is already significant state support for EVs because they are a major component of California's strategy to meet the GHG reduction goals outlined by AB 32. As a result, there are many resources already available to local governments, agencies, and businesses including information on how to grow EV infrastructure, increase customer awareness, and incentivize EV ownership. Additionally, EVs have the added benefit of reducing air pollution, making them particularly relevant for local governments for whom air pollution is a major concern.

8.4 Commuter Benefits

Because commuter benefit accounts are low cost, are financial beneficial to both employees and employers, and have significant GHG mitigation potential, we recommend that Santa Barbara County businesses establish commuter benefit accounts. Vanpooling, however, is not a cost-effective means to reduce GHG emissions because the high costs of being in a vanpool outweigh the total tax and fuel savings. Commuter benefit accounts could be utilized at a total negative cost if employees chose a cheaper mode of transportation to get to work, such as public transportation. However, the cheaper the transit mode utilized, the less money is placed into the tax-free account, which results in lower tax savings.

Alternative 9/80 work schedules can be established at no cost, reduce GHGs attributable to commuting, and provide savings to employees via reduced gasoline costs. While these schedules cannot be adopted by all businesses, we recommend that businesses that can switch to 9/80 schedules or some alternative longer workday and shorter workweek make the change.

9 Conclusion

The analysis provided in this report is a first step to implementing additional GHG mitigation strategies in Santa Barbara County. Because our findings and recommendations are limited to the 12 GHG mitigations strategies we examined, a potential next step would be to extend this analysis to include other strategies. Additionally, because this report does not provide an exhaustive GHG emissions inventory for the county, it may be useful to create a GHG emissions inventory for other sectors, such as the industrial sector, that are potentially high-emitting sectors, but were excluded from this analysis.

Furthermore, this type of analysis is limited to GHG mitigation strategies for which cost and GHG mitigation potential estimates can be quantified via existing data. This excludes strategies, such as behavioral interventions, which are critical to GHG mitigation as behavior plays a significant role in energy use, adoption of cleaner technologies, and purchasing decisions. Investigating such strategies would likely require pilot programs in order to generate data on cost, GHG mitigation potential, and ease of implementation.

Finally, an analysis of the co-benefits of the mitigation strategies examined in this report is advised in order to garner additional support for local mitigation by creating greater justification for investment in these strategies.

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11 Appendix

11.1 Appendix A. Residential and Commercial Energy Use Data

Appendix 11.1.1. Average annual residential energy use in Santa Barbara County (2015).

	Per Household	Total
Electricity Use (kWh/year)	5,837	836,415,860
Natural Gas Use (Therms/year)	451	64,583,269

Appendix 11.1.2. Santa Barbara County commercial building employee and energy use statistics per square foot (2015).

Building Type	Employee Density (ft^2/employee)	Average Annual Natural Gas Use (KBTU/ft^2/yr)	Average Annual Electricity Use (kWh/ft^2/yr)
Office Building	466	10.6	9.3
Government Building	672	10.6	9.3
Hotels/Motels	1804	8.1	41.2

Appendix 11.1.3. Total commercial natural gas and electricity use in Santa Barbara County by building type (2015).

Building Type	Natural Gas Use (Therms)	Electricity Use (kWh)	GHG Emissions (MT CO_2e)
Office Building	1.81×10^6	2.07×10^8	5.58×10^4
Government Building	1.81×10^7	2.76×10^8	1.60×10^5
Hotels/Motels	2.42×10^6	3.57×10^8	9.23×10^4
Total	2.24×10^7	8.40×10^8	3.08×10^5

11.2 Appendix B. Energy Star Data

Appendix 11.2.1. The mean, maximum, and minimum energy efficiency of Energy Star geothermal heat pumps, air source heat pumps, and room air conditioning

	Geothermal Heat Pump		Air Sourced Heat Pump		Room AC	
	COP Rating	Energy Efficiency Ratio	COP Rating	Energy Efficiency Ratio	Energy Efficiency Ratio	Combined Energy Efficiency Ratio
Mean	4	23	21	13	11	11
Max	6	57	30	17	12	12
Min	3	16	18	12	10	10

Source: Energy Star Product Finder (2015)

Appendix 11.2.2. The mean, maximum, and minimum energy efficiency of Energy Star certified commercial HVAC units

	Commercial HVAC	
	Cooling Capacity (kBtu/hr)	SEER Rating (Btu/Wh)
Mean	53	15
Max	236	16
Min	28	14

Source: Energy Star Product Finder (2015)

Appendix 11.2.3 The mean, maximum, and minimum Natural gas (therms/year) and electricity use (kWh/yr) use of Energy Star certified water heaters by type.

	Energy Star Water Heaters							
	Tankless		Heat Pump		Solar		Storage	
	Therms/yr	kWh/yr	Therms/yr	kWh/yr	Therms/yr	kWh/yr	Therms/yr	kWh/yr
Mean	169	0	0	1475	0	0	218	143
Max	184	0	0	2007	0	0	273	290
Min	153	0	0	5	0	0	21	74

Source: Energy Star Product Finder (2015)

Appendix 11.2.4. The mean, maximum, and minimum electricity use of Energy Star certified refrigerators.

	Energy Use (kWh/yr)	
	Residential Refrigerator	Commercial Refrigerator
Mean	418	1640
Max	855	10340
Min	150	138

Source: Energy Star Product Finder (2015)

Appendix 11.2.5. The wattage and price of commercial and residential LED light bulbs from 2015 to 2040

	Commercial LEDs		Residential LED	
	Wattage	Price ($2014)	Wattage	Price ($2014)
2015	7.7	90.8	9.44	21.17
2020	3.8	68.5	5.0	5.15
2025	3.5	66.2	4.5	4.31
2030	3.2	63.8	4.0	3.09
2035	3.2	63.8	4.0	3.09
2040	3.2	63.8	4.0	3.09

Source: EIA (2013)

11.3 Appendix C. Solar PV Prices from 2015-2040

Appendix 11.3.1. Cost per watt of Solar PV for 2015 – 2040

	Purchase Cost ($/W)		Operation and Maintenance Cost ($/W/yr)	
	Residential (PV w/4 kW DC)	Commercial (100kW DC)	Residential (PV w/4kW DC)	Commercial (100kW DC)
2015	4.34	3.84	0.05	0.05
2020	3.75	3.34	0.05	0.05
2025	3.46	3.09	0.04	0.04
2030	3.29	2.96	0.04	0.04
2035	3.19	2.86	0.04	0.04
2040	3.09	2.77	0.04	0.04

Source: NREL (2012)

11.4 Appendix D. EMFAC Data

Appendix 11.4.1. Reduction factors applied in EMFAC2011-SG to emissions estimates to generate carbon dioxide reductions expected from the Pavley Bill and the Low Carbon Fuel Standard (EMFAC2011 technical documentation)

	Pavley Bill		Low Carbon Fuel Standard
Model Year	LDA/LDT1	LDT2/MDV	Reduction Factor
2008 and Older	0.00%	0.00%	N/A
2009	0.00%	0.90%	N/A
2010	3.50%	5.20%	N/A
2011	14.40%	12.00%	0.25%
2012	25.30%	18.50%	0.50%
2013	27.20%	19.50%	1.00%
2014	28.80%	21.00%	1.50%
2015	31.70%	23.00%	2.50%
2016	34.30%	25.10%	3.50%
2017	34.30%	25.10%	5.00%
2018	34.30%	25.10%	6.50%
2019	34.30%	25.10%	8.00%
2020	34.30%	25.10%	10.00%

		Passenger Cars		Light Duty Trucks (LDT1)		Light Duty Trucks (LDT2)		Transit Buses	
		Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas
2011	Vehicle Population	626	104224	20	8072	17	45710	139	43
	VMT (per day)	23005	4264913	702	331375	633	1893062	22330	6968
	Total CO2e (tons/day)	8.95	1533.72	0.28	140.14	0.25	940.33	62.55	5.73
2020	Vehicle Population	694	115607	22	8861	19	50252	152	47
	VMT (per day)	27820	4895182	897	364319	791	2139274	24359	7601
	Total CO2e (ton/day)	7.99	1240.46	0.26	115.39	0.24	815.06	58.93	5.64
2035	Vehicle Population	829	137939	25	10337	22	58358	151	47

	VMT (per day)	31187	5742370	1039	413899	873	2444571	24226	7560
	Total CO2e (tons/day)	7.85	1275.13	0.26	112.35	0.25	845.74	56.06	5.61

Appendix 11.4.2. EMFAC2011 output for Santa Barbara County (2011-2040).

		Passenger Cars		Light Duty Trucks (LDT1)		Light Duty Trucks (LDT2)		Transit Buses	
		Diesel	**Gas**	**Diesel**	**Gas**	**Diesel**	**Gas**	**Diesel**	**Gas**
2011	Vehicle Population	626	104224	20	8072	17	45710	139	43
	VMT (per day)	23005	4264913	702	331375	633	1893062	22330	6968
	Total CO_2e (tons/day)	8.95	1533.72	0.28	140.14	0.25	940.33	62.55	5.73
2020	Vehicle Population	694	115607	22	8861	19	50252	152	47
	VMT (per day)	27820	4895182	897	364319	791	2139274	24359	7601
	Total CO_2e (tons/day)	7.99	1240.46	0.26	115.39	0.24	815.06	58.93	5.64
2035	Vehicle Population	829	137939	25	10337	22	58358	151	47
	VMT (per day)	31187	5742370	1039	413899	873	2444571	24226	7560
	Total CO_2e (tons/day)	7.85	1275.13	0.26	112.35	0.25	845.74	56.06	5.61

11.5 Appendix E. Vehicle Purchase Cost

Appendix 11.5.1. Purchase cost for passenger cars and light duty vehicles by fuel type for 2015-2040 in real 2014 dollars.

	Passenger Cars		Light Duty Trucks		All-Electric Vehicles
	Gas	Diesel	Gas	Diesel	
2015	$28,305	$28,227	$27,365	$33,112	$43,661
2020	$29,299	$28,536	$28,297	$33,476	$42,265
2025	$30,802	$29,241	$29,499	$34,180	$39,879
2030	$30,841	$29,244	$29,536	$34,215	$38,066
2035	$30,859	$29,261	$29,555	$34,237	$37,605
2040	$30,875	$29,268	$29,578	$34,260	$37,519

11.6 Appendix F. Air Pollution Emissions Factors

Appendix 11.6.1. Air pollution emissions factors (g/mile) for passenger cars, light duty trucks as given by the GREET model for 2015 and 2020.

	Passenger Cars				Light Duty Vehicles				Transit Buses			
	Gas		Diesel		Gas		Diesel		Gas		Diesel	
	2015	2020	2015	2020	2015	2020	2015	2020	2015	2020	2015	2020
VOC	0.1697	0.1658	0.073	0.0716	0.276	0.268	0.078	0.077	1.67	1.669	0.095	0.095
CO	2.8652	2.8547	2.7357	2.7317	4.948	4.895	1.326	1.316	39.121	39.457	0.651	0.655
NO_X	0.1202	0.1198	0.2336	0.2311	0.31	0.308	0.947	0.939	3.536	3.538	1.422	1.423
SO_2	0.0044	0.0042	0.0021	0.002	0.006	0.005	0.005	0.005	0.018	0.018	0.012	0.012
PM_{10}	0.0332	0.0332	0.0280	0.0280	0.052	0.052	0.047	0.047	0.069	0.069	0.166	0.166
$PM_{2.5}$	0.0186	0.0186	0.0143	0.0143	0.031	0.031	0.026	0.026	0.032	0.032	0.084	0.084
CH_4	0.0117	0.0116	0.0935	0.092	0.027	0.026	0.093	0.091	0.037	0.037	0.057	0.057
N_2O	0.0044	0.0043	0.0007	0.0007	0.008	0.008	0.003	0.003	0.01	0.01	0.002	0.002

Source: GREET model

11.7 Appendix G. Flare Gas Emissions in Santa Barbara County

Appendix 11.7.1. Flare gas emission volumes and sources

Facility	GHGs Emitted Annually ($MTCO_2e$)	Gas Burned Annually (MMcf)	Heat Value (BTU/SCF)	Flare Emissions (MMBTU/ Hour)
Purisima Hills LLC- Barham Ranch	3,239	64.00	937	6.85
The Point Arguello Project	580	9.57	1107	1.21
Conway - Enos	857	16.16	1003	1.85
ExxonMobil - SYU Project	1,043	16.58	1150	2.18
Purisima Hills LLC - Blair Lease	12,671	223.40	1061	27.06
Purisima Hills LLC - Blair Lease	1,146	20.20	1061	2.45
Casmalia	899	18.50	900	1.90
Total	20,434	368.00	7,219	43.00

11.8 Appendix H. GHG Mitigation Strategies

Transportation

- Commute Trip Programs
  - Implement Commute Trip Reduction Program
  - Provide Ride-Sharing Programs
  - Implement Subsidized or Discounted Transit Program
  - Implement a Commuter Benefits Program
  - Encourage Telecommuting and Alternative Work Schedules
  - Implement Preferential Parking Permit Program
  - Implement Car-Sharing Program
  - Implement a School Pool Program
  - Implement Bike-Sharing Programs
  - Implement School Bus Program
  - Price Workplace Parking

- Transit System Improvements
  - Provide a Bus Rapid Transit System
  - Implement Transit Access Improvements
  - Expand Transit Network
  - Increase Transit Service Frequency/Speed
  - Provide Bike Parking Near Transit
  - Provide Local Shuttles

- Road and Parking Pricing
  - Implement Area or Cordon Pricing
  - Improve Traffic Flow
  - Required Project Contributions to Transportation Infrastructure Improvement Projects
  - Install Park-and-Ride Lots
  - Parking discounts for high fuel efficiency vehicles
  - Increase parking cost

- Vehicles
  - Utilize Alternative Fueled Vehicles
  - Utilize Electric or Hybrid Vehicles
  - Electrify Loading Docks and/or Require Idling-Reduction Systems
  - Diesel anti-idling
  - Tire inflation programs/incentives
  - Low rolling resistance replacement tires

Energy Efficiency and Energy Conservation

- Building Energy Use
    - Install Programmable Thermostat Timers
    - Obtain Third Party HVAC Commissioning and Verification of Energy Savings
    - Install Energy Efficient Appliances
    - Install Energy Efficient Lighting
    - Install Energy Efficient Boilers and Water Heaters
    - Improve Building Insulation

- Outdoor Lighting
    - Install Higher Efficacy Public Street and Area Lighting
    - Limit Outdoor Lighting Requirements
    - Replace Traffic Lights with LED Traffic Lights
    - Oil & Gas Industry
    - Utilize a Combined Heat and Power System
    - Reducing Flaring

Alternative Energy

- Establish Onsite Renewable or Carbon-Neutral Energy Systems-Generic
- Utilize Solar PV
- Utilize Onsite Wind Power
- Recovery Methane from Landfills/Wastewater Treatment Plants

Landscaping

- Prohibit Gas Powered Landscape Equipment
- Adopt Electric Landscape Equipment
- Urban Tree Planting
- Create new vegetated open space

Waste

- Institute/Extend Composting