YOLO COUNTY GOVERNMENT:
AN ACTION PLAN FOR REDUCING GREENHOUSE GAS EMISSIONS ASSOCIATED WITH COUNTY OPERATIONS

DRAFT FINAL REPORT

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EXECUTIVE SUMMARY

In June 2005, Governor Schwarzenegger signed Executive Order S-3-05, which established climate change emissions reduction targets for California. The passage of AB32, requiring that the state reduce its greenhouse gas emissions to 1990 levels by 2020, followed in 2006. Action on climate change has not been limited to state government. More than 100 mayors within California cities, representing 40% of the state's population, have committed their cities to greenhouse gas (GHG) emission reduction targets that reduce local emissions to below 1990 levels by the year 2012. Finally, increasingly, county governments are adopting the "U.S. Cool Counties Climate Stabilization Declaration," which sets emission reduction goals and a pledges commitment to work with other governments to reduce GHG emissions. In 2007, Yolo county's Board of Supervisors passed Resolution 07-109 adopting the Cool Cities Climate Stabilization Declaration. The Declaration commits the county to developing an inventory of its operational GHG emissions and achieving a target rate of 10% reduction every 5 years, beginning in year 2010.

This project emerges as a result of Resolution 07-109. The Yolo county Department of General Services (DGS) operates and maintains the county's buildings and vehicle fleet, and is directly responsible for managing the county government's operational GHG mitigation plan. The DGS has targeted a 5% per year GHG emission reduction goal from the county's overall operations. In 2006, the county prepared a baseline inventory of GHG emissions and reported the inventory through the California Climate Action Registry (CCAR). The CCAR was established by California statute to assist companies and organizations in establishing baseline inventories that are verifiable and in concurrence with established reporting protocols.

At the request of DGS, a review of Yolo county building and vehicle operations was conducted. The county is currently engaging, or has engaged in a number of very useful and important activities that impact the county's overall GHG emissions. This report reviews these activities and provides a summary of general strategies designed to reduce operational GHG emissions, and that are expected to be cost-effective within a specified time. As part of this study, in conjunction with a UC Davis engineering class, a detailed inventory and analysis of three county facilities was also conducted. Students taking the course, which included a total of thirty-four undergraduate and graduates, were organized into student project groups specializing in appliance efficiency and practices, vehicle fleet operations, and building energy usage in three specific county buildings. Aspects of their case studies have also been synthesized and incorporated into this report.

In general, the short-term actions we considered were new policies aimed at educational outreach, optimizing management of power consumption, better or expanded utilization of sensing technologies, and some types of retrofitting, all of which have immediate implications in terms of reducing GHGs. Mid-term strategies included those with higher front-end costs, but critical for upgrading the building infrastructure. Finally, long-term improvement strategies included changes that would require significant capital outlay and/or those considered to have a fairly long payback period.

The county also needs a more complete and comprehensive GHG inventory by building that includes, for example, all equipment and appliances by technology type and model year. Although three of largest energy building consumers have been inventoried in detail, the county manages more than 50 additional buildings that do not have inventories available. Inventories should begin with the most energy-intensive and long-lifetime equipment, in the HVAC (e.g. boilers, chillers, packaged air-conditioning unit) and lighting (e.g. technology type and date of installation), moving then to durable appliances (e.g. water heaters, refrigerators) and other shorter-life smaller units like computers. Inventory protocol should also include periodically logging energy consumption data so that expected performance is actually achieved and maintenance actions are flagged well in advance.

Finally, we recommend that the county consider adoption of a no GHG emissions growth from individual projects policy. Inevitably, county government can be expected to expand in terms of operations and services as population growth continues. Where these expansions translate to added floor space or additional vehicles, without careful deliberation, GHG gas reductions can be easily overtaken by emissions created by expansion. The potential growth in emissions from new activities can be counterbalanced by (a) designing new activities (e.g., buildings) with state-of-the-art efficiency technologies (such as the new Yolo county Bauer building) and (b) possibly offsetting all additional new facility GHG emissions with carbon reduction credits, carbon offsets, or installing on-site county-operated renewable (or co-generation) energy to compensate for those new building energy and GHG emission consequences. We emphasize this aspect to make it clear that GHG reductions in existing buildings cannot offset new building expansions if the county wants to ensure that GHG emissions are actually reduced, as opposed to stabilized, over time.

INTRODUCTION

With greenhouse gas emissions increasing yearly (Figure 1), nearly every level of government in California is acting to mitigate greenhouse gas emissions (GHG) emissions. In 2006, California passed the Global Warming Solutions Act (AB32), which set an ambitious GHG emissions target of 1990 levels by 2020, with still further reductions, 80% of 1990 emissions by 2050, mandated by executive order S-20-06 (State of California, 2005). At the local level, over 600 U.S. mayors have committed their cities to GHG emission reduction targets to reduce their local emissions to below 1990 levels by the year 2012 (U.S. MCPA, 2007). Over 100 of these mayors are within California cities, representing 40% of the state's population.

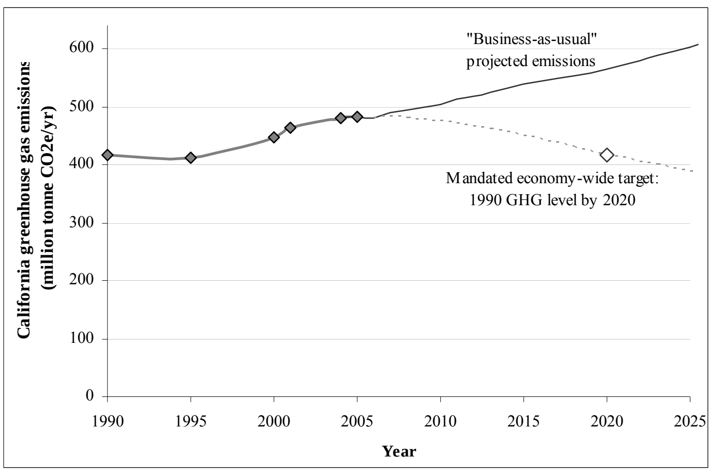

Figure 1. California projected greenhouse gas emissions and emission reduction target

The "U.S. Cool Counties Climate Stabilization Declaration," is increasingly being adopted at the county level. The commitment sets emission reduction goals and a commitment to work with other governments to reduce GHG emissions. California cities and counties are beginning to implement improved efficiency technologies and practices into their buildings, vehicles, street lighting, and waste management.

Local governments have several advantages that lend to their ability to effect GHG mitigation. City and county initiatives have the ability to reduce not only the direct operational GHG emissions, but also the GHG footprint of the individual, industrial, and business activities with their jurisdiction. Local governments, through visibility and purchasing power, can set an example for households and businesses in their GHG-reduction practices. Also of particular importance is local governments' unique jurisdictional capacity to enact long-term land use and transportation planning initiatives that influence GHG emissions. Finally, local governments have the benefit of proximity to their constituents, enabling the development and implementation location relevant educational and awareness programs designed to encourage individual and community actions that reduce GHG emissions.

Project Objectives

The primary objective of this study was to holistically assess the range and scope of current GHG emissions for Yolo county governmental operations and to recommend improvements in the county's operations and technology stock to mitigate those emissions.[2] This project was conducted as part of the *Public Service Research Project* through the John Muir Institute on the Environment.

The project emerged from the Yolo county's Board of Supervisors Resolution 07-109 (Appendix A), which promulgated adoption of the "U.S. Cool Cities Climate Stabilization Declaration." The Declaration commits the county to developing an inventory of its operational GHG emissions and achieving "significant, measurable and sustainable reduction" of those emissions with a target rate of 10% every 5 years, beginning in year 2010.

Project Overview

The Yolo county Department of General Services (DGS), operates and maintains the county's buildings and vehicle fleet, and is directly responsible for managing the county government's operational GHG mitigation plan. The DGS has targeted a 5% per year GHG emission reduction goal from the county's overall operations. In 2006, the county prepared a baseline inventory of GHG emissions and reported the inventory through the California Climate Action Registry (CCAR). The CCAR was established by California statute to assist companies and organizations in establishing baseline inventories that are verifiable and in concurrence with established reporting protocols (State of California, 2000; State of California, 2001). The Registry encourages participation by entities like corporations, municipalities, and state agencies to maintain records for GHG emission baselines and reductions (CCAR, 2007a).

Beginning with the baselines reported in CCAR, we reviewed county operations by first segmenting the data to help clarify and highlight the types of facilities and activities that are most closely associated with the county operations' GHG emissions. In this report, we describe various past and ongoing Yolo county initiatives that are impacting, and/or will impact, the county's GHG emissions. We took a two pronged approach in preparing this report. First, for both stationary and mobiles sources, we examined general strategies that the county could consider in terms of improving operational practices, we discussed

[2] Within the context of this report, references to "Yolo county," or "the county" refer only to Yolo county governmental operations, and not to the larger geographical county and all of its constituents.

specifications of currently available GHG-reducing technologies, relying on a literature review for emerging technologies that are likely to be available in future years.

From this, we developed a broad list of recommended actions for GHG reductions in stationary and non-stationary sources. All of the broadly considered GHG mitigation practices and technologies were expected to be cost-effective within a specified time period (Table 1): near-term (implementable between 2008 and 2010), mid-term (2010-2015), and long-term (2015-2020). Because many GHG emission-reduction options involve an increased measure of energy efficiency, there is the potential for options that have lifetime benefits that fully offset the initial costs of implementing the strategies. These options have energy-saving benefits that outweigh costs – independent of any potential benefits of reducing eventual climate change damage. A higher premium was placed on all such "no regrets" GHG mitigation actions with net-positive economic impacts.

Our second thrust was aimed at conducting a detailed inventory and analysis of three county facilities. This portion of the study was conducted in association with a UC Davis engineering class on Urban Sustainability. Students taking the course, which included a total of thirty-four undergraduate and graduates, were organized into student project groups specializing in appliance efficiency and practices, vehicle fleet operations, and building energy usage in three specific county buildings,. Aspects of their case studies have been synthesized and incorporated into this report.

Table 1. Categories for Yolo County GHG mitigation actions

Category	Implementation Timeframe	Description
Near-term	2007-2010	Technologies that are either available off-the-shelf or in limited availability (for bulk government purchasing); Practices that are immediately implementable in terms of county personnel maintenance and employee actions
Mid-term	2010-2015	Technologies that are currently emerging in state-of-the art efficiency prototypes and are projected to be available by 2010; Practices that require some level of education and training of county personnel on maintenance and employee actions and therefore will take several years to be fully adopted at county facilities.
Long-term	2015-2020	Technologies projected for deployment in 2015 and beyond, with greater potential GHG emission reductions; Practices that entail large institutional challenges in terms of personnel awareness, training, and adoption of operational and behavioral changes

County Operations Baseline Emissions

Over the past year, Yolo county has collected general data on fuel and energy uses from its operations, using this information to quantify its 2006 baseline for carbon dioxide (CO_2) emissions in the CCAR. There are five other GHG emissions that are included in official international GHG reporting: methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). These emissions are generally reported in units of carbon dioxide equivalent (CO_2e) emissions, which are calculated by multiplying the emissions (in metric tons) by their global warming potentials (GWPs). The global warming potential of a greenhouse gas is reflective of its ability to trap heat in the atmosphere relative to that of CO_2, with GWP equal to one by definition. Under the CCAR protocol, the county has until the 2009 emissions-reporting period to include any of the remaining five pollutants for which county operations are responsible.[3]

For the 2006 baseline, the county reported approximately 8,200 metric ton of CO2e emissions. Roughly half of the county emissions are directly generated at county facilities or by county vehicles Table 2), with the remaining emissions generated indirectly at the utility electricity generation sites. Segmenting GHG emissions according to type shows that about 75% of emissions are from stationary sources while 27% are mobile. Building electricity use accounts for 49%, building natural gas use 17%, building co-generation of heating and electricity use 7%, portable power 2%, and vehicle operations 25% of total GHG emissions.

Table 2. Yolo County GHG emissions from government operations

Category	Type	Use (energy source)	GHG emissions (tonne CO_2) by fuel				Percent
			Electricity	Natural gas	Diesel	Gasoline	
Indirect	Stationary	Buildings (electricity)	4,018	-	-	-	49%
Direct	Stationary	Buildings (natural gas)	-	1,379	-	-	17%
Direct	Stationary	Buildings (co-generation)	-	563	-	-	7%
Direct	Stationary	Portable power	-	-	176	19	2%
Direct	Mobile	Vehicles	-	-	133	1,894	25%
Percent			49%	24%	4%	23%	

[3] The CCAR (2007b) reporting protocol practices are used for all energy use-to-GHG emission conversions.

STATIONARY SOURCE EMISSIONS

Stationary sources generally refer to a fixed site producer of pollution, in this case greenhouse gas emissions (e.g., power plants, industrial stacks, etc.). For the purposes of this report, stationary sources represent those buildings operated and maintained by Yolo county. From the CCAR-reported baseline, stationary source GHG emissions from building energy use of electricity and natural gas totaled 5,960 tonnes CO_2e per year, or 73% of the total county operational GHG emissions. In this section of the report, we begin with a background discussion of the range of county operations producing GHG emissions and the existing county programs aimed at impacting energy and GHG emissions. We then provide an overview of the available GHG mitigation options that resulted from our research, using information from the case studies to highlight opportunities for improvements and recommended GHG mitigation actions and rationale.

Background on County Building Operations

To characterize the baseline emissions reported in the Registry, we drew on a variety of more detailed data sources. Records from Pacific Gas & Electricity (PG&E) were used to assess natural gas and electricity usage at county facilities. Additional data were collected from various departments to assess the vehicle fleet stock and use characteristics, the county stationary and portable power generation, and landfill operations. From these data sources, we present trends and breakdowns of operations and their GHG emissions characteristics. We have provided a discussion of county sponsored projects that have impacted, are impacting, or are likely to impact GHG emissions, independent of the recommendations of this report.

In 2006, there were a total of 57 county operated facilities with energy usage and related GHG emissions. These office buildings, law enforcement facilities, libraries, storage centers, and garages are the workplaces of approximately 1,600 county employees. The GHG emissions that we were able to quantify from these facilities result from electricity use and natural gas consumption, which is primarily used for heating. Table 3 shows GHG emissions by building, or facility, for 2006. The facilities are listed in descending order, from the most GHG emissions to the least, in metric tonnes of CO_2e per year. Also provided are each facilities percent of total GHG emissions, the square footage for each facility, the percent of building area, and the measure of the facilities' GHG emissions per square foot. From these calculations, it is easy to see that a relatively small proportion of the facilities account for a relatively large proportion of the GHG emissions. The first eight facilities account for about one-half of all the buildings' GHG emissions. These eight facilities (Leinberger, Cameron, Monroe Jail, Sheriff, Morgue, Administration, Department of Education and Social Services, and Courthouse) represent 39% of the floor space and 50% of the calculated building GHG emissions. It is important to note that a complex of five buildings (row 1 in the table) is linked through common energy use and metering to the county's cogeneration unit.

Table 3. Yolo County facilities' greenhouse gas characteristics

Facility	Electricity (kWh)	Natural gas (therm)	GHG emissions[a] (CO_2e/yr)	Percent of building GHG	Area (sq. ft.)	Percent of building area	Unit GHG (kg CO_2e/sqft/yr)
Monroe jail, Sheriff, Leinberger, Cameron, Morgue (cogeneration)	1,911,792	221,394	1,868	31%	141,586	15%	13.2
Administration	897,440	14,952	407	7%	70,618	7%	5.8
Dept of Empl. and Social Serv.	840,815	6,278	341	6%	63,000	7%	5.4
Courthouse	614,080	17,176	315	5%	48,983	5%	6.4
County service center	576,000	19,746	315	5%	49,363	5%	6.4
New juvenile hall	575,840	13,566	282	5%	38,900	4%	7.3
Woodland offices (120 W Main)	575,652	3,332	228	4%	31,273	3%	7.3
Davis Library	521,400	5,765	221	4%	30,000	3%	7.4
West Sac offices (500 A)	407,721	5,584	179	3%	29,946	3%	6.0
West Sac offices (500 B)	411,780	5,115	178	3%	28,000	3%	6.3
Communication center	473,440	0	173	3%	7,424	1%	23.3
Landfill	445,490	0	163	3%	8,928	1%	18.2
Distr. attorney	385,120	1,348	148	2%	20,550	2%	7.2
Fleet services/garage	299,120	7,158	147	2%	23,932	2%	6.1
Old jail	301,680	5,547	140	2%	23,267	2%	6.0
Public health	230,120	0	84	1%	13,427	1%	6.3
Alcohol & drug, Mental health	43,727	1,554	24	0%	6,733	1%	3.6
Storage (55 C st)	24,032	2,713	23	0%	125,127	13%	0.2
Bauer County Health (new)	0	1,926	10	0%	70,000	7%	0.1
Probation (old)	0	1,695	9	0%	8,335	1%	1.1
Other buildings (~33 buildings)	1,451,831	33,175	706	12%	120,588	13%	5.9
Total, all buildings	**10,987,080**	**368,024**	**5,960**	**100%**	**959,980**	**100%**	**6.2**

[a] *Conversion to CO_2-equivalent GHG emissions is based on CCAR (2007b) reporting guidelines*

Of particular interest are those facilities exhibiting relatively high GHG emissions intensity, measured in annual GHG-per-square-foot of floor space. The GHG intensity can be thought of as an overall measure of a facility's relative efficiency in the consumption of energy for heating, cooling, and appliances. The average intensity of all the county facilities is to about 6.2 kg CO_2e per year per square foot of floor space. There are several facilities that are substantially above this level of GHG intensity. Two facilities (the landfill building and the communication center) are responsible for 18 and 23 kg CO_2e per year per square foot, respectively, or about three to four times the county facility average building GHG intensity. Also, the five-building complex (Monroe Jail, Sheriff, Leinberger, Cameron, Morgue) linked to the cogeneration unit has a GHG intensity that is double the county building average.

The GHG emissions characteristics of county buildings vary somewhat from year to year as well as month by month. Generally, without programs designed to conserve energy use, energy consumption will tend to increase incrementally over time due to factors such as increases in numbers of personnel or total appliances, such as refrigerators and computers, operating in given facilities.

Electricity and natural gas use data for county facilities were available for the 1999-2001 and 2005-2006 time periods. Converting these energy use statistics to GHG emissions, and interpolating between 2001 and 2005, the county facility GHG emissions from 1999 to 2006 are shown in Figure 2. The GHG trend indicates a steady creep of energy use-related GHG emissions over time. GHG emissions from natural gas and electricity combined increased about 28% over the seven-year span from 1999 to 2006. This is equivalent to an average increase of 3.5% per year.

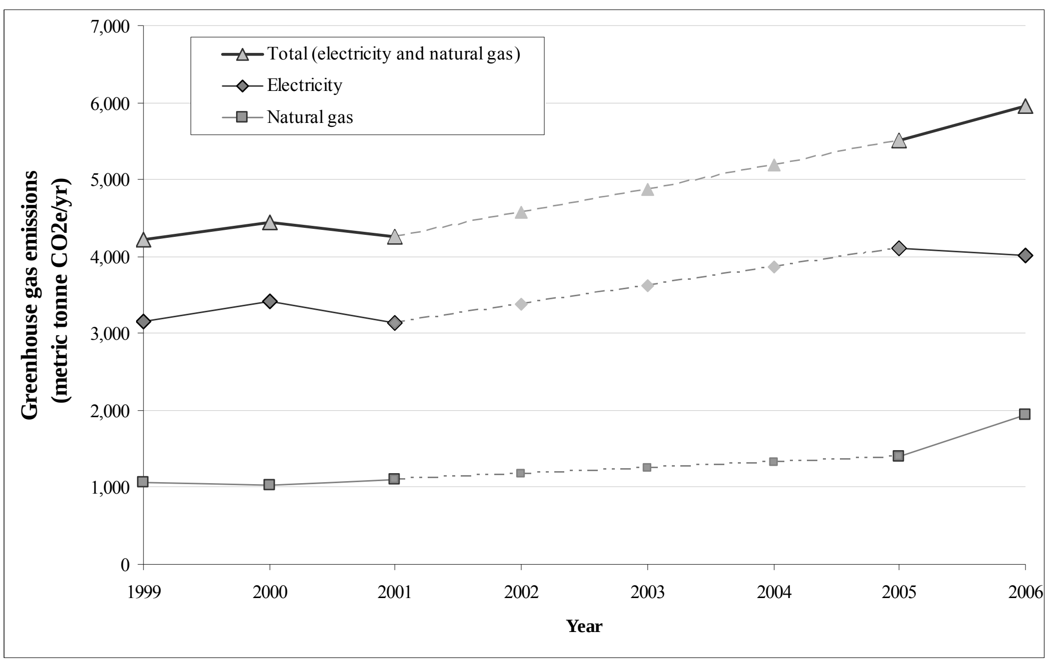

Figure 2. Estimated Yolo County GHG emissions from buildings, 1999-2006

Energy-related GHG emissions from buildings vary within each year, largely as a result of winter/summer heating and air conditioning needs. Figure 3 depicts this seasonal variation in heating and cooling needs. The GHG emissions from natural gas are over eight times greater in January than August, in large part due to the much greater heating requirements in winter. The GHG emissions variation in electricity is more moderate due to the diversity of electricity uses (appliances, lighting, computers, fans, and air conditioning) that are demanded year-round; the electricity used in June and July is about 50% greater than in January and February.

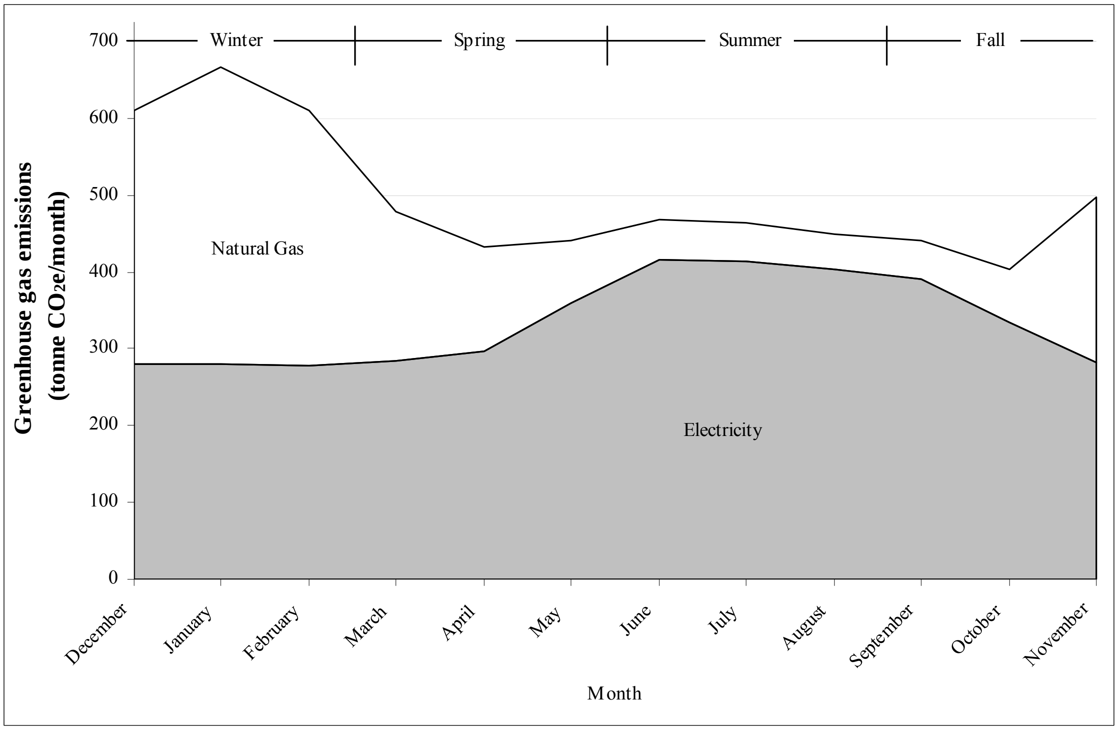

Figure 3. Seasonal variation in Yolo County building GHG emissions by energy source

Existing County Programs Impacting Building Emissions

The county has undertaken a number of measures aimed at reducing GHGs including some that have recently been completed or are ongoing. There are also a number of planned actions for the immediate future. Table 4 shows five major projects with quantifiable GHG reduction impacts on building GHG emissions. An extensive retrofit program was conducted from 2002 through 2004 which included overhauling older equipment, installing newer automated systems for heating and cooling, and replacing older lighting with newer more-efficient technologies. As part of this project, the county installed a natural gas-fired cogeneration unit which has the ability to simultaneously provide heating and electricity to the five building complex near the Monroe Detention facility where it is installed; the unit is generally utilized during peak-electricity rate times. More recently, the Bauer Health Building was designed with efficient building design principles and includes a 147-kW photovoltaic solar power array on its roof to power most of the buildings' electricity needs. There are also plans to close several older buildings and expand the use of the cogeneration unit use. It is important to note that the cogeneration unit (fueled by natural gas) produces methane, which is a greenhouse gas with a much higher GWP relative to CO2. Research has shown that natural gas displacement of fossil fuels, despite increased methane production, results in a net reduction in greenhouse gas emissions (USEPA/GRI 1996). Thus, the strategy of closing older buildings and expanding the cogeneration unit accommodates both increased energy use and reduced GHG emissions.

Table 4. Yolo County projects with GHG emissions impacts

Project	Description
Building conservation and retrofit project (2002-2004)	Installment of improved efficiency lighting, boilers, HVAC, economizers, chillers, fans, water heaters, motors, automated computerized climate control (performed by Aircon Energy)
Co-generation at Monroe Detention Facility (2003-2004)	Installment of co-generation unit to provide on-site heating and electricity from natural gas
Bauer health building efficiency and renewable energy (2004-2006)	Building designed to LEED-Silver equivalent energy efficiency specifications; roof-top 147-megawatt solar cell installation
Building closure plan (2007-2008)	Closure and demolition of five older inefficient facilities (Alcohol & drug, mental health, probation, health, C street storage)
Co-generation efficiency improvement (2007-2008)	Improve co-generation unit efficiency to power energy needs of jail expansion
Landfill bioreactor (2000-2004)	Capture and manage landfill decomposition gases, including methane (CH_4) and use to generate energy

The GHG effects of the already planned or implemented projects are quantified in Figure 4. The building retrofit (2002-2004), the installation of the co-generation unit at the Monroe detention center (2003-2004), and the new Bauer Health Building efficiency and solar energy projects (2004-2006) had already been completed previous to Yolo county's entry into the climate registry in 2006. We estimate the GHG emission reductions that result from these energy efficiency projects. County data on estimated energy savings from these projects was taken from the DGS (2007) "Energy/Emissions Report."

These three projects together are estimated to have reduced 2007 county GHG emissions by 20% (from about 7,500 to 6,000 tonne CO_2e per year) from what they would have otherwise been. In Figure 4, we show the net effect of the introduction of each of these energy saving strategies over the current baseline. These previously implemented energy-saving actions will not be credited within the official 2006-established county baseline with the California Climate Action Registry; however, we estimate these measures' impacts to highlight that the county's GHG reduction goals are part of continuing progression of related county energy and GHG mitigation improvements. The solar project came on line in 2007 and is not included in the CCAR baseline.

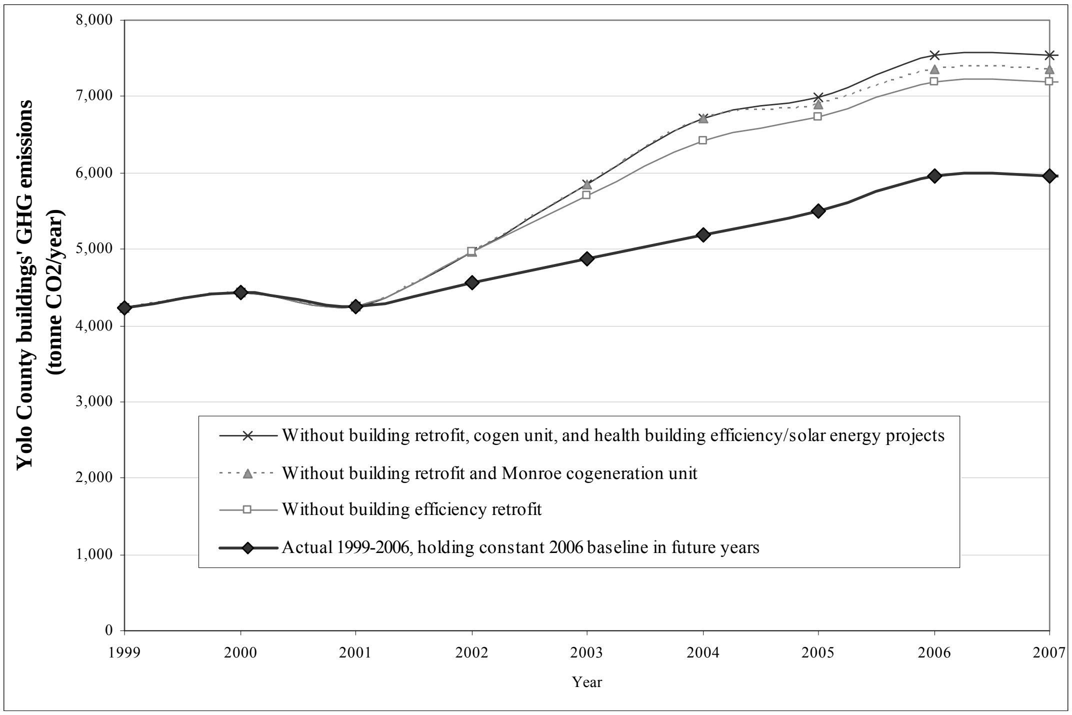

Figure 4. GHG emissions from Yolo county facilities from 1999-2007

Over time, and despite improvements in energy efficiency, the county's actual building GHG emissions has increased. This is largely due to building expansions that occurred from 2001 to 2007. Within the last four to five years, the overall facility square footage increased 22% from about 750,000 (2003) to 960,000 (2007). During the same period, the GHG footprint increased an estimated 15%, indicating that the overall GHG intensity of county facilities has improved. The closure and demolition of five older buildings (Alcohol & Drug, Mental Health, Probation, Mental Health, and the C Street storage facility) in 2007 and 2008 will eliminate approximately 140 tonnes CO_2e/year, or about 2.4% of total GHG emissions associated with energy use. We have not taken any planned or anticipated expansions into consideration in this analysis.[4]

Several other ongoing projects are planned by the DGS. The Monroe co-generation plant will be retrofitted for improve energy efficiency to power the new energy demand associated with the 2007-2008 jail expansion. The county also regularly participates in various PG&E energy programs, such as rebate programs, peak-time-of-day electricity load demand reduction, and non-critical peak-day load reductions. Since 2003, six generators and boilers have been retrofitted to improve their criteria pollutant (i.e., non-GHG) emissions and permitted by the Yolo-Solano Air Quality Management District. The county also

[4] For example, we have not included the new jail expansion. This will obviously increase the county's GHG footprint beyond what we have accounted for here.

will implement programs in their buildings to more optimally automate energy management practices and replace older energy-inefficient appliances. All of these programs are likely to have a beneficial effect on GHG emissions, but have not yet been quantified by the county.

Potential GHG Mitigation Options

There are a number of ways in which existing and new buildings can be improved for GHG emission reductions without significant retrofit. These improvements can broadly be categorized into several focus areas: (i) improved appliance efficiency, (ii) improved lighting efficiency, (iii) improved heating, ventilation, and air-conditioning (HVAC) systems , and (iv) building shell technologies (e.g., improved insulation and windows). Improvements to county facilities in each of these areas generally include replacement of older equipment with new, more energy efficient equipment, as well as practices for reduced use of avoidable operations of current equipment. This section focuses on describing investigated measures, along with their costs and energy saving potential, for each of the broad categories of improvements.

Data on available and emerging technologies for improved efficiency in buildings is taken from many difference sources. A particularly important source is the Sachs *et al* (2004) report, *Emerging Energy-Saving Technologies and Practices for the Building Sector as of 2004* which provided detailed information on emerging technologies being developed for use in buildings. Also a host of web references to U.S. Department of Energy and U.S. Environmental Protection Agency web sources (US DOE and US EPA, 2007; US DOE, 2007) were used extensively in our investigation of available technologies and a data collection of their potential costs and energy savings. Other primary data sources that have been utilized are individually referenced in specific sections below. Two small surveys of county workers were used to help quantify existing practices in county buildings. A internet-based survey conducted by the county and another survey, conducted by UC-Davis students, each collecting information from over 200 employees.

1. Appliances and Office Equipment[5]

Of the county buildings annual 5,960 tonnes CO_2e emissions (2006), we estimate that approximately 32% of these emissions result from energy used by electrical appliances, with an estimated 8% from computer use, 7% from refrigerators, and 17% from all other electric appliances (copiers, fax machines, etc.). We focused on alternatives for reduced energy use for computers and refrigerators with some general suggestions for managing energy consumption from other miscellaneous electrical appliances and equipment, including water heaters, copiers, fax machines, and water coolers.

Beginning with computers, there are two main energy efficiency strategies that can be undertaken: procurement of more efficient computers and improved computer power management. The identification of energy efficient computers and monitors is simple and low-to-no cost to access; information is available at the ENERGY STAR website (U.S. EPA and U.S. DOE, 2007). Every major computer brand offers ENERGY STAR-qualified computers, which have no distinguishable incremental cost difference. All ENERGY STAR computers have “stand-by” modes that require less than 2 watt (W), “sleep” modes of less than 4 W, and “idle” states of less than 95 W. In addition these computers are set to a default power management setting where computers that are inactive for 15 minutes go into monitor sleep mode and, after 30 minutes into system sleep mode.

However, it should be noted that in most cases the power management setting of computers can be adjusted by office workers. Computer users that dislike the active-sleep-active computer cycling can easily disengage the power management settings. One solution to user disengagement are networked computer software packages that allow an office department’s system administrator or an Information Technology (IT) department to remotely set and maintain power management setting for computers. These software systems range from being free to costing $15 per computers installed; three such systems are EZ GPO, EZ Save, and EZConserve.

county specific computer use varies by building and user; however, some broad trends were identified through data collection, surveys and general observations. The county IT department provided data on the

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[5] Information on low-GHG office equipment is derived from a number of different sources. A joint U.S. Department of Energy and U.S. Environmental Protection Agency program (ENERGY STAR) promulgates standards for a range of energy-efficient appliances. ENERGY STAR-qualifying equipment and on-line calculators are provided to enable comparisons between energy efficient office equipment and conventional (non-qualifying) equipment for many different office appliances, including computers, refrigerators, copiers, water coolers, and fax machines (See US EPA and US DOE, 2007). In Appendix C, we have also provided Internet resources from the ENERGY STAR program that have been useful for this study and that can be consulted for future equipment purchasing decisions. Information is also taken from Sachs et al (2004).

stock of computers by make, model, and department currently being used. The county has 1,940 computers, and they are predominantly (about 75%) the Dell OptiPlex model line. About 95% of the observed monitors are of the flat liquid crystal display (LCD) type, which is more efficient than the cathode ray tube (CRT) type. Cross-referencing the computer inventory with the ENERGY STAR list indicated that 75% meet an earlier (i.e. year 2000) ENERGY STAR 3.0 level; and only 20% meet the current 2007 ENERGY STAR 4.0 level.

A survey for county employees provided an indication of general computer usage patterns. The average reported time in active mode for county computers is about 40 hours per week. Almost all computer-using employees replied that their computers were 'on' for the work-day hours and 'off' or in stand-by the remainder of the time. However, there are some indications that computers on left on for more than the typical working hours. Only 60-70%% of employees reported that they shut down their computers when they leave. Only a small number of employees knew about or engaged their 'stand-by' mode functions. This means that when employees are away from their computers during the workday for extended period, computers will remain on. We also found that disabling the power management setting was a common practice; employees often expressed annoyance and were distracted when computers routinely went into stand-by or hibernation modes. In some cases, employees' computers remained fully "on" in active mode after employees left the premises. In other cases, for example at the Davis Library, computers are intentionally left "on" overnight and on weekends to enable automatic downloads for security and upgrades. These practices suggest that the county could benefit from improved power management policies.

For another major appliance we focused on – refrigerators – two main options exist to reduce energy consumption. First, employees and departments can use fewer refrigerators where possible by consolidating use, and unplugging (and selling) excess capacity refrigerators. This applies to all personal computers that are being used for workers in department with available full-size refrigerator space. This might apply to particularly small departments that are currently using one refrigerator for two or fewer employees, while another refrigerator with space is available nearby. The second option is to identify older refrigerators and replace them with ENERGY STAR units. For refrigerators, ENERGY STAR units consume 15% less electricity than the federal standard performance for refrigerator performance and 40% less than 2001 model refrigerators. For refrigerators of standard size (18 to 20 cubic feet), ENERGY STAR units cost approximately $30-$70 more than comparable non-ENERGY STAR units; these unit pay for their initial incremental cost in less than 4 years (based on SunPower, 2003; LGE, 2003; Unger, 1999; US DOE, 2004).

Our investigation of county refrigerator usage uncovered several useful findings. The county-conducted survey revealed that 99% of employees have access to communal refrigerators. About 70% of county employees use communal refrigerators. Approximately 5% of employees reportedly had small refrigerators at their office for personal use. Our particular observations into the three buildings of our case studies (the Administration, DESS, and Davis Library facilities), revealed differing numbers of refrigerator units. The Administration building had a total 15 units (2 for personal use); the DESS had 6 total units (3 for personal use); the Davis Library had 4 units. Of the refrigerators identified, more than half were pre-2001 model year units. From these observations, we find that there is potential for eliminating excess refrigerator capacity (especially in the case of the personal refrigerator units) and in replacing the older units with newer ENERGY STAR-qualified refrigerators.

With respect to the remaining appliances, there are two options for improving energy efficiency for appliances. The first addresses policies for the energy consumed while appliances are "on" but unused, and the second option is a replacement solution where current equipment is replaced by newer high-efficiency alternatives. We start with on-time related issues. There are often many appliances and devices dispersed throughout an office complex; this makes it difficult to turn devices off during non-work times. However, turning appliances off during non-work hours is of primary importance because non-work times (night and weekends) represent 70-90% of annual hours. Put more simply, turning off equipment during non-work hours represents a 70-90% energy use reduction at no cost. Obviously policies aimed at reducing the spent time on for any devices during non-work times is of critical importance with respect to appliances and office equipment. The county should ensure that a consistent cross-building policy is promulgated. The second option is again to replace current appliances with more energy efficient models.

For example, more efficient bottle-type water dispensers, or "water coolers," can result in modest energy savings. The two main types of water coolers, cold-water only and hot-and-cold water; both have more efficient ENERGY STAR-qualified models available. Conventional cold-water units generally consume 0.3 kWh/day, and their ENERGY STAR counterparts reduces that amount by 55%; these units cost about $5 more than conventional units and offer a payback period of less than a year. For the cold-and-hot units, the conventional units consume about 1.9 kWh per day per unit, while more efficient models reduce energy use by 62%; these units cost an additional $12 per unit and have a 4-year payback period.

Other small electric appliances in county building offices with potential efficiency savings include printers, copiers, and fax machines. More efficient copy machines, like the ENERGY STAR-qualified units, reduce energy by 30%-50%, print double-sided, and tend to run cooler, which could in turn reduce the overall air-conditioning requirements of office rooms. Similar technology for fax machines offer 50% energy use reductions at no additional cost from conventional models (Industry data 2007; LBNL 2006).

Finally, water heaters are in most county facilities for employee and public use. Several low-cost practices can result in savings to the overall energy use of water heaters. Two such practices for existing water heaters with significant savings are setting water heater thermostats to 115-120F (some are set as high as 140F) to reduce electricity use by 5-10% and installing an insulation blanket around the hot water tank, which also reduces electricity use by about 4-9%. Also two water heater technologies are available with potential energy use savings. The use of a heat pump water heater, with it use of a vapor compression refrigeration cycle, is more efficient than conventional tank water heater, and instantaneous (or "tankless" or "on-demand") water heaters avoid the water heater tank altogether by quickly heating waters as needed. The heat pump water heater, costing about $600 more initially, pays for itself within two years in energy savings. The "on-demand" systems, however, only offer marginal energy savings and may not ever return their initial price increase over conventional water tank systems.

Table 5 summarizes the measures that can be taken with respect to appliance technologies and practices to reduce county GHG emissions. In all the cases mentioned, with the two exceptions of the large printer and on-demand water heater, the measures are either no-cost measures or have breakeven periods that are well within the lifetime of the appliance (e.g. the ENERGY STAR refrigerator lasts 15-20 years but has a payback period of 4 years). In each of the case studies discussed later, we review a number of specific changes that can assist the county in these buildings, and provide a roadmap to reducing energy consumption in the remaining county buildings.

Table 5. Appliance GHG emission reduction measures

Measure	Description	Initial cost [a] ($/unit)	Payback period [b] (yr)	Data source(s)
Computer efficiency	ENERGY STAR-certified computer procurement (many available brands); offers approximately 20% reduction in electricity use compared with conventional	$0	<1	US EPA and US DOE 2007; LBNL 2006
Computer and monitor power management	Networked computer software for IT department (network administrator) control of computer and monitor power management (e.g., EZ GPO, EZ Save, EZConserve); offers 50-90% reduction use, depending on current power management practice.	$0-$15	<1	US EPA and US DOE 2007; Degans 2003; LBNL 2002; Sachs et al, 2004
Refrigerator efficiency	ENERGY STAR-certified refrigerator procurement; 15% reduction in electricity use from federal standards; 40% lower electricity use than conventional 2001 models	$30-$70	4	Sunpower 2003, LGE 2003, Unger 1999, Vineyard and Sand 1997; US DOE 2004
Refrigerator excess capacity reduction	Unplugging (or selling) excess refrigerators; Consolidation between departments or groups of workers with nearby under-utilized refrigerators	$0	<1	-
Water cooler efficiency (cold)	ENERGY STAR-certified water coolers (cold water only) 55% more efficient due to improved chilling mechanism	$5	<1	LBNL, 2004
Water cooler efficiency (hot-cold)	ENERGY STAR-certified water coolers (hot-and-cold water type) 62% more efficient with better insulation/separation of hot and cold	$12	4	Nadel et al, 2006; PG&E, 2004a; LBNL, 2004
Printer efficiency (small)	ENERGY STAR-qualified printers use 50% less energy, print double-sided, and run cooler (small, 10 page/min)	$37	2	Industry data 2007; LBNL 2006
Printer efficiency (large)	ENERGY STAR-qualified printers use 30% less energy, print double-sided, and run cooler (large, 40+ page/min)	$565	10	Industry data 2007; LBNL 2006
Fax machine efficiency	ENERGY STAR-qualified fax machines with 50% energy use reduction	$0	<1	Industry data 2007; LBNL 2006
Copy machine efficiency	ENERGY STAR-qualified fax machines with 50% energy use reduction	$0	<1	Industry data 2007; LBNL 2006
Water heater thermostat setting	Changing the water heater thermostat setting to 115-120 F (normally set to 140F) for 5-10% energy use reduction	$0	<1	DOE, 2007
Water heater insulation	Installing low heat exchange (R > 8) insulation blanket around water heater tank for 4-9% energy use reduction	$15	<1	DOE, 2007
Water heater efficiency (heat pump)	Improved heat pump efficiency	$600	2	Nadel, 2002; Sachs et al, 2004
Water heater efficiency (gas-fired "on-demand")	Instantaneous, or tank-less, gas-fired, high-modulating water heater	$650	20	GAMA, 2003; Thorne 1998; Sachs et al, 2004

[a] *initial cost is the additional cost above the standard conventional alternative technology or practice, per unit (e.g. computer)*
[b] *payback period estimated based on energy savings in future years with 7% discount rate*

2. Lighting Systems

Of the building total annual 5,960 tonne CO_2e emissions (2006), we estimated that approximately 18% was associated with lighting. Lighting improvements for GHG reductions involve three general strategies: more optimally using the existing lighting systems in a building, replacing lighting technologies within a building, or developing some combination of optimal use of lighting with technology enhancements.

There are many practices with existing lighting systems in buildings that should be examined for energy use reductions. Within the county facilities, there are a number of opportunities in which artificial lighting is relied upon when there is significant natural lighting and rooms with partial or infrequent use throughout normal workdays. Many lobby areas, office cubicle rooms, and conference rooms receive some natural lighting. The county-conducted survey revealed that many employees are in places where natural lighting provides for some of their lighting needs. From the survey, 5% of respondents reported that they can use natural lighting for all of their lighting needs, and another 39% reported that natural lighting can be used for part of their lighting requirements. However, in most cases, these areas in buildings have the same amount of artificial lighting fixtures and light bulbs per square foot of floor space as those areas having no access to natural light. Solutions include reducing the amount of lights per fixture near windows, installing different light switches for building areas that often have ample day-lighting, or installing automated dimming lighting systems that manage the amount of artificial lighting required based on the availability of natural light.

In many of the buildings we noticed artificial lighting of entire rooms in which there were no occupants. Rooms that are particularly susceptible to this problem are sporadically used conference or meeting rooms and bathrooms. Enacting workplace policies that encourage turning off lights may help to some extent, but installation of automated occupancy-sensing lighting systems can eliminate these types of lighting overuse altogether. In each of these instances where improvements can be made to reduce unnecessary light use, the costs are either net-positive (e.g. using less lights per fixture), negligible (e.g., remembering to manually shut off lights), or minimal (e.g. installing day-lighting and/or occupancy sensors).

The next step to increasing energy savings related to lighting are technology replacement options that can deliver further GHG emission reductions (Table 6). Technology replacement options are specific to current lighting uses. For example, a number of different lighting efficiency options exist for the office use, hallways, warehouses, exit lights, and outdoor use. In any place that incandescent light bulbs are still in use, their replacement with ENERGY STAR-qualified compact fluorescent lights (CFLs) offers a 75%

efficiency improvement that has a breakeven as an energy investment within one year, and the bulbs also last ten times longer, thereby reducing the maintenance costs that would be required for replacing incandescent bulbs over their lifetime (Industry data, 2007; US EPA, 2007). For office fluorescent tube-style lighting, shifting from the conventional T12 office fluorescent lighting to state-of-the-art T8 lighting offers an 81% efficiency improvement and does so with longer life (Sardinsky and Benya 2003; Sachs et al, 2004).

Even the replacement of exit sign light bulbs can yield energy savings. Exit sign bulbs, which are generally 36-W incandescent bulbs, can be replaced with off-the-shelf ENERGY STAR-qualified light-emitting diodes (LEDs) that draw only 5 W per unit and breaks even as an energy investment within one year of their purchase (US EPA 2006; US EPA, 2007; Industry data, 2006; LBNL, 2007). For outdoor, high ceiling, and parking garage lighting, there are two excellent technologies: metal halide lamp fixtures with pulse-start technology which offer a 25% reduction and one-year payback (Nadel et al 2006; PG&E, 2004b) and high intensity discharge (HID) lighting which offers a 60% electricity reduction over metal halides with a two-year payback period (Gough, 2003; DOE, 2002; Sachs et al, 2004). Further reductions could result in outdoor applications where automated occupancy- sensing light-dimming technology could be installed.

As we have shown, there are several types of lighting efficiency approaches that integrate improved technologies and practices for potential energy and GHG reductions. One final strategy worth considering is decreasing overall lighting requirement by simultaneously reducing the ambient overhead lighting while increasing the immediate workspace lighting (or "task lighting") with 5-W LED lights at each occupants working area. This integrated approach both reduces overall energy needs (in watt per square foot of floor space) and improves each individual lighting (foot candles or lumens per square foot of desk space). Reducing the ambient lighting can be done by simply reducing the lights per fixture or through the installation of integrated day-light sensing systems. The use of more efficient LED task lighting and the installation of integrated office space lighting systems both are highly cost-effective, returning their initial cost well within the lifetimes (Ton et al 2003; Kendall and Scholand 2001; LumlLed 2003, DOE 2003; Sachs et al, 2004; Marbek 2003, DOE 2002). This strategy is discussed in more detail in the case studies.

Table 6. Lighting GHG emission reduction measures

Measure	Description	Initial cost [a] ($/unit)	Payback period [b] (yr)	Data source(s)
Use of natural day-lighting	Reducing lights per fixture where sufficient day-lighting exists; putting lights near window on different electrical switch	$0	<1	-
Unused lighting management	Turning off lights in un-used rooms	$0	<1	-
Compact fluorescent light (CFL) bulbs	Replacing incandescent bulbs with ENERGY STAR-qualified CFL which use 75% less energy and last 10 times longer (rated 120000 hrs)	3	<1	Industry data, 2007; US EPA, 2007
Exit light efficiency	Use of ENERGY STAR-qualified 5-W light-emitting diode (LED) exit signs lights in place of standard 36-W incandescent (2 bulbs per sign)	114	<1	US EPA 2006; US EPA, 2007; Industry data, 2006; LBNL, 2007
Task lighting efficiency	Replace incandescent and halogen lights with light-emitting diode (LED) used in under-cabinet lighting, office task-lighting; solid-state conversion of electricity to light with high efficiency, long life	58	8	Ton et al 2003; Kendall and Scholand 2001; LumlLed 2003, DOE 2003; Sachs et al, 2004
High efficiency premium T8 fluorescent tube lighting	Replace fluorescent T12 and generic T8 with Super T8 lamp (100 lumen/W) and ballast systems that offer efficacy improvement (31% vs. generic T8, 81% vs. T12) and longer life	5	<1	Sardinsky and Benya 2003; Sachs et al, 2004
Advanced integrated daylighting controls	Integrated and personalized office space lighting that delivers lighting only where needed with occupancy-sensing, daylight-sensing, and dimming (from 0.92 to 0.5 watt/square foot)	0.50	2	Marbek 2003, DOE 2002; Sachs et al, 2004
Automated occupancy-sensing lighting	Occupancy-sensing with adjustable time delay, lighting with high-intensity LED light capability (e.g., "night-light") for bathrooms, other partially utilized rooms.	50	3	Page, 1999; Bisbee (SMUD); Sachs et al, 2004
Use of CFL-only fixtures	Fixtures designed specifically for CFLs (making fixtures incompatible to incandescent bulbs)	30	4	ENERGY STAR 2003; Sachs et al, 2004
One-lamp premium T8 fluorescent fixtures	Reducing excess ambient lighting in offices where computer-oriented tasks predominate (with additional cost of task lighting included)	20	<1	Thorne and Nadel 2003; Sachs et al, 2004
Metal halide lamp fixtures	Replacing any metal halide (generally high ceiling and outdoor applications) with pulse-start higher efficiency ballast (25% reduction)	30	<1	Nadel et al, 2006; PG&E, 2004b; Sachs et al, 2004
Advanced high intensity discharge (HID) lighting	Outdoor applications (street, parking garage, etc) to replace metal halide HID lamps (60% reduction)	118	2	Gough 2003; DOE 2002; Sachs et al, 2004
Universal light dimming control device	Device (DimALL) can dim fluorescent, incandescent, halogen lamps without special ballast with microprocessor attached to a lighting circuit	71	10	Kang, 2003; Sachs et al, 2004

[a] *initial cost is the additional cost above the standard conventional alternative technology or practice, per unit (e.g. light bulb)*
[b] *payback period estimated based on energy savings in future years with 7% discount rate*

3. Heating Ventilation and Air Conditioning Systems

This section focuses on potential improvements in the county's heating, ventilation, and air conditioning (HVAC) systems. Of the annual 5,960 tonnes of CO_2e emissions (2006), we estimate that about 23% is from natural gas-fired heating, 17% is from electricity for air-conditioning, 10% is for electricity generated air ventilation systems and another 9% is from the cogeneration unit which provides both heat and electricity. These HVAC components combined equate to more than half of the county buildings' GHG footprint and are therefore crucially important to examine as part of any strategy to reduce those emissions.

To reduce the overall energy use and GHG emissions, both the ways that the HVAC systems are operated and the technologies of those systems must be addressed. Some county buildings have HVAC systems that date back to the years that the buildings were constructed, but most have to some extent been updated or retrofitted since then. Many of the retrofits occurred during the 2001-2004 time period, when Aircon Energy installed and/or retrofit a number of different HVAC units and improved overall operations; the retrofits often included centralized automated control of the temperature throughout the buildings.

The heating requirements for the county buildings are predominantly from November through April and almost exclusively are fueled by the use of natural gas in commercial boilers. Heating efficiency from boilers for larger commercial buildings (and furnaces generally in smaller buildings) is measured by its Annual Fuel Utilization Efficiency (AFUE). The standard in 1989 was an AFUE of 78% for hot-water boilers. That is, a minimum of 78% of the thermal energy of the fuel is converted to heat; the remaining energy is lost. Most boilers today are 80-84% AFUE, and available high efficiency boilers and furnaces are 87-90% AFUE, depending on type and size.   Several improved efficiency heating technology options are shown in Table 7. When replacing a new boiler or furnace, the choice to get a state-of-the-art unit is clearly beneficial, with paybacks of 6-8 years on units that last 20-25 years (Nadel et al, 2006; FEMP, 2007). However, because the prices of new boiler and furnace equipment are generally very high (tens of thousands of dollars per unit), the replacement of fully operational equipment is not generally considered except for units that are particularly old or are incurring large annual maintenance costs and thus are already slated for replacement. In some circumstances, because of the large potential energy savings for particularly old units, there is some retrofitting of operational units for new efficiency that can still be highly cost-effective (CEE, 2001; Sachs et al, 2004).

Table 7. Building heating GHG emission reduction measures

Measure	Description	Initial cost [a] ($/unit)	Payback period [b] (yr)	Data source(s)
Furnaces	Minimum of 90% AFUE for condensing units (or minimum 80% for "non-condensing")	370	6	Nadel et al, 2006
Commercial boilers	From a 80% AFUE commercial boiler to 87% (for large units, greater than 300,000 Btu/hr units)	3000	8	FEMP, 2007; Nadel et al, 2006
Solar pre-heated ventilation air systems	Use of vertical unglazed solar collector to pre-heat air on exterior surface of building; heated air raises incoming air temp by 30-50 F (for 50,000 sf building, $9/sf, SolarWall brand, northern/colder climates)	18,000	3	Hollick, 2003; Sachs et al, 2004
Advanced condensing boilers	Replacing gas boilers (300,000 Btu/hr or greater) with improved efficiency condensing builers for larger commercial buildings; boilers recover latent heat of combustion	58,000	<1	CEE, 2001; Sachs et al, 2004

[a] *initial cost is the additional cost above the standard conventional alternative technology or practice, per unit*
[b] *payback period estimated based on energy savings in future years with 7% discount rate*

Similar to heating sources like boilers that convert natural gas to heated air in buildings in the winter, air conditioners convert electrical energy to cool air in the summer. In general, public buildings tend to have one or several larger “chiller” units on site or numerous packaged roof-top air-conditioning units. These air conditioning systems typically run during the daytime from April through October. Several energy efficiency technology options for these types of air conditioning systems are shown in Table 8. One low-cost measure is to replace the compressor (one component of the refrigeration cycle of the air conditioner) for the air conditioning systems with more advanced multiple-speed technology. Because conventional compressors are typically “on” at full load or “off” they are typically overpowered for all of the regular partial loads of air conditioning systems. Modulating compressors can cost $150 over conventional compressors and yield payback periods of around three years (US EPA, 2003; Sachs et al, 2004).

Much larger potential energy reductions can result from replacing air-conditioning units to best available technology. For packaged roof-top air-conditioning units, the conventional Energy Efficiency Ratio (EER) of 10.3 can be improved to EER 13.4 units at an incremental cost of about $1500 to $2000 per unit and with a 3-year payback period (FEMP, 2003; LBNL undated; Sachs et al, 2004). By instead replacing electric roof top units to best available natural gas-fired air conditioning units, the initial unit cost could be somewhat lower with a similar payback period (Shaw 2003; CEC, 2002; Sachs et al, 2004). Note that in both of those package air-conditioning unit replacements situations, replacement is considered only for units at the end of their expected lifetime. As our later discussion will show, Yolo’s units for the DESS building are SEER rated 9 and 10. New more advanced solid state refrigeration (e.g. CoolChips) are in development but the data indicate that they are not yet viable from a cost efficiency perspective. As with larger capital expenditures on boilers discussed above, the purchase of entirely new air conditioning systems become a viable option when existing air conditioners are somewhat older technology (less than EER rating of 10), and/or requiring significant repair (whereby the new replacement purchase would be partially offset by the avoided cost of repairing the existing unit).

Table 8. Building air conditioning GHG emission reduction measures

Measure	Description	Initial cost [a] ($/unit)	Payback period [b] (yr)	Data source(s)
Advanced A/C compressors	Modulating (not single-speed) compressors to improve efficiency in part-load situations for centralized air-conditioning for smaller commercial buildings	150	3	EPA 2003; Sachs et al, 2004
High efficiency gas-fired rooftop A/C units	Using condensing heat exchangers and pulse combustion can boost efficiency from conventional 78-82% to 89-97% (10-ton unit)	1,000	4	Shaw 2003, CEC 2002; Sachs et al, 2004
Advanced roof-top packaged air conditioners	Improved efficiency from federal regulation (for 10-ton unit) of EER 10.3 to EER 13.4, without economizer	1,500	3	FEMP, 2003; LBNL (43165) ; Sachs et al, 2004
Solid state refrigeration for heat pump and power generation	Thermoelectric devices directly convert electricity to cooling, eliminating refrigerant-based mechanical vapor compression cycles (3-ton heat pump equivalent system); Cool Chips product	2000	19	Magdych, 2003; Sachs et al, 2004
Advanced roof-top packaged air conditioners	Improved efficiency from federal regulation (for 10-ton unit) of EER 10.3 to EER 13.4, with economizer	2,035	6	FEMP, 2003; LBNL (43165) ; Sachs et al, 2004

[a] *initial cost is the additional cost above the standard conventional alternative technology or practice, per unit*
[b] *payback period estimated based on energy savings in future years with 7% discount rate*

The ventilation portion of the HVAC systems relates to how efficiently the conditioned air that has been either heated (from a boiler) or cooled (from an air conditioning system) is transported throughout the buildings to maintain comfortable space temperatures. Some of the general technologies available for use by the county are shown in Table 9. The most simple technology measure is to improve the efficiency of the ventilation motor to a modulating (i.e., not single speed) motor that can be optimized for the amount of air flow that is required for given heating and cooling circumstances. In one of the building case studies below (the Davis Library), installing such a variable frequency drive ventilation motor was recommended as a substantial energy-reduction action for the HVAC system. There are also several duct-sealing options, including the use of an aerosol-based sealing (one brand is Aeroseal), can seal up duct holes and cracks up to 1/4-inch in diameter for existing building HVAC systems (Kallett et al, 2000; Bourne and Stein, 1999; Modera et al, 1996). Also, the use of mastic mechanical fastener systems can more drastically reduce air flow leakage when built into the original HVAC design in new building construction (Proctor, 2003). Some of the county's buildings have been sealed, others have not. Finally the use of sensors in space conditioned "zones" within buildings can be used to trigger ventilation controls to more optimally manage air flow requirements in buildings (Shaw, 2003; CEC, 2002).

Table 9. Building ventilation GHG emission reduction measures

Measure	Description	Initial cost [a] ($/unit)	Payback period [b] (yr)	Data source(s)
Ventilation motor efficiency	Use of improved HVAC motors; modulating (not single-speed) of the air handler fans for delivery of cooled A/C air or heated furnace/boiler air (1/2-hp motor)	80	3	Sachs and Smith 2003
Aerosol-based duct sealing	Use of improved materials and diagnostic testing to fix existing building duct lekage of HVAC system; aerosol (Aeroseal) seals duct holes up to 1/4-inch in diameter (based on 3-ton central AC/furnace)	700	4	Kallett et al, 2000; Bourne and Stein, a999, Modera et al 1996
Leakproof duct fittings	Use of mastic, mechanical fasteners, and UL-181-approved duct tapes to make "tight" duct systems with low (<6%) air flow leakage of heated or cooled air for new construction (based on 3-ton central AC/furnace)	100	<1	Proctor 2003
Building design for low parasitics, low pressure drops	Reduction of parasitic losses by improvements to air and fluid handling systems (especially in large building with chilled water cooling systems for new buildings operations, 100k sf)	0	<1	Westphalen and Koszalinski 1999
Optimized heating, cooling ventilation control with IAQ sensors	Using CO2 sensors to trigger ventilation controls for un- or under-utilized zones in commercial buildings (50,000 sf, six zones, $575/zone)	3,450	3	Shaw 2003, CEC 2002

[a] *initial cost is the additional cost above the standard conventional alternative technology or practice, per unit (e.g. light bulb)*
[b] *payback period estimated based on energy savings in future years with 7% discount rate*

4. Building Design and Operation

The building shell refers to the overall structure of the building, including its walls, insulation, windows, doors, etc and represents another means of improving energy efficiency. The specific percent of the county GHG emissions that this category is responsible for is not easily quantifiable. Much of what is included in the building shell concept overlaps with other areas (e.g., HVAC and lighting). For the purposes of this report, we'll use building shell to capture the ways in which HVAC loads in both heating and cooling requirements can be reduced (Table 10). Generically speaking, the optimal method for reducing HVAC loads is through temperature management and periodic HVAC maintenance.

There are also a number of technology changes that greatly affect building energy use. Buildings lacking computerized automation of their HVAC systems (with timing and temperature controls) would benefit from advanced building diagnostics systems. Even retrofit systems that cost $50,000 per building can break even from their resulting energy savings within three years of installation (Krepchin, 2001; Sachs et al, 2004). Other retrofit ideas include the use of simple structures to better manage passive lighting and heat from windows. For example, the use of simple and inexpensive “light shelves” on the external wall of the building can help direct more natural light into the building, and the use of automated “smart” integrated Venetian-type blinds can better manage the natural daylighting and the passive solar heat as a resource in winter (and as an undesired load in summer) (Lee and Selkowitz, 1998; CBECS, 1999). Also, there are available "cool roof" paints that have the ability to more effectively reflect solar heat in the summer to reduce building air conditioning loads.

Larger building design changes can be made to buildings during the construction phase. Using integrated building designs that incorporated energy-efficient design and technologies (e.g. the design principles of the U.S. Green Building Council LEED certification program) can reduce energy use intensity of buildings by 30% with estimated initial building cost increases of $1-$2 per square foot of construction, and payback periods of about two years (Brown & Koomey, 2002; Criscione 2002; IEA, 2002; NRCan, 2002). Other specific building improvements that can be implemented in the pre-construction building design phase include active window glazing that dynamically changes for seasonal heating and cooling considerations (Sage, 2003; RECS, 2001; Nadel, 2004) and improved insulation to better maintain, and reduce demand for, the space conditioned air (DEG, 2002; Lea, 2003; Stover, 2001).

Table 10. Building design and operational GHG emission reduction measures

Measure	Description	Initial cost [a] ($/unit)	Payback period (yr)	Data source(s)
Thermostat temperature setting	Setting thermostat temperatures for energy conservation (e.g. 68F in winter and 72F in summer)	0	<1	-
Thermostat timing settings	Monitoring and re-setting temperature timers for times of building occupancy (and	0	<1	-
HVAC system maintenance	Routine and frequent maintenance schedules to ensure chillers, boilers, air handlers, controls, and other hardware to function at peak performance are performing as designed	0	<1	PECI, 1999
Improved service contracts	Require that service contracts support energy-efficient operation and maintenance practices	0	<1	PECI, 1999
Full utilization of existing automatic controls	Using timers and automatic temperature control where they are already installed but not being used (incorporating indoor and outdoor environment)	0	<1	PECI, 1999
Bulls-eye building commissioning	Quicker form of retro-commissioning to spot largest energy issues efficiently on smaller (5000 to 50000 sf) buildings with data collection from automated meter reading (AMR) meters over 15-minute intervals	2000	<1	Price and Hart 2002
Retro-commissioning	Identify and correct problems in building operation and maintenance to restore building's designed operation	25,000	2	Thone and Nadel 2003; Gregerson 1997
Advanced automated building diagnostics	Optimize HVAC equipment through control, correction, and monitoring of overall building energy use (new large >50,000 sf buildings)	50,000	3	Krepchin 2001
Better sizing methods for HVAC systems	Use proper (*not over sizing)* HVAC furnace and A/C for smaller buildings; furnace with AFUE 80, A/C with SEER 12	35	<1	Vieira et al (undated)
Integrated building design	Designing new large (> 50,000 sf) commercial building at 30% > codes (LEED base level)	100,000	2	Brown & Koomey, 2002; Criscione 2002; IEA, 2002; NRCan, 2002
Residential cool color roofing (dark high-reflectance paints)	Reflective surfacing of roofs to reflect solar heat in summer	200	4	Desjarlais 2003, Reid 2003, Nixon 2003b
High-performance windows (U<0.25)	High insulation technology with low-e fillings, double-paned, inert gas fills, insulating spacers, improved sealing window frames during new construction or replacement	900	5	LBNL, 2003
Active window insulation	An automated "smart" integrated window/lighting/cooling system of venetian-type blinds for retrofit or new building (25k sq ft building. with 2000 sq. ft. of window)	15,000	2	Lee and Selkowitz, 1998; 1999 CBECS
Electrochromic glazing for residential windows	"Active glazing" permits dynamic changes of window's thermal, solar, and visible transmittances with small amount of electric current for new building (25k sq ft building. with 2000 sq. ft. of window)	10000	6	Sage 2003; 2001 RECS; Nadel 2004
High quality envelope insulation	Use of proper insulation through wall frames during construction, or spray-applied cellulose insulation to fill voids (from R-8.2 to R-9.7 effective R-value)	250	25	DEG 2002, Lea 2003, Stover 2001

[a] *initial cost is the additional cost above the standard conventional alternative technology or practice, per unit (e.g. light bulb*

Case Studies

We conducted three in-depth studies of how the GHG mitigation technologies could result in GHG reductions in county facilities. The three buildings were selected: the Administration building, the Department of Employment and Social Services (DESS) building, and the Davis Library. The buildings were chosen based on their current levels (substantial) of energy consumption and the ease of access for UC-Davis student researchers.

We began by evaluating the PG&E electricity and natural gas records for the three facilities. These records were available in monthly increments from 2005 through the time of the study in fall 2007. We also conducted a detailed facility inspection which included examining the floor plans, the number and type of windows, the HVAC equipment used for heating and cooling, the lighting arrangement and technology, and the appliances utilized. We also collected data on the maintenance and automated and manual operation of each building's HVAC systems, and the general operations and daily use of the buildings was observed.

UC Davis student teams were assigned to each building, with approximately eight students per building. The groups worked to assess both operational practices that the buildings could adopt and technology improvements (via retrofit or equipment replacement) that could contribute to the buildings' GHG footprint. Over a series of visits, students spoke with engineers, technicians, and employees at each of their respective case study buildings. The groups also collaborated with the other student groups to coordinate findings and approaches for analyzing potential recommendations. The collaborations, presentations, and final reports of these student groups have been summarized and incorporated into the three following case studies. For each section, we summarize student team observations, their estimated breakdown of energy by end use in each building, and recommendations for improvements. It is also important to note that, while great care has been used in preparing these inventories and recommendations, there may be some unintended errors or overlooked data owing to the shortened timeframe for completion of the report.

We can characterize the seasonal GHG emissions by energy source (Figure 3) by the end use categories shown in Figure 5. In order to segment everything into end uses, we assumed that there was a constant baseline amount of electricity for appliances, lighting, and other non-seasonal electrical loads. This allowed us to separate the seasonal electric air-conditioning-related GHG emissions (for operating the air-conditioning units and associated fans and ventilation equipment) from the other non-air-conditioning loads. We also assumed that the cogeneration unit is operated with an approximately constant monthly load and natural gas usage year-round, thus making the remaining natural gas use heating related. Finally, we further segmented the non-air-conditioning loads based on the case study estimations of energy use throughout the buildings. Annually, of the county buildings' 5,960 tonnes of CO_2e emissions in 2006, we estimated that approximately 23% resulted from electric lighting; 19% natural gas heating; 16% air-conditioning; 10% cogeneration; 8% ventilation; 8% computers; and 16% miscellaneous (i.e., all other electric appliances: refrigerators, copiers, fax machines, etc.).

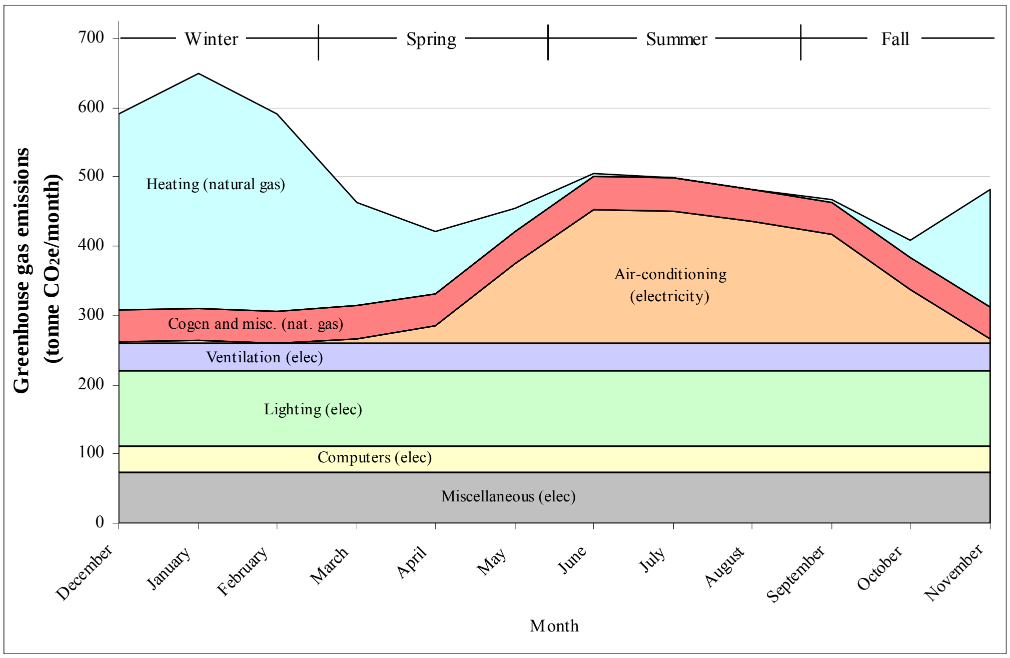

Figure 5. Yolo County buildings' GHG emissions by end use

Table 11 summarizes the breakdown estimates of emissions by end use for the three case studies and for comparison, the emissions estimates of all of the county facilities. We note that the county average does not match up with a simple average of the three buildings due to both uncertainty in the estimations, and due to basic differences in the facilities. For example, one fundamental difference between the county facilities generally and the three buildings in particular is the usage of the cogeneration unit that supplies heating and electricity to a number of county buildings (but none of the case study buildings). The HVAC systems alone equate to roughly 41 to 47% of GHG emissions at county buildings while lighting produces between 23 to 32% of county buildings' GHG emissions. These estimates are designed to help characterize some of the more important end uses for targeted GHG mitigation and are constructed in more detail in each of the individual building's discussion.

Table 11. Breakdown of buildings' GHG emissions by end use

End use	Case study buildings			Estimated county facility average
	Administration	DESS	Davis Library	
Heating (natural gas)	12%	10%	13%	19%
Air-conditioning (electricity)	17%	17%	25%	16%
Ventilation (electricity)	12%	10%	9%	9%
Cogeneration (gas and elec)	0%	0%	0%	7%
Lighting (electricity)	27%	23%	32%	23%
Computers (electricity)	8%	11%	10%	8%
Misc.(electricity)	18%	30%	8%	16%
Misc. (natural gas)	8%	0%	3%	3%

1. Administration Building

As a general overview, we found that much of the equipment in the Administration building, including the HVAC system, the water heating, and a majority of the lighting were all relatively new from the 2001-2002 county retrofit program. The thermostat setting for the building's centralized, automated, and timer-set HVAC system were reported as always being set to between 68F and 72F. The fluorescent tube lighting appeared to all be efficient T8 technology, although in some cases this artificial lighting was redundant with natural lighting. Lighting in the atrium (mercury vapor technology) also appeared to be redundant with natural solar day-lighting. All of the windows inspected were single-paned. Computers appeared to be "on" through the day, and potentially through the night. The orientation of the building, with longer wall faces on the north and south sides, had largely deciduous trees, which are advantageous for potential day-lighting and passive solar heating.

Estimating from PG&E records on monthly electricity and natural gas usage and our own breakdowns of specific appliance and equipment energy usage, we estimated the monthly breakdown of GHG emissions in the Administration building by end (Figure 6). Annually the building GHG emissions breakdown is 27% from lighting, 17% air conditioning, 12% heating, 12% ventilation, 8% computers, and the remaining 26% from miscellaneous electrical and natural gas usage that can not be accounted for in those categories.

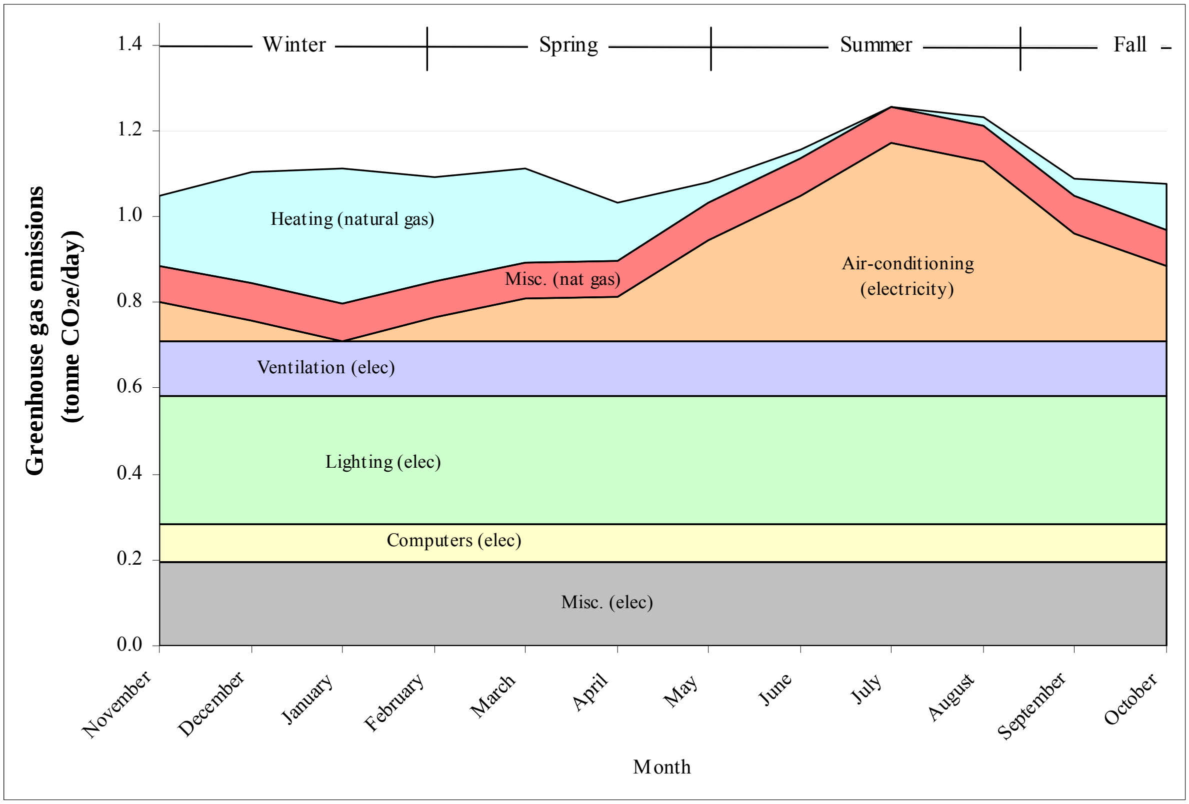

Figure 6. Administration building GHG emissions by end use

The Administration building student researchers offered several recommendations related to the building's lighting, HVAC, and building shell. With respect to increasing the efficiency of lighting, four different GHG reduction actions were suggested as options for the Administration building: 1) LED technology can be used to replace exit sign lights and wall mount metal vapor lights; 2) Fluorescent lighting could be used for exterior lighting (where currently there is high-pressure sodium lighting) and ceiling-recessed HID fixtures; 3) Occupancy sensors could be installed to cut down on excessive lighting in the emergency stairwells and bathrooms, and 4) Approximately 5% of the building receives ample natural lighting, in these areas that artificial lighting could be reduced or eliminated.

As an example of the lighting changes that can be made, consider that there are roughly 45 exit signs in the administration building. Each sign has two six-watt fluorescent bulbs, which are on all the time. In 2007, these signs used approximately 4.7 KWh which equates to roughly 1.7 tonnes CO_2e and $627 in energy costs. The state of the art standard for exit signs are LED models, requiring less power and lasting longer. Energy star estimates the average LED exit sign uses roughly 2.5 watts and lasts nearly 15 years (Energy Star, 2005). Installing LED signs would lead to a 58% reduction in energy use, CO_2e emissions, and energy costs associated with operating the exit signs in the building.

The recommended HVAC improvements involve three practices to ensure the system is being optimally utilized. The temperature setting should be adjusted seasonally to reduce the heating and cooling loads. Adjusting the settings (e.g., winter thermostat setting to 65 F and the summer thermostat setting to 75 F), is the largest single GHG-reduction measure found. Scheduling to temporarily disengage the HVAC system to portions of the building that are not in use (e.g., the wedding chapel and the infrequently used Board and conference rooms) would reduce HVAC system use. It appears that one consequence of this practice would be the necessity of scheduling the use and re-engagement of the HVAC system to these rooms in advance. Routine inspection and maintenance of the ventilation system could cut down on the leaks (and therefore energy losses) of the HVAC system. Maintenance is often deferred under tight budgetary conditions, with the reduced of decreased efficiencies and higher GHG emissions. A regular maintenance policy that can be maintained during budgetary cycles should be developed and adhered to. Finally, student teams also recommended that water heaters be fitted with insulation jackets to reduce their stand-by energy losses.

In terms of the building shell, we have one significant recommendation: replacement of single paned glass with triple paned glass. The building's 166 windows (covering 4,276 feet of the 70,000 sqft building's skin) are single-pane. State of the art high-performance windows will decrease demand for the building's HVAC system by reducing heat transfer through the building's skin (some high performance windows have heat loss rates as little as 1/10 of those of single-pane windows). A summary of the findings from the student group case study on the Administration building is shown in Table 12. The implementation of all of the measures together is estimated to roughly result in a reduction of 77 tonnes of CO_2e emissions per year, or about 19% of the building's annual GHG emissions.

Table 12. Administration building recommended GHG-reduction action

Area	Recommended action	GHG reduction (tonnes CO_2e/yr)
Lighting	Replace EXIT signs with LED technology	1.4
	Replace exterior high-pressure sodium lights with fluorescents	1.7
	Replace wall-mount metal vapor lights with LED	0.7
	Replace ceiling-recessed HID fixtures with fluorescent	2.7
	Install bathroom occupancy sensors	0.4
	Install emergency stairwell occupancy sensors	1.2
	Utilize natural daylighting in 3500 square feet (5%) of building	3.3
HVAC	Seasonal temperature settings adjustment during working hours (65 F in winter, 75 F in summer) and during non-working hours (57 F in winter, 83 F in summer)	20.7
	Sealing off unused building spaces (10% of building)	8.2
	Ventilation inspection, repair	17.2
Appliance	Water heater insulation jackets	6.6
Building shell	Installation of triple-paned windows throughout the building	13.0
Total, all measures (as percent of total building GHG emissions)		77.0 (19%)

2. Department of Employment and Social Services Building

The DESS building is newer than most of the county buildings and was built with many efficiency considerations in mind. There are double-paned window throughout the building, and the lighting was upgraded in 2001 to include all T8 lighting and automatic sensors in many places. Some of the T8 lighting fixtures, which hold 3 bulbs per fixture, had already been reduced to 2 bulbs per fixture where lighting was not compromised to conserve energy. The department policy is to have their computers set to hibernate after 20 minutes of inactivity and to shut down computers and monitors at the end of the day.

The buildings' HVAC space conditioning system is a decentralized system with 60 "zones" within the building that can be independently temperature-controlled and that are each connected to their own packaged rooftop air conditioner. The packaged rooftop units are all either SEER rated 9 or 10. Another finding of note is that, when the HVAC system was installed and operations commenced, the system was drawing too much outside air into the building, to the degree that doors couldn't be opened. To correct this problem, additional duct work was installed to vent air to compensate for the air conditioning units' operation.

Based on the PG&E records, we estimated the monthly breakdown of GHG emissions in the Administration building by end (Figure 7). Roughly, annually the building GHG emissions breakdown is 17% from office lighting, 17% air conditioning, 11% computers, 10% heating, 10% ventilation, 6% outdoor electricity, and the remaining 30% from miscellaneous electricity usage that can not be accounted for in those categories.

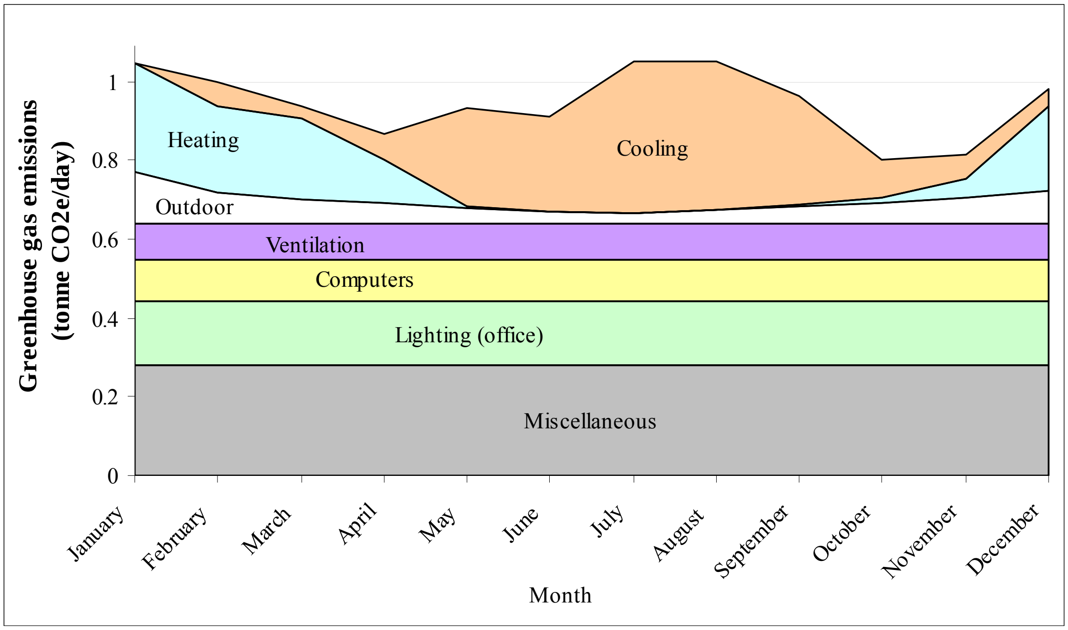

Figure 7. Department of Employment and Social Services building GHG emissions by end use

Recommendations for the DESS building focus on improvements in HVAC, lighting systems and in the education of employees on energy-saving practices Table 13. In terms of the HVAC system, one important recommendation is to remedy the situation with the package AC unit and the added ducts, which are used to release already conditioned air so that interior doors can close. To balance the loads, the duct work that is venting conditioned (heated or cooled) directly to the environment should be removed or closed, and the ventilation fan speeds could be reduced. The labor of hiring a technician to reduce these fan speeds would pay back in energy savings within the first year. The replacement of the existing SEER 9-10 air-conditioning units with state-of-the-art SEER 15+ units, was considered; however the purchase of the new, high-SEER units is only cost-effective when the existing units are at the end of their life-cycle.

Electrical lighting demand within the building could be reduced in a number of different ways. In office areas, a simple fix would be to reduce the amount of lights per fixture where the lighting intensity for work stations is not compromised. The student groups found many places in which lights could be removed without compromising lighting capacity throughout the building. A more sophisticated, and potentially larger potential energy saver, would be to install integrated office lighting systems. This involves simultaneously reducing ambient lighting, while improving office task lighting with individual LED lighting. Also, improved efficiency smart lighting fixtures with occupancy-sensing and bi-level dimming technology would drastically reduce the outdoor lighting requirements in areas like parking lots, walkways, etc. Both of these systems have been piloted at UC Davis under the direction of the UC Davis

Lighting Technology Center and found to be very effective in both reducing energy efficiency while maintaining appropriate levels of lighting. Finally, it's important to remind employees of building policies in terms of turning off their office equipment (computers, printers, etc.).

Table 13. DESS building recommended GHG-reduction actions

Area	Recommended action	Annual GHG reduction (tonne CO_2e/yr)
HVAC	Reducing the fan speeds of the roof-top packaged AC units	2.7
Lighting	Installing bi-level smart fixtures for the parking lot	7.4
	Installing integrated office lighting system with reduced ambient lighting and individual office task lighting	24.0
	Removal of excess light bulb capacity	19.3
Total GHG emission reduction, all measures		53.4
Percent of total building GHG emissions		16%

3. Davis Library

The Davis Library has had several upgrades, but there are lots opportunities for improvement. A series of initial observations were made about the building equipment and practices of the Yolo county For example, the HVAC system was upgraded with an automated control system in 2001, but there are several areas of the HVAC system that were not improved at that time. The older part of the building is heated and cooled using the original 1968 system. There are also 7 older (1992) packaged AC units that could be replaced with newer more efficient models. A few other general observations include a relatively high thermostat set-point (70F) and the hot water pump appeared to run constantly, regardless of the hot water demand.

With respect to lighting, there appeared to be redundant interior lighting in several areas, including around the perimeter of the building, where can lights co-existed with amply side window day-lighting, and hanging lights positioned on wooden structures that were directly beneath skylights. In the Geography Room, on separate occasions the room was fully lit while no occupants were present. Some energy efficiencies had already been achieved. For example, the Library was already almost entirely equipped with compact fluorescent lighting, and there were occupancy sensors for lighting in infrequently utilized rooms (e.g., bathrooms and study rooms).

One important item to note with regard to the Davis Library was passage of Davis' local ballot Measure P in November 2007. The measure's passage ensures that some funding will be available for modernization, repair, and energy-reduction measures at this facility. Many of the items of Measure P involve increased energy usage, due to expanded facilities, additional floor space, and additional computers. It is very critical to understand that although Measure P will likely include funds for the overhaul and repair of the HVAC system, it will not necessarily yield net GHG reductions.

Based on PG&E records on monthly electricity and natural gas usage, we estimated the monthly breakdown of GHG emissions in the Library by end use (Figure 8). Annually the GHG emissions breakdown is 32% from lighting, 25% air conditioning, 13% heating, 10% computers, 9% ventilation, 3% water heating, and the remaining 8% from miscellaneous electricity usage that can not be accounted for in previous categories.

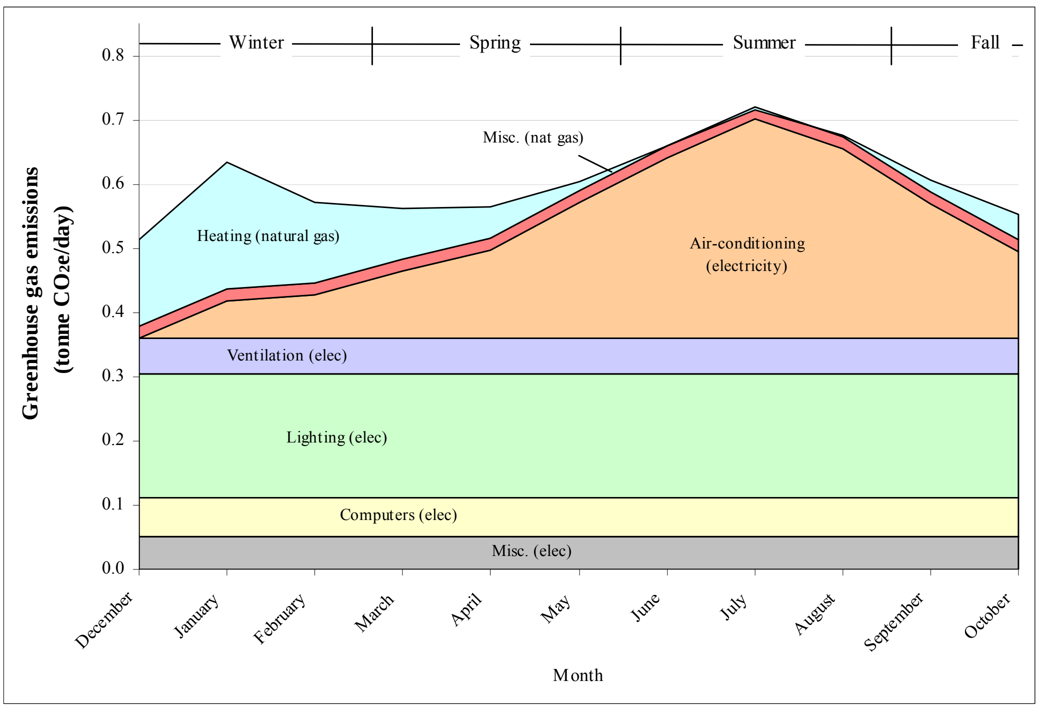

Figure 8. Davis Library GHG emissions by end use

Eight different strategies were recommended for implementation at the Davis Library (Table 14). The lighting could be reduced by bringing overhanging lights closer to book stacks (and removing bulbs), reducing the number of lights per fixture in ceiling fixtures and removing some of the ceiling can lighting bulbs. Installing a personal lighting system (e.g., the pilot system devised by the California Lighting Technology Center) in working and reading areas would entail replacing fluorescent fixtures with low overhang lights and high quality LED task lights and result in reductions in GHGs.

In terms of the HVAC system, three significant recommendations were developed. The ventilation system for the heating and cooling could be improved by installing a VFD motor for air handler #4 which handles the air for the majority of the Library. The 1968-vintage central heating and cooling system could be replaced with a current state-of-the-art system with a water chiller. The eight 1992-vintage packaged AC units, which have expected lifetimes of 15-20 years, are due for replacement with more efficient updated models. Opting for a new SEER 16 AC unit over a SEER 13 costs more upfront but offers an approximate 4-year payback period. Alternatively the option of overhauling the area of the Library with the package AC system with centralized air-conditioning should be considered

One large capital improvement was suggested. The large flat roof could be modified to utilize solar energy with photovoltaic solar energy-harnessing panels. Analysis of a 50-kW photovoltaic system could result in approximately 130,000 kWh per year and offer a payback period of about 25 years, without including any state or utility rebates. The cumulative effect of all of the recommended actions would be to reduce the Davis Library's GHG emissions by about one-half. Excluding the larger capital investment in the solar array, the remaining GHG-reduction measures that were identified could reduce the building's GHG footprint by about 27%.

Table 14. Davis Library recommended GHG-reduction actions

Area	Recommended action	Annual GHG reduction (tonne CO2e/yr)
Lighting	Reduced of excess lighting	12.6
	Personal lighting system	1.4
	Advance daylighting controls	15.5
HVAC	Ventilation improvement: installation of a variable frequency drive on air handler #4	2.0
	Replacing 1992-model-year packaged AC units with SEER 16	10.5
	Replacement of the outdated 1968 central heating and cooling system (New water chiller)	5.0
Computers	Fully utilize and maintain power management of computers	13.3[6]
On-site renewable energy	Installation of rooftop photovoltaic solar energy system	48.1
• **Total GHG emission reduction, all measures (excluding solar energy)**		**60.2**
Total GHG emission reduction, all measures		**108.3**
• **Percent of total building GHG emissions (excluding solar energy)**		**27%**
Percent of total building GHG emissions		**49%**

4. Priorities: Recommendations and Rationale

Drawing from the case study findings as well as the types of general GHG mitigation strategies for buildings that we laid out in the first section, we have formulated a series of short (2008-2010), mid

[6] This estimate is being verified.

(2010-2015), and long-term (2015-2020) recommendations for each of the three case study buildings (Table 15. Recommendations and Priorities for Building Case Studies). In this section we describe the recommendations and the underlying rationale for the ways in which they have been prioritized.

In general, we considered new policies aimed at educational outreach, optimizing management of power consumption, better or expanded utilization of sensing technologies, and some types of retrofitting as short-term improvements that have immediate implications in terms of reducing GHGs. Mid-term strategies include those with higher front-end costs, but critical for upgrading the building infrastructure, Finally, long-term improvement strategies included changes that would require significant capital outlay and/or those considered to have a fairly long payback period.

In general, short-term improvements include energy saving mechanisms like occupancy sensors in emergency stairwells and bathrooms, which are very cost effective retrofits and highly recommended for immediate implementation. Most sensor and lighting additions/retrofits have payback periods on the order of roughly one to two years. Mid-term improvements can be made in all three buildings and tend to include items such as replacing the single-paned windows and atrium mercury vapor lights in the administration building, which have moderate payback periods and moderately high upfront costs. The county has already explored replacement of the mercury vapor lights and has received a recommendation from an architect. Thus, this option is relatively straightforward to implement, but we recommend implementation of short-term improvements as a first step. It is also important that for some options recommended, that additional inventory and assessment occur prior to implementation. For example, reducing excess lighting in the DESS building should be carefully implemented to ensure that adequate lighting exists for operations. Ideally, the reduced lighting strategy would be implemented concurrent with a tiered lighting system. Finally, long-term strategies require additional investigation and significant upfront costs, but represent good investment potential over the long-term.

Table 15. Recommendations and Priorities for Building Case Studies

Recommended action	Admin	DESS	Davis Library	Est. GHG reduction (tonnes CO_2e/yr)
SHORT-TERM STRATEGIES (2008-10)				
Seasonal temperature settings adjustment during working hours (65 F in winter, 75 F in summer) and during non-working hours (57 F in winter, 83 F in summer)	◙			20.7
Replace ceiling-recessed HID fixtures with fluorescent	◙			2.7
Install bathroom occupancy sensors	◙			0.4
Install emergency stairwell occupancy sensors	◙			1.2
Utilize natural daylighting in 3500 square feet of building where there is ample day-lighting (5% of lighting)	◙			3.3
Sealing off unused building spaces (10% of building)	◙			8.2
Ventilation inspection, repair[7]	◙			17.2
Water heater insulation jackets	◙			6.6
Replace EXIT signs with LED technology	◙			1.4
Reducing the fan speeds of the roof-top packaged AC units		◙		2.7
Removal of excess light bulb capacity		◙		19.3
Fully utilize and maintain power management of computers			◙	13.3[8]
MID-TERM STRATEGIES (2010-15)				
Replace exterior high-pressure sodium lights with fluorescents	◙			1.7
Replace wall-mount metal vapor lights with LED	◙			0.7
Installation of triple-paned windows throughout the building	◙			13.0
Installing bi-level smart fixtures for the parking lot		◙		7.4
Installing integrated office lighting system with reduced ambient lighting and individual office task lighting		◙	◙	1.4 - 24.0[9]
Advance daylighting controls			◙	15.5
Reduced of excess lighting throughout the building			◙	12.6
Ventilation improvement: installation of a variable frequency drive on air handler #4			◙	2.0
LONG-TERM STRATEGIES (2015-20)				
Replacing 1992-model-year packaged AC units (SEER 16)			◙	10.5
Replacement of the outdated 1968 central heating and cooling system (new water chiller)			◙	5.0
Installation of rooftop photovoltaic solar energy system			◙	48.1

[7] As mentioned earlier, deferred maintenance results in inefficient performance and generally increasing GHG emissions. The county should develop a maintenance plan that can be followed through budgetary cycles.
[8] This estimate is still being verified.
[9] This estimate is still being verified.

MOBILE SOURCES EMISSIONS

Mobile Source Emissions

Approximately 2,027 metric tons of CO_2e, or roughly 27% of total GHG emissions from 2006 combined vehicle and county building operations, resulted from vehicle use. This estimate is based on operation of all county-owned light- and heavy-duty vehicles, including sedans, trucks, SUVs, vans, and a vast assortment of heavy equipment. For the purposes of this report, we consider only the emissions produced by county-owned and operated vehicles.

Background on County Vehicle Fleet Operations

The county owns and operates approximately 604 vehicles. Of these, 438 vehicles are classified as "light-duty" and 166 are considered "heavy duty". In general, the light-duty designation refers to those vehicles capable of safely hauling less than one ton of cargo. This category includes sedans, SUVs, and most of the county trucks; the vehicle fleet is fueled almost exclusively by petroleum. In 2006, county vehicles consumed 108,465 gallons of gasoline and 5,302 gallons of diesel fuel. This consumption of fuel for transportation produced approximately 1,894 and 133 metric tons of CO_2e, respectively[10]. There are also approximately six electric vehicles (similar to golf carts) and one natural gas vehicle in the county's light-duty fleet. Since the impact of diesel fuel consumption currently represents less than 2% of the county's total GHG emissions (and only 15% of the GHG emissions from transport), we focused our analysis mainly on the county's gasoline powered vehicles.

There are eight sub-categories into which the 438 light-duty vehicles can be divided (sedan, SUV, pickup, van, pursuit, hybrid, electric, and natural gas), and as many as 60 sub-categories for the 166 heavy-duty vehicles Figure 9. The difference in sub-categorization is largely due to the functions associated with the various heavy-duty vehicles, which include large trucks, trailers, boats, RVs, tractors, sweepers, and other portable equipment (e.g. construction). Since the majority (73%) of vehicles fall within the light-duty category, and since nearly all are fueled by gasoline, we focused on vehicle management and operational improvements for light-duty gasoline fueled vehicles. This seems to be the area where the county has the greatest potential to make cost-effective GHG reductions, particularly in the near-term.

Currently, there is virtually no centralized management of the county vehicle fleet. Of the 604 vehicles owned by the county, all but one 'pool vehicle' are distributed throughout the region and are largely

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[10] We assume that the combustion of gasoline and diesel fuels produces 8.55 and 9.56 kg CO_2/gallon of fuel, respectively. The emissions factors are then multiplied by total fuel consumption to estimate the total annual emissions: ***(221,520 gallons) x (8.55 kg CO_2e/gallon) x (1 tons /1,000 kg) = 1,894 metric tons CO_2e***

managed independently by county departments. From the perspective of DGS, this decentralization of vehicles into “mini fleets” results in an inefficient use of vehicle resources. Some of the problems noted are the lack of ability to enforce the existing county policies related to vehicle retirement cycles (every 6 years), the vehicle “minimum use” standards (e.g. 400 miles/month), the operations and maintenance best practices, and the policies related to vehicle pool services, among others (CSD, 2001). Given what is known about the county fleet, the key challenges lie in determining which changes in fleet operations are both technically feasible and cost-effective, and for the purposes of our examination, will result in reductions to GHG emissions.

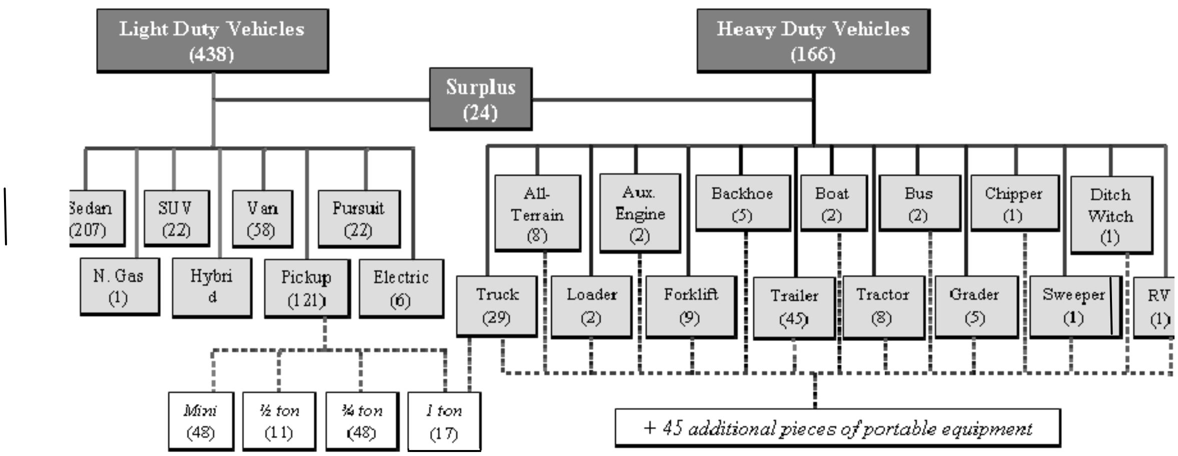

Figure 9. The categories and sub-categories used in classifying the Yolo County vehicle fleet.

The fleet management difficulties expressed by DGS are supported by inspection of county vehicle records. Of the reported 604 vehicles in the fleet, 548 vehicles are currently assigned to a particular department (with 1 pooled vehicle and 24 unused vehicles designated as surplus). The distribution of vehicles between departments is shown in Figure 10. Of these vehicles, 457 are supposed to have monitored mileage and fuel use, though a significant portion of records for these vehicles (about 1/2) are either missing or incomplete. The discrepancies between the information required by county policy in terms of monitoring vehicle use (CSD, 2001) and the data that are currently available has largely been attributed to the decentralized structure of the fleet.

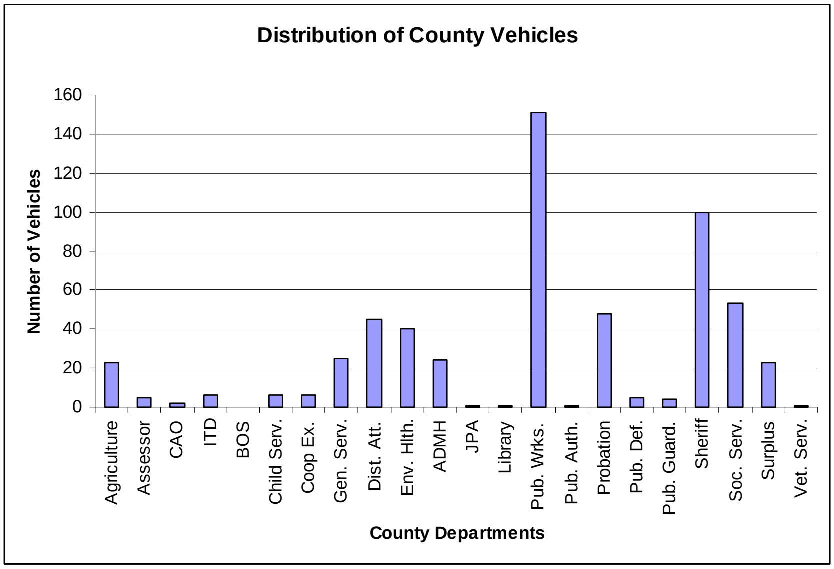

Figure 10. The distribution of all county vehicles (light and heavy) by department.

The DGS is currently developing a proposal aimed at restructuring the county vehicle fleet (Table 16),[11] which calls for centralizing the fleet and discarding old vehicles and equipment. The DGS perspective is that these changes will save the county money and improve the overall efficiency of fleet operations. It is important to note that this proposal does not *directly* address the issue of GHG emission reductions, though it can be shown that a successfully consolidated and efficiently managed fleet should produce fewer GHG emissions, all things equal. For example, properly inflating tires that are under-inflated by 8-10 psi on a typical smaller vehicle can produce a savings of around 250 lbs of CO_2 annually. It is also currently unclear whether or not there will be changes or addendums made to the county's vehicle purchasing procedures, which could play a significant role for mid- and long-term GHG reduction efforts. The effects of such a change in policy are also considered in this analysis.

Table 16. Proposed changes to fleet management procedures and expected results.

Current Practice	Proposed Change	Policy Agreement	Expected Result(s)
Decentralized fleets, managed by departments	Centralize more vehicles	Agrees with policy	Efficient fleet operation, creates vehicle pool, enables fleet oversight
Old and 'surplus' vehicles remain in fleet	Remove vehicles from fleet after 6 years	Agrees with policy	Improved utilization rate, lower maintenance cost
County maintains old, heavy duty vehicles and equipment	Discard old equipment, contract services as needed	Agress with policy	Reduced maintenance costs and needed expertise

[11] Provided by Fleet Manager, Eileen Jacobs

The average fuel economy for the county's light-duty gasoline vehicle fleet is approximately 17.5 mpg. For an average trip, this is equivalent to a GHG production rate of about 500 grams of CO_2e/mile. Though it is difficult to predict exactly how fleet restructuring will affect the county's total GHG emissions rates, it is fairly simple to show that vehicle emissions factors can be reduced by either improving vehicle fuel economy or reducing the carbon content of the transportation fuel. Additionally, a reduction in GHG emissions can also be achieved by limiting or reducing vehicle miles of travel. To achieve any significant reductions in light-duty GHG emissions given historic trends in population and consumption growth (IPCC, 2007), it will almost certainly be necessary to implement all feasible methods of GHG reduction.

We estimated the fuel economy rates using the fuel and mileage records that existed for approximately 330 (or 67%) of the county's light-duty vehicles. The distribution of fuel economy rates across the light-duty fleet is shown in Figure 11. Here, it is clear to see that the vast majority (> 95%) of the county's light-duty vehicles have a fuel economy rate below 25 mpg. Given that many of these vehicles are used primarily for local transport, there seems little practical reason for using larger vehicles with low fuel economy. Using the equation presented in footnote [10], the CO_2e/mile can be determined for each vehicle based on its fuel economy rating. From this, the total tonnes of CO_2e is calculated based on the data available for fleet miles traveled. The data considered for this analysis were collected over a 6 month period (Jan – Jun) in 2006. Figure 12 shows the distribution of vehicles based on CO_2e produced during that period.

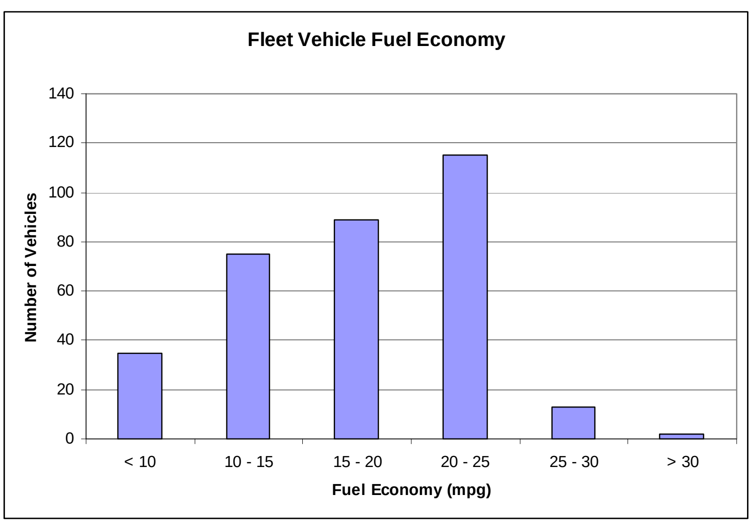

Figure 11. The fuel economy distribution for the county light-duty gasoline vehicle fleet.

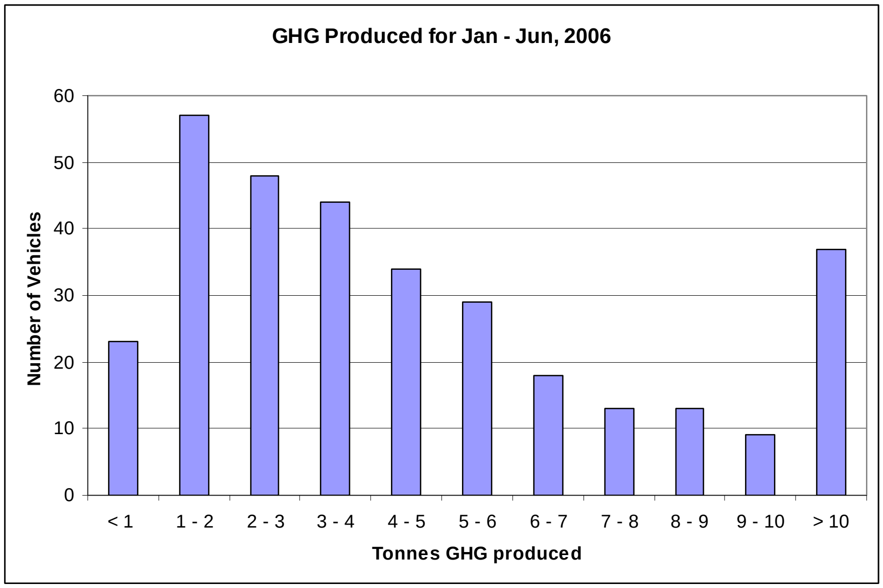

Figure 12. Distribution of county LD gasoline vehicles by CO2 produced (6 month period).

For the purposes of this report, we are most interested in those vehicles producing significantly large amounts of CO_2e. From Figure 12, it is clear that a relatively small proportion of the vehicle fleet (11%) is producing a disproportionately large amount of GHG emissions (587 tonnes, or about 35%). However, there are some caveats to this relationship.

First, since much of the data are incomplete (i.e. missing either fuel consumption numbers, mileage, or both) there may be misclassifications relative to the rest of the fleet. That is, there may be more or fewer vehicles that create the disproportionate emissions. Also, a number of the vehicles in the 11% group are identified as pursuit vehicles and are operated by county law enforcement agencies. Reducing emissions from these vehicles may be very difficult due to the high performance and mileage demands placed on them.

Given what is known or assumed about the county's light-duty gasoline vehicle fleet, in the following sections we describe and quantify potential GHG mitigation options. These options are compared and evaluated based on technical feasibility, cost effectiveness, and ease of implementation.

Potential GHG Mitigation Options

To characterize the potential reductions of transportation-related GHG emissions we've divided the contributing factors into three categories: *vehicle*, *fuel*, and *travel* (Figure 13). This concept emphasizes that reductions must be made in all three aspects if long-term reductions in GHGs are to be achieved. Using a three-pronged approach, the GHG contributions can be identified as,

$$\begin{pmatrix} Vehicle \\ GHG \\ Emissions \end{pmatrix} = \left(\frac{gallon\_fuel}{mile}\right) \times \left(\frac{CO_2\_equivalent}{gallon\_fuel}\right) \times \left(\frac{miles}{year}\right)$$

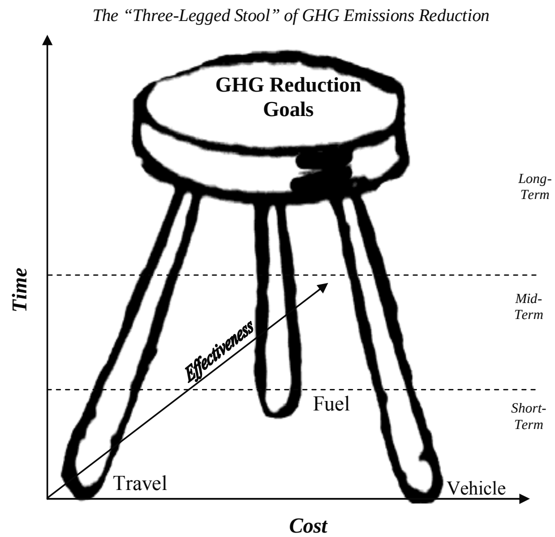

Figure 13. Three-pronged concept for GHG reduction from transportation

where GHGs are quantified in terms of fuel economy (gallons of fuel consumed per distance traveled); fuel type (equivalent CO_2 produced per unit of fuel consumed), and travel (vehicle miles of travel). With default units of gallons, miles, and years, this equation can be used to calculate the GHG emissions from the county's conventional light-duty gasoline vehicles in standard units. To quantify the GHG emissions from other transportation modes, such as alternatively fueled vehicles or transit, a slightly modified version of this equation can be applied (see Appendix D).

There are a wide range of design strategies and government policies that have been proposed and implemented to varying degrees across the country in an effort to encourage the reduction of transportation-related GHGs. Table 17 provides a brief overview of the kinds of GHG mitigation strategies that have been implemented. We have evaluated many of these strategies in assessing the potential opportunities available to the county.

Table 17. Examples of GHG reduction methods and potential barriers.

GHG Mitigation Categories	Sample Mitigation Options	Constraints & Barriers
Reduce Vehicle Miles Traveled	carpool, telecommute, transit	Requires change in behavior
Purchase Efficient Vehicles	purchase small/light/efficient vehicles	Safety and performance concerns
Use Vehicles More Efficiently	adjust driving style, match vehicle to trip	Requires oversight, change in behavior
Switch to Low Carbon Fuel	electricity, biofuels, natural gas	Requires new fuel source and/or vehicles
Purchase Alt. Fueled Vehicles	electric, hybrid, plug-in hybrid	Requires new vehicle purchases

The next few sections described ways in which the county could reduce mobile source GHG emissions across three different action areas: *fleet operations and maintenance procedures (O&M)*, *vehicle purchasing*, and *low-GHG fuels*. Within each of these categories, there are a number of possibilities for reducing GHGs that also allow the county a high degree of control and implementation flexibility over the next several years. We have generally assumed that most 'near-term' reductions are likely to be realized through improved operations and maintenance (O&M), while, given current budget and infrastructure constraints, changes in vehicle purchases and alternative fuels use are more likely to be implemented or aggregated in the mid- to long-term timeframes, respectively.

1. Fleet Operation and Maintenance Practices

Fleet operations and maintenance changes generally have the highest potential for achieving near-term, cost-effective reductions in GHGs. This is due in part to the rapidity with which policy changes can be implemented, the availability of fleet management staff, the potential to work within the given infrastructure, and the large number of potential 'no regrets' GHG reduction options, which include, for example, fleet consolidation, downsizing, and/or capping; creating a functional motor pool; developing a ride sharing tool, and supporting or increasing the use of personal vehicles for work trips. Some of the possible operational strategies include,

- Fleet consolidation: *discarding*, *pooling*, *sharing*, and *distributing vehicles*
- Developing a vehicle check-out protocol
- Developing a vehicle sharing and mile-reduction protocol
- Supporting the use of personal vehicles for work-related trips if they are more efficient
- Developing a sound best-practices maintenance protocol
- Developing a database for recording fleet mileage, fuel, and maintenance records

Due to the shear scope and number of potential options, it is not possible for us to include a fully detailed description and/or protocol for each recommendation. In the following section, we provide a general overview of a number of strategies the county might consider, some useful descriptions of how they might be implemented, and references to supporting reports and guidelines.

2. Reducing GHG emissions through Improved O&M

Consolidated fleet management offers both efficiencies of scale as well as improvements in O&M practices that can reduce GHGs. The critical decision in effective consolidation is that of *fleet composition*. Fleet composition refers to both the number and types of vehicles that make up the fleet. For both the departmental vehicle fleets and the county vehicle pool, each vehicle should be individually evaluated to determine whether or not it should remain in the custody of a given department, added to a centralized pool, or sold/recycled.

Assuming the county retains the current policies regarding vehicle turnover, the first step in the process is actually a screening step where vehicles that are older than allowed under the current policy (6 years) are identified and a decision is made as to whether a vehicle is retained for continued county use or it is scrapped or sold. Our analysis showed that the average fleet vehicle age was 8 years so it is clear that a 6-year turnover cycle has not been actively enforced. There are trade-offs to continuing to retain these vehicles. Older vehicles tend to emit more (and require additional maintenance), while retaining vehicles saves the county the upfront costs of a new purchase. Recent research indicated that adaptive multi-stage replacement strategies, as opposed to a fixed strategy, may be preferable for achieving overall cost effectiveness (Lin, Chen, Niemeier, 2007). One study suggests that while the optimal vehicle ownership cycle for reducing criteria pollutant emissions is quite low (about 3 years), the optimized turn-over rate for reducing CO_2 emissions, energy use, and individual costs is about 18 years (Spitzley et al., 2005).

Currently, many of the light-duty vehicles (nearly 50%) are older than county policy allows (Figure 14). It is not likely that the county will be able to afford to remove and/or replace all of these vehicles at once, and thus vehicle removal and replacement/purchasing will need to be staggered over multiple years. From the perspective of optimizing lifecycle greenhouse gas emissions reductions (Spitzley et al., 2005), it seems that the county may wish to focus its energy on removing only the oldest light-duty vehicles in the fleet (e.g. > 18 years), at least in the near-term. Additionally, the county may wish to reevaluate and possibly modify its policy of a 6 year turn-over rate to better promote lifecycle greenhouse gas reductions. Regardless of the decision regarding vehicle replacement, the county should be consistent in its application of county policy or revise the county policy to reflect a slower (or adaptive) vehicle replacement strategy.

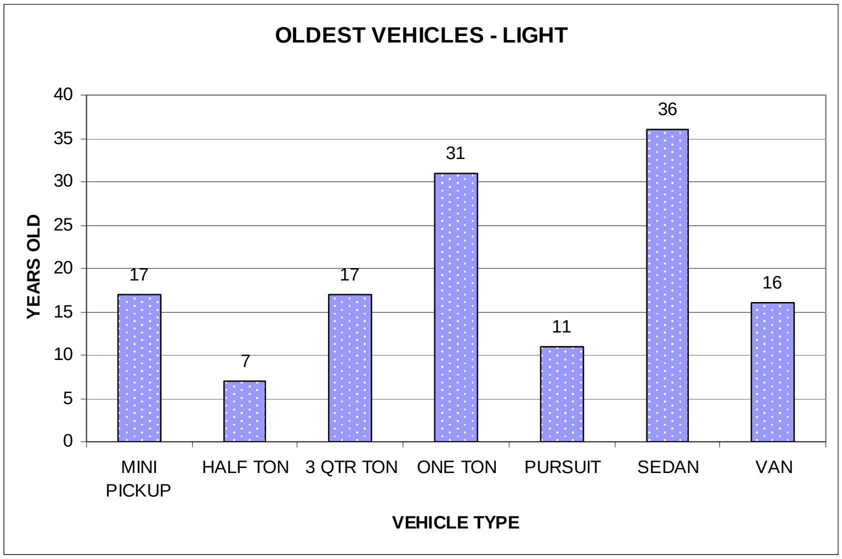

Figure 14. The oldest vehicles for a number of light-duty vehicle sub-categories.

Once it is decided whether a vehicle should remain in the county fleet, whether or not it is consolidated into a centralized motor pool should then be evaluated. County estimates show light-duty vehicle underutilization as high as 40%, meaning that there are nearly 200 fleet vehicles that are currently used only minimally, as defined by county policy (i.e., mileage less than 4,800 miles annually). The county's underutilization rate is comparatively low, with many state fleets mandating minimum mileages between 6,000 and 10,000 miles. If vehicles are not meeting the minimum annual utilization, they can usually be pooled to enable more effective use of the vehicle. Again, there are two ways in which this strategy can reduce overall GHG emissions. First, pooled vehicles must be better maintained than even infrequently used distributed vehicles and second, because the availability of pooled vehicles is sufficient to meet needs, there can be an overall reduction in the number of older (or high emission) vehicles being deployed.

This last consideration touches on the concept of 'vehicle appropriateness', where a vehicle is well-matched for its intended use. This criterion for determining fleet composition is more difficult to measure than those previously described, but it is rooted in concrete quantitative assessments of vehicle use. These include measurements such as passenger miles traveled (PMT), city and highway fuel economy, and typical vehicle use (e.g. short city trips, long highway trips, daily/weekly/monthly trip cycles, trip time, distance). Since the transportation and mobility needs of each department are likely to be widely variable, the 'appropriateness' of use must be determined for each department and the fleet composition selected accordingly.

To better understand the concept behind 'appropriate use', suppose a department has custody of 25 light-duty vehicles, all of which are under 6 years old and are driven more than 4,800 miles each year. Based only upon these two screening criteria, it would be presumed that these vehicles should probably remain as part of the fleet and continue to be individually distributed to the department. Suppose, however, upon closer inspection, it is determined that half of the vehicles have very low fuel economy (< 15 mpg) and are driven mostly on local errands (one passenger, low speeds, little cargo, and short distances). This would suggest that a better vehicle, from an emissions perspective, might be assigned if the vehicle were part of a centralized fleet. While this is obviously an extreme case, it illustrates the importance of evaluating *how* vehicles are being used in order to determine whether or not they are being used in order to ensure that fleet management is optimal for reducing GHG emissions.

Based on current policy (i.e, a 6-year turnover requirement), 210 light-duty vehicles (about 50% of the fleet records) were between the ages of 7 and 17 years. These vehicles consumed approximately 55% (or 2,900 gallons) of the total gasoline used by the fleet. This is equivalent to emissions of about 1,042 metric tons of CO_2e. If approximately 40% (based on the current under-utilization rate) of county vehicles were removed from the fleet, cost savings due to avoided maintenance would potentially be somewhere on the order of $250,000 annually.[12] Assuming a centralized fleet can provide the same level of service to the departments this obviously becomes a highly effective potential mitigation option. The remaining 35 vehicles (ideally the newer models) can be consolidated into a centralized motor pool. Again, fleet downsizing and consolidation results in GHG emissions reductions only if miles previously driven in older, or high emitting vehicles are instead avoided or trips are undertaken using a more efficient (i.e. lower-GHG-emitting) vehicle.

Once the first pass through the vehicles has been completed, a second pass should be undertaken. The primary aim of the second pass is to evaluate each department's transportation needs in terms of reallocating a vehicle specifically to that department. For passenger vehicles, measures that might be used to evaluate each vehicle could include the relationship between average "passenger fuel economy" (passenger miles traveled per gallon of fuel consumed) and both travel distance and overall VMT. By this measure, it is possible to account for both vehicle fuel efficiency and the vehicle utility required by the department. If a department has several passenger vehicles with low passenger fuel economies, they may be better served by replacement of current vehicles with smaller, more fuel efficient vehicles. A similar assessment method can be developed for larger vehicles (e.g., cargo vans and pickup trucks) to incorporate both fuel economy and the transportation utility required by the department. In order to fully

[12] This does not include any benefits due to resale.

evaluate department needs, a much better cataloguing of vehicle use must be mandated. Currently, departments are highly variable in both the ways in which vehicle use data are recorded as well as the consistency with which it is recorded.

3. Allocating vehicles from a centralized fleet

The use of a centralized fleet is effective for reducing GHG emissions only if vehicle use and O&M procedures are optimized. If a centralized vehicle fleet is developed then vehicle checkout and O&M policies must be developed and rigorously followed. Recall that there are really only three ways to reduce GHG emissions using a centralized strategy: reducing overall VMT, using more appropriate vehicles for a given trip, and following O&M procedures. A simple decision framework for assigning vehicles is shown in Figure 15.

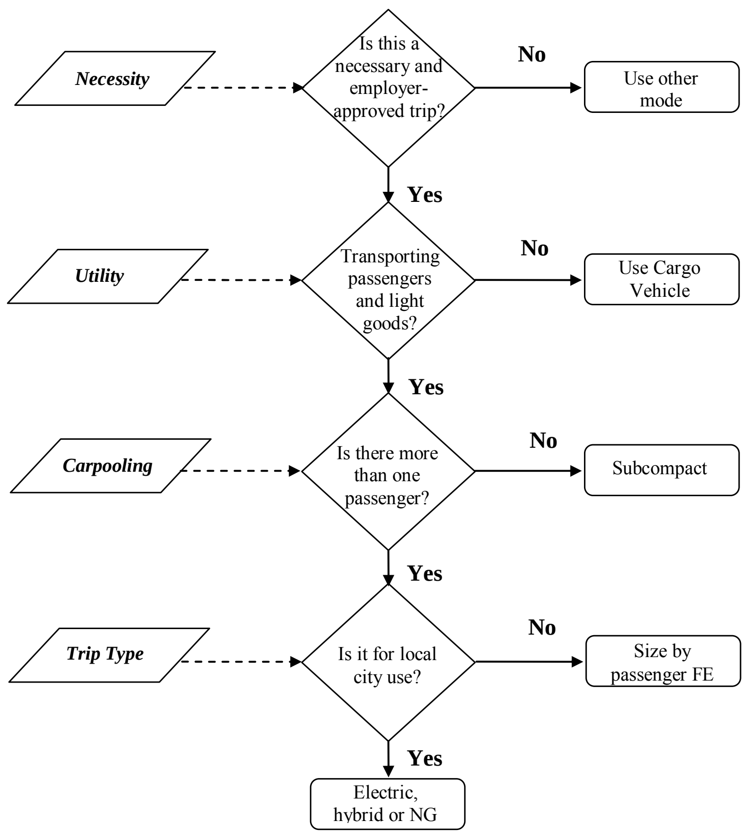

Figure 15. A decision protocol for motor pool checkout

For both pooled and distributed vehicles, routine maintenance should be regularly scheduled to ensure that vehicles remain in good working order to support efficient operation. The county needs to develop a ‘best practices’ vehicle maintenance protocol to ensure that maximum operating efficiency and reduction of GHGs is maintained throughout the vehicle life. The county also needs to establish a consistent database that can be used for keeping accurate records of vehicle fuel consumption, mileage, maintenance, and incidents. The database can be established to also regularly update the county on progress toward achieving GHG emissions targets.

4. Vehicle Purchasing

Yolo County currently follows California regulatory procedures for vehicle purchasing, with the current contract in effect through October 31, 2008. These contracts specify minimum values for passenger space, cargo volume, fuel economy, emissions (for criteria pollutants), as well as several other standard vehicle features. There is a different policy document describing the requirements for each vehicle type, including 4-door autos, sedans, light trucks, SUVs, cargo vans, hybrids, etc. Many of the policy guides also explicitly state that the vehicles must be "fueled by reformulated gasoline". This limits the county's ability to consider alternative technologies.

The U.S. EPA has recently issued a report, "Light-Duty Automotive Technology and Fuel Economy Trends: 1975 through 2007", that contains an appendix (Q) that should be useful to the county in selecting new vehicles to purchase as replacements for outgoing vehicles in each of the various light-duty vehicle classes. A sample of some of the vehicles listed in the EPA document, accompanied by listed prices for each vehicle, is provided in Appendix E.

In addition, Hawaii has recently developed minimum fuel economy standards for their vehicle fleet (Hawaii, 2007). Developing minimum fuel economy ratings for new vehicle purchases is a very straightforward and effective way of steadily reducing CO_2e emissions over time. By assigning a different minimum fuel economy rating by vehicle class (e.g., Table 18) the county can gradually improve the average fleet fuel economy without completely eliminating an entire vehicle class due to inefficiencies. This takes into consideration the intended use of the vehicle and its utility as a part of the county fleet.

Table 18. The graduated minimum vehicle fuel economy for Hawaii (Hawaii, 2007)

CLS	CLASS	MINIMUM CITY MPG	MINIMUM HWY MPG	MINIMUM COMBINED MPG	FUEL COST PER YEAR	FUEL COST PER 100,000 MI
1	TWO SEATERS	21	30	24.3	$ 1,132.74	$ 11,327.38
2	MINICOMPACT CARS	20	26	22.3	$ 1,232.21	$ 12,322.12
3	SUBCOMPACT CARS	24	32	27.0	$ 1,016.93	$ 10,169.27
4	COMPACT CARS	26	30	27.7	$ 994.23	$ 9,942.31
5	MIDSIZE CARS	23	31	26.0	$ 1,056.80	$ 10,568.02
6	LARGE CARS	20	29	23.2	$ 1,182.97	$ 11,829.74
7	SMALL STATION WAGONS	26	33	28.7	$ 956.73	$ 9,567.31
8	MIDSIZE STATION WAGONS	22	29	24.7	$ 1,114.22	$ 11,142.24
12	STANDARD PICKUP TRUCKS 2WD	18	23	20.0	$ 1,378.32	$ 13,783.21
13	STANDARD PICKUP TRUCKS 4WD	17	20	18.2	$ 1,508.46	$ 15,084.56
14	VANS, CARGO TYPE	16	20	17.6	$ 1,564.06	$ 15,640.63
15	VANS, PASSENGER TYPE	14	18	15.6	$ 1,767.86	$ 17,678.57
20	SPEC PURP VEH - MINIVAN - 2WD	19	26	21.6	$ 1,272.01	$ 12,720.14
22	SPEC PURP VEH - S.U.V. - 2WD	21	28	23.7	$ 1,162.20	$ 11,622.02
23	SPEC PURP VEH - S.U.V. - 4WD	20	25	22.0	$ 1,251.25	$ 12,512.50

The current county vehicle policy states that whenever possible departments should strive to purchase alternatively fueled vehicles, with the caveat that the vehicle should be cost competitive and provide equivalent service to a conventional vehicle (CSD, 2001). The policy also states that the county will develop a list of commercially available alternatively fueled vehicles, and that funds will be made available to help support departments in making such purchases. However, based on discussions with the current Fleet Manager, Eileen Jacobs, these policies have not been supported or enforced since they were implemented in 2001, and they appear likely to be removed from the policy in the near future.

Rather than removing policies designed to encourage alternatively fueled vehicles because they are not currently enforced, the county should consider developing new vehicle purchasing procedures (or modifying old procedures) in order to establish minimum fuel efficiency standards, encourage and enforce the purchase of alternatively fueled vehicles, and allow more room for creative vehicle purchasing options. In the next section, we've provided information that might inform the development of such new policy.

5. Alternative Low-GHG Fuels

Currently, there are very few alternative fueling options within Yolo county. The county has no biodiesel fueling stations, no ethanol stations, and only one natural gas station (in Davis). Virtually all of the fueling stations supply gasoline, a smaller fraction provides diesel fuel, and only a handful dispenses propane gas (although none at pressures high enough to enable vehicle refueling). With this limited availability of alternative fueling infrastructure, it can be difficult to envision a transition to the use of low-carbon vehicle fuels taking place any time soon. Still, within the next 20-plus years, there will likely be significant changes made to both the fueling infrastructure and the vehicle fleet. Figure 16 provides estimates of future GHG emissions from different vehicle technologies relative to a 2006 baseline.

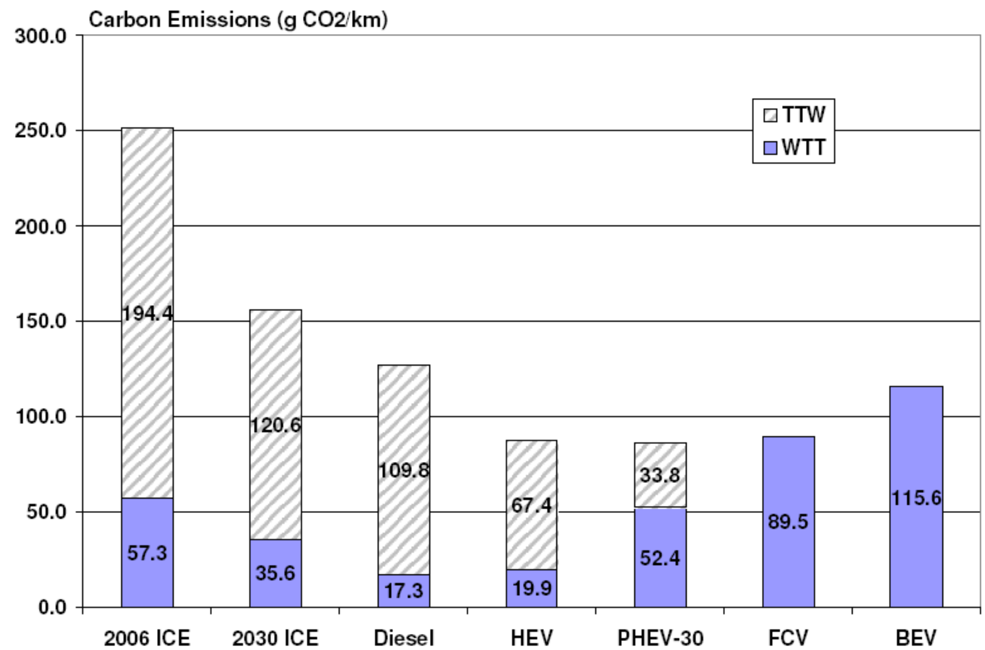

Figure 16. GHG emissions from different technologies (Kromer & Heywood, 2007)

The county currently owns approximately 30 gasoline/ethanol flex fuel vehicles. At this time, the nearest ethanol fueling station is located in Sacramento. Since there are no local cellulosic ethanol production plants, the total lifecycle GHG emissions from consuming ethanol are likely to be as great as or greater than for reformulated gasoline. For this reason, ethanol should only be seriously pursued once it is cost-effective to produce ethanol from local cellulosic materials. An even more obvious constraint is the absence of any ethanol fueling stations within the county, though this problem can be more easily addressed.

Biodiesel could potentially be produced from local and renewable resources with notable reductions in GHG emissions compared to reformulated gasoline (IPCC, 2007). However, there are many possible externalities associated with biofuels, such as competition for cropland and food stocks, as well as impacts from soil erosion, runoff, etc. These same barriers and constraints exist for other biofuels as well (e.g., ethanol). The county may realize measurable GHG savings by replacing existing fleet vehicles with passenger diesels and running them on biodiesel. Although there are not any biodiesel stations currently within the county, a number of stations are located in Sacramento and it is likely that others may be established in Davis and throughout the county in the future. One remaining difficulty, however, is the availability of light-duty diesel vehicles in the United States. Though extremely prevalent in Europe, light-duty diesels have not been produced for wide distribution in the U.S., making them relatively rare and difficult to obtain in California. In addition, maintenance costs for such vehicles (e.g. Volkswagen, Peugot, Mercedes) can be high due to the availability of parts and the necessary mechanical expertise. Figure 17 provides a comparison of the GHG emissions produced by an "average" fleet vehicle compared to anticipated emissions for similar vehicle using alternative fuels.

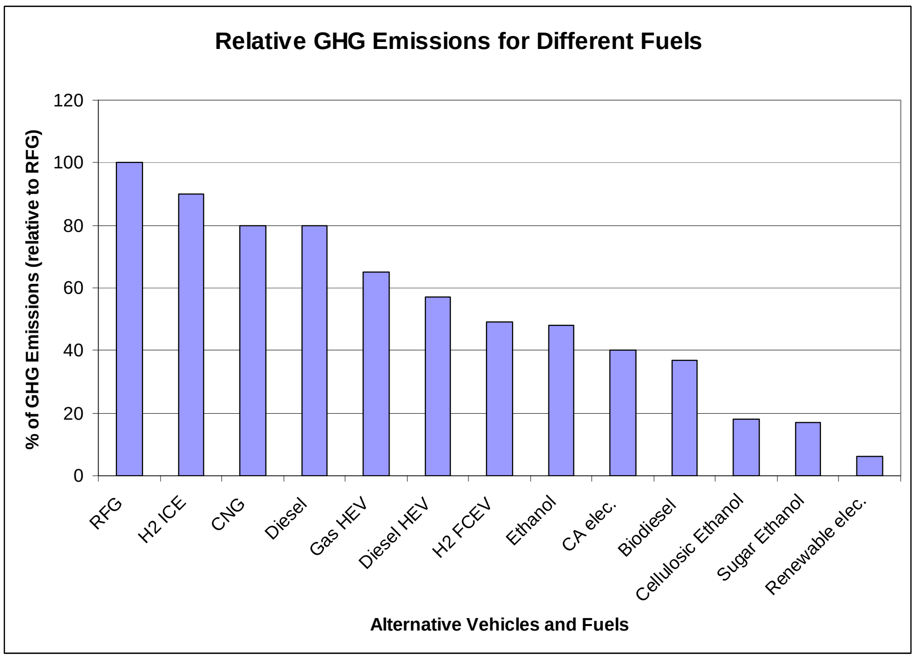

Figure 17.GHG reductions with conventional RFG vehicle as reference (IPCC, 2007).

The one alternative vehicle technology that is not currently limited by fueling infrastructure is that employed by plug-in, battery-electric vehicles. The county owns and operates six electric vehicles. These vehicles can be charged from most common sources of electricity (e.g., an electrical outlet). This option provides much more flexibility and the potential for use without the addition of any new fueling infrastructure. Also, as the mix of grid electricity supplied by PG&E continues to reduce its carbon content, the GHG reduction benefits of owning and operating an electric vehicle within the county will increase. Thus, while current GHG levels for electricity use are on the order of 60% lower than for conventional gasoline vehicles, this percentage will continue to increase as the renewable content of the grid mix continues to increase (IPCC, 2007).

In addition to GHG reductions, the use of electric vehicles provides many further benefits, including improved urban air quality, near silent operation, efficient use of energy, reduced fuel costs, and a diverse portfolio of possible fueling resources, including renewable and distributed power. In 2001, it was possible to lease a new (subsidized) EV Ford Ranger for about $200-$400/month. Today, the least expensive full-function commercial EV is available for about $40,000, presumably due to small production quantities and an absence of consumer subsidies. If the availability of a cost-efficient commercial electric vehicle were to become more available, converting as much of the fleet as possible to electric drive will provide the greatest benefits in the next 10-15 years.

Final Recommendations

The county has many possible options for reducing GHG emissions from their light-duty vehicle fleet, and they will ultimately need to select those mitigation options which are most well-suited specifically for the county. What follows is a summary of a number of general recommendations.

Near-term: Pool under-utilized vehicles and sell or scrap those vehicles that are too old and/or inefficient to serve as useful motor pool vehicles. Reevaluate the county's existing policy for vehicle turn-over age (6 years) based on what information is available regarding lifecycle GHG emissions, and begin retiring those vehicles that exceed policy guidelines. Conduct a survey of departments to assess mobility needs and reassign vehicles as necessary depending on vehicle use requirements. Explore all possibilities for the purchase and use of battery electric vehicles for local/city driving. Create a maintenance and operations policy to ensure that vehicle GHG emissions are limited, create and enforce a record keeping procedure for any remaining distributed vehicles, and establish a central pool checkout protocol.

Mid-term: Develop a database of pooled and distributed vehicles and maintain consistent records of vehicle use and maintenance. Provide appropriate access to the motor pool database to allow county employees to conveniently reserve vehicles as justified by their employment duties. Assign vehicles based on intended use (number of passengers, cargo weight/volume, trip distance, location, etc.). Begin purchasing new vehicles that meet a higher fuel economy standard, considering alternatively fueled choices (e.g. electric or biodiesel) whenever possible.

Long-term: Over time, gradually increase standards for vehicle efficiency (fuel economy) and percent alternative fuel mix. Promote policies that discourage excessive driving, encourage greater vehicle loading (passengers/vehicle), and allow for creativity in trip avoidance. Conduct a similar analysis to this one and develop a set of policy recommendations for the county heavy-duty vehicles.

INDIRECT EMISSIONS

As shown in the introductory background section, approximately 49% of the county's GHGs are emitted away from county facilities and vehicles. These emissions are defined as indirect emissions, all of which are produced by the electricity-generation facilities from which PG&E receives its mix of electricity. While the vehicle and building mitigation options that have been discussed and are designed to reduce demand-side electricity are also reducing the indirect emissions, the county can also have some influence on the indirect emissions.

The annual county GHG emissions from buildings' electricity are the product of county electricity demand (kWh/yr) and the GHG-electricity intensity (GHG/kWh). The GHG intensity of the indirect energy production is based on the utility's decisions about generating sources. The county obviously benefits when PG&E changes the mix of the primary energy sources it uses for electricity generation. As PG&E increases their use of non-fossil-fuel electricity (e.g. geothermal, wind, solar, and nuclear) and changes their fossil fuel electricity to lower GHG-intensity options (e.g. more natural gas, capturing and storing the carbon emissions), their GHG intensity drops. Trends in California and elsewhere are toward lower-GHG electricity because of these factors.

Background on State Policy and GHG Trends

From the perspective of its GHG footprint, Yolo county benefits from being in California and from having relatively clean energy generation sources (Table 19). Two factors – the lower proportion of coal and higher proportion of renewables – in California's and PG&E's electricity mixes contribute to much lower GHG emissions per electricity generation compared to the average US electricity mix. PG&E's delivered electricity has 61% less GHG emissions per kWh electricity than for the average US figure and 37% less than the average California figure.

Table 19. Electricity and GHG characteristics for the US, California, and PG&E (2005)

		United States	California	PG&E
Percent of electricity from each energy source	Natural gas	19%	44%	43%
	Coal	50%	14%	2%
	Other fossil fuels	3%	0%	0%
	Nuclear	19%	15%	24%
	Large hydroelectric	7%	16%	19%
	Renewable (small hydro, biomass, geothermal, wind, solar, others)	2%	11%	12%
Electricity (million MWh/yr)		4,055	272.4	80.0
Total emissions (million tonne CO2/yr)		2,375	99.6	18.5
GHG intensity (kg/MWh, g/kWh)		586	366	231
Data sources		US EIA, 2007; US EIA, 2006	CEC, 2006a; CEC, 2006b; CCAR, 2007	PGE, 2007a; PGE, 2006

The current and future PG&E GHG-electricity characteristics impact Yolo county's GHG mitigation strategy in two ways. First, the California Climate Action Registry protocol uses average California electricity generation GHG characteristics (i.e., 366 gram CO_2 per kWh) and the PG&E-specific value is considerably lower (231 g CO_2 per kWh, or 37% lower); the county's official baseline should be updated. The CCAR reporting protocol encourages that reporting by entities like Yolo county use their utility-specific characteristics if those utilities report an electricity delivery metric that is certified with CCAR's protocols (CCAR, 2007b).

Next, under SB107 (2006), investor-owned utilities are required to have 20% of their electricity by 2010 come from renewable sources that include small hydroelectric systems, biomass/waste generation, geothermal, wind, and solar (State of California, 2006a). As of September 2007, PGE currently has contracts for 18% renewable electricity for 2010 (with numerous new solar, geothermal, wind contracted projects coming on line) (PG&E, 2007b). In addition, Governor Schwarzenegger has set an additional goal of 33% generation from renewable sources by 2020 (CEC and CPUC, 2005).

Figure 18 shows the potential impact of the renewable portfolio standard (20% by 2010) and the longer term state goal (33% by 2020) on PG&E's average GHG emission rate from its delivered electricity. Here we assume that PG&E meets both renewable energy goals, that the renewable energy is net-carbon-neutral (embodied upstream GHG emissions are not accounted for in CCAR emissions reporting), and finally, that the new renewable electricity displaces equally all the other electricity generation types (natural gas, nuclear, large hydroelectric). The result of the increased proportion of renewable supply would be to decrease the electricity GHG emissions per kWh that Yolo county receives from PG&E by 11% in 2020 and 21% in 2030.

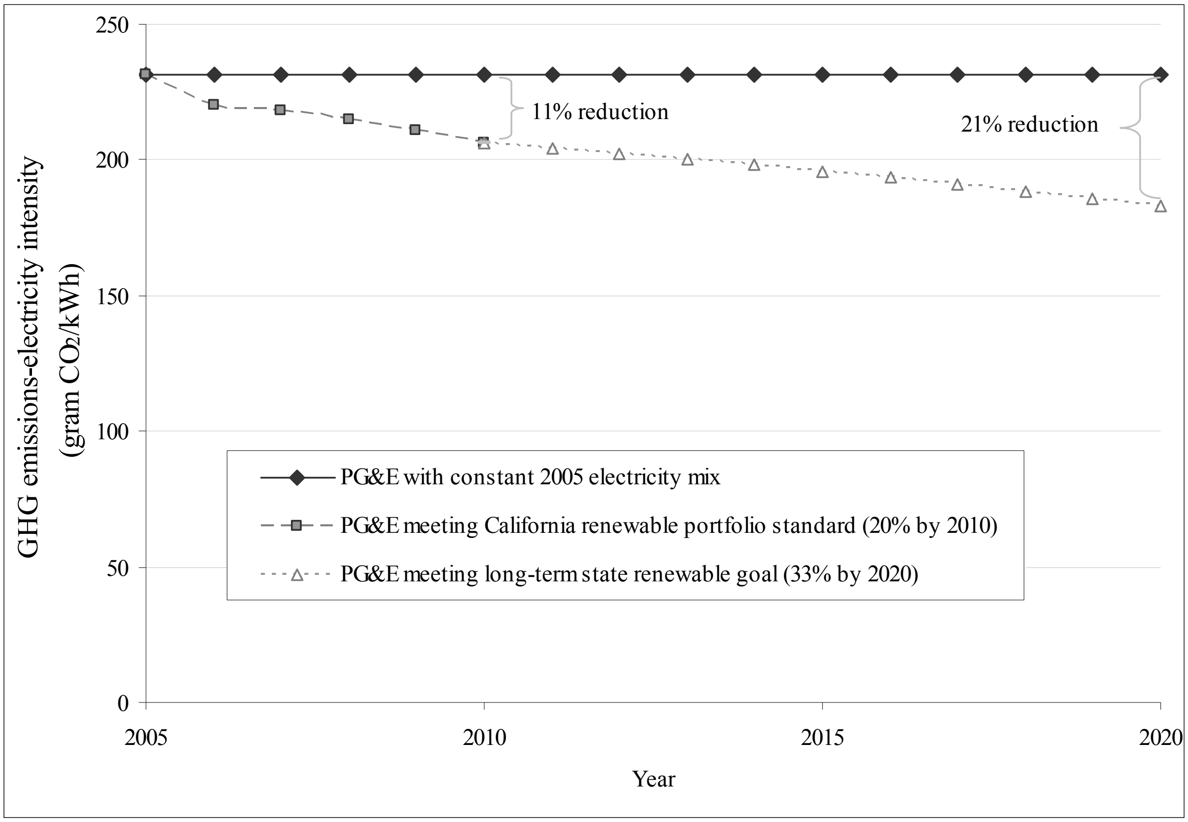

Figure 18. Impact of renewable portfolio increases on PG&E GHG emission rate

Figure 19 shows the impacts to Yolo county's overall GHG emissions footprint after for PG&E-specific delivered GHG-electricity intensity and projecting the impact of future county GHG emissions due to increased overall renewable electricity percentages in 2010. Updating the county inventory for the PG&E GHG intensity, which is 37% lower than the California average (231 g/kWh versus the California average 366 g/kWh) would reduce the county's baseline emissions from 8,183 to 6,705 tonne CO2/yr, or by 18%. The increased renewable percentage in PG&E's electricity mix from 12% in 2005 to 20% in 2010 will further reduce county overall GHG emissions from 6,705 to 6,427 tonne CO_2 per year, or 4%. Note that both of these reductions would occur if the county operations remained constant through those future years (i.e. no county GHG mitigations took place).

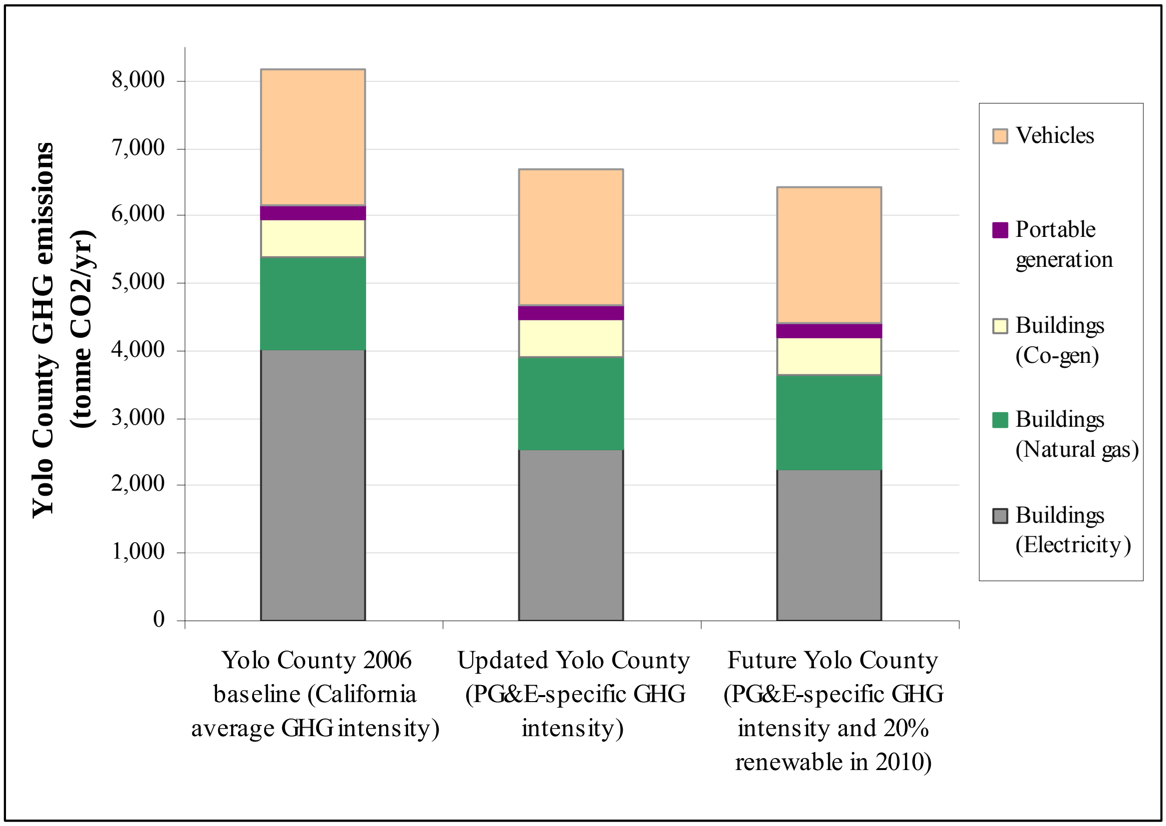

Figure 19. Yolo county GHG inventory with two electricity mix modifications

Options for County Green Electricity Purchasing

Yolo county has the ability to further reduce its indirect GHG emissions through its purchasing practices. Generally referred to as "green power purchasing," electricity customers can purchase lower-GHG products in several different ways. In deregulated markets, electricity consumers can opt for renewable electricity-intensive providers. Alternatively, utilities sometimes offer "green pricing" programs, where customers can opt to pay a premium (above the standard electricity rate) to support that utility's efforts at increasing the amount of green and/or renewable electricity within its portfolio.

"Green pricing" programs by utilities in California are shown in Table 20 (from US DOE, 2007b; PG&E, 2007c). These utilities charge a premium of up to $0.05 extra per kWh of delivered electricity generation for customers to voluntary opt in to the programs. In return these funds support the utilities' efforts at increasing their use of renewable electricity sources, including photovoltaic solar, wind, landfill gas, and hydroelectric. In Yolo county's case, PG&E offers a pricing structure called ClimateSmart, which is designed to help support increased development of renewables by charging a premium of $0.00254 per kWh, or 0.25¢/kWh, for customers to join the program. Larger customers, for example government agencies or commercial entities, can often negotiate rates and establish fixed contractual rates for renewable electricity that may be more advantageous than conventional "green pricing" options (US EPA, 2004).

Table 20. Electricity utility "green pricing" programs in California

Utility Name	Program name	Type	Start Date	Price premium over conventional electricity
Anaheim Public Utilities	Sun Power for the Schools	PV	2002	Contribution
Anaheim Public Utilities	Green Power for the Grid	wind, landfill gas	2002	1.5 ¢/kWh
Burbank Water and Power	Green Energy Champion	various	2007	2.0 ¢/kWh
Los Angeles Department of Water and Power	Green Power for a Green LA	wind, landfill gas	1999	3.0 ¢/kWh
PacifiCorp: Pacific Power	Blue Sky Block	wind	2000	1.95 ¢/kWh
Pacific Gas & Electric	ClimateSmart	various	2007	0.25 ¢/kWh
Palo Alto Utilities/3 Phases Energy Services	Palo Alto Green	wind, PV	2003 / 2000	1.5 ¢/kWh
Pasadena Water & Power	Green Power	wind	2003	2.5 ¢/kWh
Roseville Electric	Green Roseville	wind, PV	2005	1.5 ¢/kWh
Sacramento Municipal Utility District	Greenergy	wind, landfill gas, hydro, PV	1997	1.0 ¢/kWh or $6/month
Sacramento Municipal Utility District	SolarShares	PV	2007	5.0 ¢kWh or $30/month
Silicon Valley Power / 3 Phases Energy Services	Santa Clara Green Power	wind, PV	2004	1.5 ¢/kWh

Sources: US DOE, 2007b; PG&E, 2007c

To put the incremental premium prices of green electricity in perspective in terms of their cost-effectiveness as a GHG mitigation strategy, everything must be converted according to the GHG intensity of the electricity that the renewable will displace. If it is true that the renewable electricity generation would not have occurred otherwise (without the additional customer support), then it is displacing electricity from the average baseline or marginal GHG per kWh in the region in which the electricity customer is located. From Table 19 we know that the average GHG intensity for the US (and California) are both considerably higher than for PG&E customers. This means that there is going to be less impact in terms of both GHG per electricity generation and the cost per ton of GHG emission avoided for purchasing premium renewable electricity in California, but particularly in northern California, than might be seen elsewhere.

As shown in Table 21, the cost-effectiveness of purchasing green electricity as a GHG mitigation strategy depends greatly on the price premium charged by the electricity service provider and the displaced electricity GHG intensity. At premium price of 1¢ per kWh of green electricity, an average US electricity customer would be mitigating GHG emissions at a cost of $17/tonne CO_2 reduced, an average Californian at \$27/tonne, and a PG&E customer at \$43/tonne. For Yolo county in particular, with PG&E's price premium of 0.25¢ per kWh and GHG intensity of 231 g CO_2 per kWh, the cost-effectiveness of using the PG&E ClimateSmart program would be \$11/tonne CO_2 reduced. The implication of this is that the county should implement all *direct* GHG mitigation strategies (as discussed for buildings and the vehicle fleet) that have a cost-effectiveness ratio below \$11/tonne CO_2 before considering participation in the PG&E climate program.

Table 21. Effect of "green energy" price premium and electricity GHG rate on cost-effectiveness

Price premium for green electricity (¢/kWh)	Cost-effectiveness as GHG mitigation option ($/tonne CO2)		
	US average (586 g CO2/kWh)	California average (366 g CO2/kWh)	PG&E (231 g CO2/kWh)
0.25	4	7	11
0.50	9	14	22
1.0	17	27	43
2.0	34	55	86
3.0	51	82	130
4.0	68	109	173
5.0	85	137	216

Beyond direct changes by building operators, the use of outside building energy consultants can also help troubleshoot larger energy loses. The practice of "retro-commissioning" entails a thorough analysis of buildings' operations to pinpoint energy use reduction opportunities. A similar practice, called "bulls eye commissioning," does this troubleshooting in a more streamlined (but less comprehensive) manner that seeks out and finds the several largest building improvements more quickly. Both of these commissioning techniques are generally highly cost-effective in delivering energy savings that offset the consulting and diagnostic fees within two years, and they are more effective in newer buildings with some level of computerized automation (Price and Hart, 2002; Thorne and Nadel, 2003; Gregerson, 1997; Sachs et al, 2004).

CONCLUSIONS

This report has highlighted dozens of strategies for the county of Yolo to consider for adoption into its vehicle management and purchasing and building operation practices. Recommended actions at county facilities have been categorized into particular building areas, from appliances to lighting to heating and cooling systems, and vehicle fleet management practices and according to their near-term viability.

There are a number of practices and technologies that were reviewed in the discussion on general GHG mitigation options for buildings that have already been adopted (with ranging rates of implementation) in a number of the county buildings. These include, for example, the use of compact fluorescent lighting (CFL) and efficient T8 fluorescent tube lighting, double-paned windows in some buildings, and state-of-the-art HVAC equipment with efficient boilers and chillers and automated temperature controls. All of these energy-saving technologies provide examples of good energy practices that should be fully implemented across all county facilities, before considering large scale technology changes.

For those buildings, or portions of buildings in which these types of changes have not been implemented, we recommend that retrofits be of high priority. For example, in the case studies (which included just three buildings) we found a 1960's air-conditioning chiller and 1992-vintage packaged air-conditioning units (both in the Davis Library), single paned windows in the Administration building, and the DESS building has a duct system with the purpose of venting conditioned air (for which the county has used energy to produce).

Before any discussion of the technology-based options, where current equipment is replaced by newer high-efficiency alternatives, the more basic question of power management should be addressed. Many appliances are dispersed and communal, making their disengagement difficult and sporadic. Managing power consumption of appliances and computers during non-work hours is of primary importance because non-work times at night and weekends represent 70-90% of all hours of the year. Efficient technology products generally improve efficiency (e.g. in kWh per year) from conventional options by about 10-40% for any particular device or appliance *while it is in use*. Therefore, power management strategies (and policies) during non-work hours represents a clear and substantial savings.

The county should, either through the DGS or on a departmental level, inventory its equipment and appliances by technology type and model year. Although three of largest energy building consumers have been inventoried in detail, the county manages more than 50 additional buildings that do not have inventories available. Inventories should begin with the most energy-intensive and long-lifetime equipment, in the HVAC (e.g. boilers, chillers, packaged air-conditioning unit) and lighting (e.g. technology type and date of installation), moving then to durable appliances (e.g. water heaters, refrigerators) and other shorter-life smaller units like computers.

Along with inventorying the equipment on hand at county facilities, the county should begin logging data on the performance of the equipment with the highest energy impact. For example, the cogeneration system and the Bauer building solar energy system both involve large initial costs and large potential energy savings, and large potential losses if they are not performing as designed. By periodically logging the energy consumption data, the county could monitor performance to ensure the GHG emission reductions that are hoped for are actually achieved, flag whether or not maintenance or attention is required, and provide reference for future purchases (both by Yolo county or other interested parties).

The ENERGY STAR on-line resources guide should be consulted before the purchasing of all office equipment. There are particular listings of ENERGY STAR-certified for virtually ever major piece of equipment for commercial buildings, including boilers, air-conditioning units, light bulbs, computers, refrigerators, water coolers, copiers, and fax machines. In almost every case, choosing ENERGY STAR is highly cost-effective. Sometimes ENERGY STAR product cost the same initially as non-ENERGY STAR, and even when this is not the case, the energy savings of the ENERGY STAR product over its lifetime outweighs the modest increase in that product's initial price over the non-ENERGY STAR alternative (except in rare cases of seldom used equipment).

The county should periodically (e.g., on annual basis) revisit the existing equipment inventory and consider the retrofitting or upgrading to new equipment. A periodic reassessment will ensure that older energy-inefficient equipment is eventually retired for new equipment, and also offer an opportunity to review possible new technologies.

In the mid-term, strategies that include vehicle replacement, improved efficiency smart lighting fixtures with occupancy-sensing and bi-level dimming technology would drastically reduce the outdoor lighting requirements in areas like parking lots, walkways, etc. As noted earlier, these lighting systems have been piloted at UC Davis under the direction of the UC Davis Lighting Technology Center and found to be very effective in both reducing energy efficiency while maintaining appropriate levels of lighting.

Finally, over the longer-term, strategies aimed at increasing alternative fueled vehicles, replacement of older equipment, and new energy generation (i.e., similar to the co-generation unit), to offset any county operational expansions, should be evaluated for implementation.

Finally, the county should consider adaptation of a policy of no GHG emissions growth from individual projects. Inevitably, county government can be expected to expand in terms of operations and services as population growth continues. Where these expansions translate to added floor space or additional vehicles, without careful deliberation, GHG gas reductions can be easily overtaken by emissions created by expansion. The potential growth of emissions from new activities can be counterbalanced by (a) designing new activities (e.g., buildings) with state-of-the-art efficiency technologies (such as the new Yolo county Bauer building) and (b) possibly offsetting all additional new facility GHG emissions with carbon reduction credits, carbon offsets, or installing on-site county-operated renewable (or co-generation) energy to compensate for those new building energy and GHG emission consequences. We emphasize this aspect to make it clear that GHG reductions in existing buildings cannot offset new building expansions if the county wants to ensure that GHG emissions are actually reduced, as opposed to stabilized, over time.

REFERENCES

Anderson, J. (Ambien Climate Technologies), 2003. Personal communication with Steve Brennan. September 11. As cited in Sachs et al, 2004.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) 1998. *Operating Experiences with Commercial Ground-Source Heat Pump Systems.* Special Publication. Atlanta, GA

Babyak, R., 2003. "Technology Update: Air Conditioning & Refrigeration 'Gas Cooling Breakthrough.' " *Appliance Manufacturer* 51(6): 20-23.

Bisbee, D.(SMUD). 2003 . Personal communication with Hugh Dwiggins. August 14.

Bourne, D. and J. Stein., 1999. *Aeroseal : Sealing inside from the Inside Out. Report ER-99-16. Boulder, Colo.: E Source.*

Bauman,F., 2003. *Under floor Air Distribution Design Guide***.** Atlanta,Ga.: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

California Climate Action Registry (CCAR), 2007a. "About Us." https://www.climateregistry.org/ABOUTUS/. Accessed November 2.

California Climate Action Registry (CCAR), 2007b. *California Climate Action Registry General Reporting Protocol: Reporting Entity-Wide Greenhouse Gas Emissions*. Version 2.2. March.

California Energy Commission (CEC), 2006a. *Inventory of California Greenhouse Gas Emissions and Sinks: 1990 to 2004 - Final Report.* December 22.

California Energy Commission (CEC), 2006b. Revised Methodology to Estimate the Generation Resource Mix of California Electricity Imports: Update to the May 2006 Staff Paper. CEC-700-2007-007. March

California Energy Commission (CEC), 2002. "Measure Analysis and Life-Cycle Cost Report ." Publication 400-02-011. Sacramento, Calif.: California Energy Commission.

California Energy Commission and California Public Utilities Commission (2005). *Energy Action Plan II - Implementation Roadmap for Energy Policies*. Report 2005-09-21. September.

Center for Resource Solutions, 2007. "Green-e: Certification Services." http://www.green-e.org/getcert_re.shtml. Accessed November 19.

Central Services Division (CSD) of Yolo County (2001). *County of Yolo Administrative Policies and Procedures Manual: Vehicle Policy*. Policy number 52 published on March 20, 2001. Yolo County, CA

Chicago Climate Exchange, 2007. "CCX Carbon Financial Instrument Market Data Charting Tool." http://www.chicagoclimatex.com/data/cfi_closing_prices_historical.xls. Accessed November 18.

Commercial Buildings Energy Consumption Survey (CBECS), 1999. "1999 Detailed Tables, Table B6: Building Size, Number of Buildings." http://www.eia.doe.gov/emeu/cbecs/ set3.html. Washington, D.C.: U.S. Department of Energy, Energy Information Agency.

Consortium for Energy Efficiency (CEE), 2001. *A Market Assessment for Condensing Boilers in Commercial Heating Applications.* http://www.cee 1.otrg/gas/gs-blrs/Boiler_assess.pdf. Boston,Mass.:Consortium for Energy Efficiency.

Cool Chips PLC.2003."Cool Chips PLC Business Plan." Gibraltar: Cool Chips PLC.

Criscione, P., 2002a. "A Change in the Wind for Natural and Hybrid Ventillation."ET C*urrents,* August.

Criscione, P., 2002b. "A new Reality for Refrigeration?" ET C*urrents*, 19:6-7.

Dakin, B. (Davis Energy Group Inc.), 2003. E-mail correspondence to G. Todesco. July. As cited in Sachs et al, 2004.

Davis Energy Group (DEG), 2002a. *Residential Construction Quality Assessment project: Phase II Final Report.* CEC 400-98-004. Davis, Calif.: Davis Energy Group, Inc.

Davis Energy Group (DEG), 2002b. "SMUD/Truckee Donner Geothermal Heat Pump Project 2001/2002 Monitoring Report." Davis, CA. Davis Energy Group, Inc.

Davis Energy Group (DEG), 2003. *Analysis of Standadrs Options of Residential Pool Pumps, Motors, and Controls.* Prepared for Pacific Gas & Electric Company. Davis, Calif.: Davis Energy Group.
Degens,P. (NEEA), 2003. Personal communication with Hugh Dwiggins. September 25. As cited in Sachs et al, 2004.
Department of General Services (DGS), 2007. "Energy/Emissions Report." County of Yolo. April.
Desjarlais, A., 2003. Oak Ridge National Laboratory. Personal communication with Steve Brennan. August 21. As cited in Sachs et al, 2004.
Gas Appliance Manufacturers Association (GAMA), 2003. *Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment*. http://www.gamanet.org/consumer/certification/certdir.htm. Arlington, Va.:.
Gough, A., 2003. Electric Power Research Institute. Personal Communication with Marycel Tuazon. July.
Gregerson, J., 1997. "Commissioning Existing Buildings." *Tech Update,* TU-97-3.
Groll, E. A., 2003. Personal communication with Hugh Dwiggins. November 20. As cited in Sachs et al, 2004.
Hollick, J., 2003. Personal communication with Steve Brennan. Conserval Engineering Inc. September 18. As cited in Sachs et al, 2004.
Industry Data, 2004. Unpublished data from industry partners of EPA/DOE ENERGY STAR program.
Industry Data, 2007. Unpublished data from industry partners of EPA/DOE ENERGY STAR program.
Intergovernmental Panel on Climate Change (IPCC), 2007. "Summary for Policymakers of the Synthesis Report of the IPCC Fourth Assessment Report." In *Climate Change 2007*, Cambridge. University Press, Cambridge, United Kingdom and New York, NY, USA.
International Counsel for Local Environmental Initiatives (ICLEI). Green Fleets. n.d. 15- oct-07 <http://www.greenfleets.org >
International Energy Agency (IEA), 2002."Hybrid Ventillation in New and Retrofitted Buildings." *Principles of Hybrid Ventilation.* IEA – ECBCS Annex 35.
Kahn R., S., S. Kobayashi, M. Beuthe, J. Gasca, D. Greene, D. S. Lee, Y., Muromachi, P. J. Newton, S. Plotkin, R. Wit, P. J. Zhou (IPCC) (2007) Transport and its infrastructure. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
Kallet, R., E.Hamzavi, C.Sherman, and J.Erickson, 2000. "SMUD's New Residential Duct Improvement Program Using an Aerosol -Based Duct Sealant." In *Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings,* 2.163-2.174. Washington, D.C.: American Council for an Energy-Efficient Economy.
Kang,S., 2003. MaxLite. Personal Communication with Marycel Tuazon. August. As cited in Sachs et al, 2004.
Kendall,M. and M. Scholand.2001.*Energy savings Potential of Solid State Lighting in General Lighting Applications.* Final Report. Prepared foe U.S. Department of Energy, Building Technlogy, State and Community Programs, Energy Efficiency and Renewable Energy. http://www.eere.energy.gov/buildings/documents/pdfs/ssl_fianl_report3.pdf . Arlington, Va.: Arthur D Little, Inc.
Krechpin, I.,2001. *Automated Building Diagnostics:Improving Energy Performance and Occupant Comfort.*E Source Report ER-01-18. Boulder, Colo.: E Source, Inc.
Krechpin, I., 2002."Stirling Technology II: Free Piston Devices." *ET Currents,* March.
Kromer, M. and Heywood, J. B. (2007). *Electric Powertrains: Opportunities and Challenges in the U.S. Light-Duty Vehicle Fleet*. Laboratory for Energy and the Environment, Sloan Automotive Lab. Massachusetts Institute of Technology. Cambridge, MA
Lawrence Berkeley National Laboratory (LBNL), 2003. *Average Values: Manufacturer Price, Customer Equipment Price, Installation Cost, and Total Installed Cost.* Presentation slide. Berkeley, Calif.: Lawrence Berkeley National Laboratory, Environmental Energy Technologies.

Lawrence Berkeley National Laboratory (LBNL), 2002. Unpublished data for EPA/DOE ENERGY STAR program.
Lawrence Berkeley National Laboratory (LBNL), 2004. Unpublished data for EPA/DOE ENERGY STAR program.
Lawrence Berkeley National Laboratory (LBNL), 2006. Unpublished data for EPA/DOE ENERGY STAR program.
Lea, D., 2003. Cellulose Insulation Manufacturers Association. Personal communication with Steve Brennan. August. As cited in Sachs et al, 2004.
Lee, E.S. and S.E. Selkowitz, 1998. "Integrated Envelope and Lighting Systems for Commercial Buildings: A Retrospective." In *Proceedings of the ACEEE 1998 Summer Study on Energy Efficiency in Buildings.* Washington, D.C.: American Council for an Energy Efficient Economy.
LG Electronics (LGE), 2003. http://www.lge.com/. As cited in Sach et al, 2004.
Lighting Research Centre (LRC), 2003a. *Draft Technology Transfer Plan for Project 3.2: Energy Efficient Load Shedding Technology.* Prepared for the California Energy Commission, PIER Lighting Research Program. Lighting Research Centre National Lighting Product Information Program. Troy, NY.: Lighting Research Centre.
Lighting Research Centre (LRC), 2003b."Integrated Skylight Luminaire." DELTA Field Test Report (1).
LumiLeds, 2003. "Lumileds to Ship Warm White, Incandescent – Equivalent LED in August." Press Release. http://www.lumileds.com . San Jose, Calif.: Lumileds.
Magdych,J., 2003. Cool Chips PLC. Personal communication with Steve Brennan. July.
Marbek Resource consultants, 2003. *BC Hydroconservation Potential Review 2002: Commercial Sector.* Prepared for BC Hydro .Vancouver,B.C.,Canada: Marbek Resource consultants.
McCullough,J, 2003. Pacific Northwest National Laboratory. Personal Communication with Hugh Dwiggins. August 14. As cited in Sachs et al, 2004.
Modera,M., D. Dickerhoff , O. Nilssen, H. Duquette, and J. Geyselaers, 1996. "Residential Field Testing of an Aerosol Based Technology for Sealing Ductwork." *In Proceedings of the ACEEE 1998 Summer Study on Energy Efficiency in Buildings, 1.169-1.176.* Washington, D.C.: American Council for an Energy Efficient Economy.
Muhs, J., 2003a. "Hybrid Solar Lighting: Shedding New Light on Solar Energy…Bringing Sunlight Inside." Presented at the American Council for an Energy Efficient Economy Market Transformation Conference, Washington, D.C., May .
Muhs, J., 2003b. Oak Ridge National Laboratory. Personal Communication with Marycel Tuazon. August. As cited in Sachs et al, 2004.
Nadel,S., 2002. *Packaged Commercial Refrigeration Equipment* **:** *A Briefing Report for Program Planners and Implementers* . Washington, D.C.: American Council for an Energy Efficient Economy.
Nadel, S., deLaski, A., Eldridge, M., and Kliesch, J. 2007. *Leading the Way: Continued Opportunities for New State Appliance and Equipment Efficiency Standards*. American Council for an Energy-Efficient Economy. ASAP-6/ACEEE-A062. March 2006
Nadel, S., A. deLaski, J. Kleisch, and T. Kubo, 2005. *Leading the Way: Continued Opportunities for New Stated Appliance and Equipment Efficiency Standards*. Wash., DC: American Council for an Energy-Efficient Economy. Report ASAP-5/ACEEE-A051. January.
Nixon, J.D., 2003a."The Chemistry Behind 'Cool Roofs.'" *Eco Structure* , Summer :63-65.
Nixon, J.D., 2003b. Shepherd Color Company. Personal communication with Steve Brennan. August 13.
Natural Resources Canada (NRCan), 2002a. http://oee.nrcan.gc.ca/equipment/English/page50.cfm?PrintView= N& Text = N. Ottawa , Ontario: Natural Resources Canada, Office of Energy Efficiency.
Natural Resources Canada (NRCan), 2002b. "Standards for Window Energy Performance." Ottawa, Ontario: Natural Resources Canada, Office of Energy Efficiency.
Natural Resources Canada (NRCan), 2002c. http://greenbuilding.ca/C2000/abc-abc – 2kcr.htm. Ottawa, Ontario: Natural Resources Canada, Buildings Group.

Page, E. et al., 1997. *Lighting Energy Savings opportunities in Hotel Guestrooms.* Lawrence Berkeley National Laboratories. Berkeley, CA. LBNL-L-217.
Pacific Gas & Electric (PG&E), 1997. “Annual Summary Report on DSM Programs in 1995 and 1996.” San Francisco, Calif.: Pacific Gas & Electric.
Pacific Gas & Electric (PG&E), 2000. “Pacific Gas & Electric Company 2001 Energy Efficiency Programs Application.” Attachment K, Workpapers, K-110 – K-111. San Francisco, Calif.: Pacific Gas & Electric.
Pacific Gas and Electric (PG&E), 2004a. *Codes and Standards Enhancement Initiative for PY2004: Title 20 Standards Development, Analysis of Standards Options for Water Dispensers.* Prepared by the Davis Energy Group. San Francisco, California.
Pacific Gas and Electric (PG&E), 2004b. Codes and Standards Enhancement Initiative for PY2004: Title 20 Standards Development, Analysis of Standards Options for Metal Halide Lamps and Fixtures. Prepared by the American Council for an Energy Efficiency Economy. San Francisco, California.
Pacific Gas & Electric Company (PG&E), 2005. “PG&E’s 2006 Electricity Mix.” http://www.pge.com/education_training/about_energy/how_electric_system_works/2005_energy_mix.html. Accessed November 17, 2007.
Pacific Gas & Electric Company (PG&E), 2006. “PG&E’s 2006 Electricity Mix.” http://www.pge.com/education_training/about_energy/how_electric_system_works/2006_energy_mix.html. Accessed November 17, 2007.
Pacific Gas & Electric Company (PG&E), 2007a. "Annual Emissions Report." California Climate Action Registry. January.
Pacific Gas & Electric Company (PG&E), 2007b. "PG&E Commits to Double Its Solar Thermal Power Purchases During Clinton Global Initiative." September 27. http://www.pge.com/news/news_releases/q3_2007/070927.html. Accessed November 17.
Pacific Gas & Electric Company (PG&E), 2007c. “ClimateSmart–FAQ.” http://www.pge.com/about_us/environment/features/climatesmart_faq.html. Accessed November 17.
Portland Energy Conservation, Inc (PECI), 1999. Fifteen O&M Best Practices for Energy Efficient Buildings. September
Price, W. and R. Hart, 2002. “Bulls-Eye Commissioning: Using Interval Data as a Diagnostic Tool.” In *Proceedings of the ACEEE 2002 Summer Study on buildings,* p.3.295. Washington, D.C.: American Council for an Energy Efficient Economy.
Proctor, J., 2003. Proctor Engineering Group. Personal communication to Marc Hoeschele. October 30. As cited in Sachs et al, 2004.
Reid, A., 2003. Duraloc Systems. Personal Communication with Steve Brennan. August 18.
Ryan, W., 2002. “New Developments in Gas Cooling.” ASHRAE Journal 44(4): 23-26.
Rubinstein, Francis, 2003. Lawrence Berkeley National Laboratory. Personal Communication with Marycel Tuazon July and October. As cited in Sachs et al, 2004.
Sachs, Harvey M . and S. Smith, 2003. *Saving Energy with Efficient Residential Furnace Handlers: A Status Report and Program Recommendations.* Washington, D.C.: American Council for an Energy Efficient Economy.
Sachs, H., Nadel, S., Amann, J., Tuazon, M., Mendelsohn, E., Rainer, L., Todesco, G., Shipley, D., Adelaar, M., 2004. *Emerging Energy-Saving Technologies and Practices for the Building Sector as of 2004.* American Council for and Energy Efficient Economy A042. October.
Sage Electrochromics, Inc., 2003. Untitled. Presentation at DOE’s Windows R&D Roadmap Implementation Meeting, AAMA Fall Meeting.
Sardinsky,R. and J. Benya, 2003. *Super T8’s : Super Lamps, Siper Balasts.* Report ER-03-16. Boulder, Colo.: Platt’s research and Consulting.
Shaw,J., 2003. Carrier Corporation. Personal Communication with Steve Brennan. September 18. As cited in Sachs et al, 2004.
Shipley , A.M. and R.N. Elliot, 2004. *Stationary Fuel Cells : Future Promise, Current Hype.* Washington, D.C.: American Council for an Energy Efficient Economy.

Siminovitch, M., 2004. Lawrence Berkeley National Laboratory. Personal Communication with Marc Hoeschele. January 22. As cited in Sachs et al, 2004.
Spitzley, D. V., D. E. Grande, G. A. Keoleian, and Kim, H. C. (2005). "Life cycle optimization of ownership costs and emissions reduction in the U.S. vehicle retirement decisions". University of Michigan, Ann Arbor, MI
State of California, 2005. *Executive Order S-3-05*. Executive Department, Governor Schwarzenegger.
State of California, 2006a. *Senate Bill 107.* "Renewable energy: Public Interest Energy Research, Demonstration, and Development Program." September 26.
State of California, 2006b. *Assembly Bill 32.* "California Global Warming Solutions Act of 2006." September 27.
Stover, M., 2001. Pulte Homes. Personal Communication with Marc Hoeschele.
Sunpower, 2003."Linear Compressors for Refrigeration." http://www.sunpower.com/technology/line_comp.html. Athens,Ohio: Sunpower.
Thorne,J. and S. Nadel, 2003a. *Commercial Lighting Retrofits: A Briefing Paper for Program Implementers.*Washington, D.C.: American Council for an Energy Efficient Economy.
Thorne,J. and S. Nadel, 2003b. *Retrocommissioning: Program Strategies to Capture Energy Savings in Existing Buildings.* Washington, D.C.: American Council for an Energy Efficient Economy.
Technology and Innovation Business Unit LLC (TIAX), 2002. *Application of Best Industry Practices to the Design Of Commercial Refrigerators: Development of a High Efficiency Reach-In Refrigerator.* Prepared for the U.S. Department of Energy , National Energy Technology Laboratory . Cambridge, Mass.: Technology and Innovation Business Unit LLC
Ton, M., S. Foster, and C. Calwell, 2003. *LED Lighting Technologies and Potential for Near- Term Applications.* Market Research Report # E03-114. Prepared for the Northwest Energy Efficiency Alliance. http://www.nwalliance.org/resources/reports/114ES.pdf . Portland,Oreg.: Ecos Consulting.
Unger, R.. 1999. "Development and Testing of a Linear Compressor Sized for the European Market." http://www.sunpower.com/pdf/Doc0074.pdf. Athens, Ohio: Sunpower.
US Mayors Climate Protection Agreement (US MCPA), 2007. Personal communication, Amanda Eichel. October 2.
US Department of Energy (US DOE), 1995. "Residential Heat Pump Water Heaters:Energy saving Alternative for Home Hot Water." *Federal Technology Alert.* http://www.eere.energy.gov/femp/prodtech/pdfs/FTA_res_heat_pump.pdf. Washington, D.C.: Federal Energy Management Program.
US Department of Energy (US DOE), 1995. "Unitary Air Conditioner Procurement." http://www.pnl.gov/uac. Washington, D.C.: Federal Energy Management Program.
US Department of Energy (US DOE). 2001a. *Technical Support Document for Energy Efficiency Standards for Residential Central Air Conditioners.* Washington, D.C.: U.S. Department Of Energy.
US Department of Energy (US DOE), 2002a."Fluorescent Lamp Ballast Technical Support Document." http://www.eere.energy.gov/buildings/appliance_standards/residential/gs_fluorescent_0100_r.html. Washington, D.C.: U.S. Department Of Energy., Office of Energy Efficiency and Renewable Energy.
US Department of Energy (US DOE), 2002b. *U.S. Lighting Market Characterization, Volume 1: National Lighting Inventory and Energy Consumption Estimate.* September. Prepared by Navigant Consulting. Washington, D.C.: U.S. Department Of Energy., Office of Energy Efficiency and Renewable Energy, Building Technologies Program.
US Department of Energy (US DOE), 2002c. Technical Support Document: Energy Efficiency Standards for Consumer Products Residential Central Air Conditioners and Heat Pumps , Including Regulatory Impact Analysis. http://www.eere.energy.gov/buildings/appliance_standards/residential/pdfs/title_page.pdf. Washington, D.C.: U.S. Department Of Energy.
US Department of Energy (US DOE), 2002d. *Water Heater Rating Method.* 10 CFR Ch.II (1-1-02 Edition) Pt.430,Subpt. B,App .E.
US Department of Energy (US DOE), 2002e. *In hot Water, a Newsletter,* 2(2) : 1. U.S. Department of Energy.

US Department of Energy (US DOE), 2006. *Furnaces and Boilers: Notice of Proposed Rulemaking.* http://www.eere.energy.gov/buildings/appliance_standards/residential/fb_tsd_0906.html. Accessed November 15.

US Environmental Protection Agency (EPA) (2007). "Light-Duty Automotive Technology and Fuel Economy Trends: 1975 through 2007". Appendix Q. EPA420-R-07-008. Research Park Triangle, VA

US Department of Energy (US DOE), 2007a. "A Consumer's Guide to Energy Efficiency and Renewable Energy." http://www.eere.energy.gov/consumer/. Accessed November 13.

US Department of Energy (US DOE), 2007b. "Green Power Network: Buying Green Power: Can I Buy Green Power in My State?" http://www.eere.energy.gov/greenpower/buying/buying_power.shtml?state=CA. Accessed November 17.

U.S. Energy Information Administration (U.S. EIA). *Annual Energy Outlook 2007*. U.S. Department of Energy Report DOE/EIA-0383. February 2007.

U.S. Energy Information Administration (U.S. EIA). *Electric power annual 2005 – state data tables: 1990 - 2005 net generation by state by type of producer by energy source*. U.S. Department of Energy Report DOE/EIA-906. November 2006.

US Environmental Protection Agency (US EPA), 2003a. *Commercial Solid Door Refrigerators & Freezers.*Washington,D.C.: ENERGY STAR Program.

US Environmental Protection Agency (US EPA), 2003b. *Lighting The Way to a Brighter Future.* http://www.lightingfortommorow.com/pdf/ESNewsltrJune2003.pdf. Washington, D.C.: ENERGY STAR Program.

US Environmental Protection Agency (US EPA), 2003a. "The ENERGY STAR Residential Light Fixture Advancement Project." March 15. http://energystar.gov/ia/partners/manuf_res/The_Energy_Star_RLF_Ad_Invitation.pdf. Washington, D.C.

US Environmental Protection Agency (US EPA), 2003b. "ENERGY STAR Central Air Conditioner Calculator." http://www. energystar.gov/ia/business/bulk_purchasing?bpsavings_calc?Calc_CAC.xls.

US Environmental Protection Agency (US EPA), 2004. *Guide to Purchasing Green Power: Renewalbe Electricity, Renewable Energy Certificates and On-Site Renewable Generation.* EPA-430-K-04-014. September.

US Environmental Protection Agency and US Department of Energy (US EPA and US DOE), 2007. "Office Equipment: ENERGY STAR." http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductCategory&pcw_code=OEF. Accessed November 12.

Vieira, Robin K., Danny S. Parker, John F.Klongerbo, Jeffrey K.Sonne, and Jo Ellen Cummings."How Contractors Really Size Air Conditioning Systems." http://www.fsec.ucf.edu/Bldg/pubs/Acsize.

Vineyard, Edward and James R. Sand, 1997. "Experimental and Cost Analyses of a One Kilowatt-Hour/Day Domestic Refrigerator – Freezer." *ASHRAE Transactions,* Symposia 103, Paper BN-97-7-2, 621-629.

Vorsatz, D., L. Shown, J. Koomey , M. Moezzi, A. Denver , and B. Atkinson, 1997. *Lighting Market Sourcebook for the U.S.* LBNL-39102. Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Westphalen, D. and S. Koszalinski., 1999. *Energy Consumption Characteristics of Commercial Building HVAC Systems. Volume II: Thermal Distribution, Auxiliary Equipment, and Ventilation.* Arthur D . Little , Inc. Reference No. 33745-00. Published for the U.S. Department of Energy. Contract No.: DE-AC01-96CE23798. Cambridge, Mass.: Arthur D. Little, Inc.

GLOSSARY OF TERMS, ABBREVIATIONS, AND SYMBOLS

Caltrans:	California Department of Transportation
CARB:	California Air Resources Board
CCAR:	California Climate Action Registry
CEC:	California Energy Commission
CH_4:	Methane
CO_2:	Carbon dioxide
CO_2e:	Carbon dioxide equivalent
CRT:	Cathode ray tube
GHG:	Greenhouse gas
GWP:	Global warming potential
HVAC:	Heating, ventilation, and air conditioning
IPCC:	Intergovernmental Panel on Climate Change
IT:	Information Technology
LCD:	Liquid crystal display
NO_x:	Oxides of nitrogen
PG&E:	Pacific Gas & Electric
PM:	Particulate matter
ppm:	Parts per million
UC-Davis:	University of California, Davis
US DOE:	U.S. Department of Energy
US EPA:	U.S. Environmental Protection Agency

APPENDICES

Appendix A. Yolo County Resolution No. 07-109

Resolution No. 07-109

U.S. Cool Counties Climate Stabilization Declaration

WHEREAS, there is a consensus among the world's leading scientists that global warming caused by human emission of greenhouse gases is among the most significant problems facing the world today; and

WHEREAS, documented impacts of global warming include but are not limited to increased occurrences of extreme weather events (i.e., droughts and floods), adverse impacts on plants and wildlife habitats, threats to global food and water supplies – all of which have an economic impact on communities and their local governments; and

WHEREAS, leading scientists have projected that stabilization of climate change in time to minimize such impacts will require a reduction of global warming emissions to 80 percent below current levels by the year 2050; and

WHEREAS, currently the United States is responsible for producing approximately 25 percent of the world's global warming pollutants; and

WHEREAS, many leading U.S. companies that have adopted greenhouse gas reduction programs to demonstrate corporate and operational responsibility have also publicly expressed preference for the federal government to adopt precise and mandatory emissions targets and timetables as a means by which to provide a uniform and predictable regulatory environment to encourage and enable necessary and long-term business investments; and

WHEREAS, state, regional and local governments throughout the United States are adopting emissions reduction targets and programs and that this effort is bipartisan, coming from Republican and Democratic leadership; and

WHEREAS, the U.S. Conference of Mayors has endorsed the U.S. Mayors Climate Protection Agreement, which commits cities to reduction of global warming emissions to 7 percent below 1990 levels by 2012, and calls for a federal limit on emissions; and

WHEREAS, the State of California has mandated statewide reduction of greenhouse gas emissions to 80 percent below 1990 levels by 2050; and

WHEREAS, more than 100 county leaders signed a letter written by Dane County, Wisconsin, that was sent to the President in March 2006 calling for increased energy investment and development of jobs focused on clean energy technologies; and

WHEREAS, counties have a unique role to play in reducing greenhouse gas emissions and preparing for the impacts of climate change through their regional jurisdiction over policy areas such as air quality, land use planning, transportation, zoning, forest preservation, water conservation, and wastewater and solid waste management; and

WHEREAS, the economic arguments for implementing climate solutions are compelling, from the near-term economic gains of energy efficiency to the long-term climate stabilization that can prevent irreparable harm from catastrophic climate change impacts; and

(page 1 of 2)

WHEREAS, many counties throughout the nation, both large and small, are reducing global warming pollutants through programs that provide economic and quality of life benefits such as reducing energy bills, preserving green space, implementing better land use policies, improving air quality, promoting waste-to-energy programs, expanding transportation and work choices to reduce traffic congestion, and fostering more economic development and job creation through energy conservation and new technologies.

NOW, THEREFORE, BE IT RESOLVED that we as Cool Counties will take immediate steps to help the federal, state, and governments within our county to achieve the 2050 climate stabilization goal by making the following commitments:

i. Create an inventory of our county government (operational) greenhouse gas ("GHG") emissions and implement policies, programs and operations to achieve significant, measurable and sustainable reduction of those operational GHG emissions to help contribute to the regional reduction targets as identified in paragraph ii;

ii. Work closely with local, state, and federal governments and other leaders to reduce county geographical GHG emissions to 80 percent below current levels by 2050, by developing a GHG emissions inventory and regional plan that establishes short-, mid-, and long-term GHG reduction targets, with recommended goals to stop increasing emissions by 2010, and to achieve a 10 percent reduction every five years thereafter through to 2050.

iii. Urge Congress and the Administration to enact a multi-sector national program of requirements, market-based limits, and incentives for reducing GHG emissions to 80 percent below current levels by 2050. Urge Congress and the Administration to strengthen standards by enacting legislation such as a Corporate Average Fuel Economy ("CAFE") standard that achieves at least 35 miles per gallon (mpg) within 10 years for cars and light trucks.

We will take immediate steps to identify regional climate change impacts; we will draft and implement a county plan to prepare for and build resilience to those impacts.

PASSED AND ADOPTED this 11th day of September 2007 by the following vote:

AYES: Chamberlain, McGowan, Thomson, Rexroad, Yamada.

____
Mike McGowan,
Yolo County Board of Supervisors,
District 1

____
Helen Thomson,
Yolo County Board of Supervisors
District 2

____
Mariko Yamada, Chair
Yolo County Board of Supervisors
District 4

____
Matt Rexroad, Supervisor
Yolo County Board of Supervisors
District 3

____
Duane Chamberlain, Vice-Chair
Yolo County Board of Supervisors
District 5

Appendix B. UC-Davis Sustainability Course Students

Table 22. UC-Davis student groups

Team	Student name
Administration building (equipment)	Ahmadi, Mohammad Y.
	Bacani, Jonald Jeffrey R.
	Lui, Michael
	Easton, Samuel T.
Administration building (Operations and maintenance)	Barker, Jesse R.
	Chan, Alexander S.
	Cvijanovic, Vojislav
	Gellerman, Erik M.
Davis Library (equipment)	Engelbert, Patrick R.
	Ma, Jackie S.
	Nichols, Alexandra R.
	Rockholm, Lars N.
Davis Library building (Operations and maintenance)	Green, Thomas J.
	Kawakita, Eric S.
	L'Amoreaux, Philip M.
	Nolan, Daniel B.
DESS building (equipment)	Shyu, Samuel M.
	Tsou, Allan B.
	Wai, Edgar C.
	Yousefi, Sina
DESS building (Operations and maintenance)	Palmeno, Ulises E.
	Sullivan, Ryan A.
	Tatyosian, John Y.
	Tsukamoto, Timothy T.
Appliances	Hyman, Kenneth W.
	Lam, Carl W.
	Tanaka, Kenneth H.
	Tu, Denise S.
	Wrightson, Katie J.
Vehicle fleet	Kao, Jane Y.
	Montgomery, David C.
	Munoz, Josef P.
	Shaw, Sean M.
Indirect emissions	Wendin, Caesara

Appendix C. Additional Resources for Energy Reduction

Table 23. Appliance efficiency and practices resources

Area	Link
General site	http://www.energystar.gov/index.cfm?c=home.index
Energy calculators	http://www1.eere.energy.gov/femp/procurement/eep_eccalculators.html
Office Equipment	http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductCatego ry&pcw_code=OEF
Computer, general	http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup &pgw_code=CO
Computer, product list	http://www.energystar.gov/ia/products/prod_lists/computers_prod_list.xls
Computer, energy savings calculator	http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_compute rs.xls
Computer purchasing and procurement language for contracts	http://www.energystar.gov/index.cfm?c=computers.pr_proc_computers
Computer power management	http://www.energystar.gov/index.cfm?c=power_mgt.pr_power_management
Computer power management energy savings estimator	http://pmdb.cadmusdev.com/powermanagement/quickCalc.html
Computer power management system instructions	http://www.energystar.gov/index.cfm?c=power_mgt.pr_pm_step3
Refrigerator	http://www.energystar.gov/index.cfm?c=refrig.pr_refrigerators
Refrigerator product list	http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorCo nsumerResidentialRefrigerator.xls
Water cooler, general	http://www.energystar.gov/index.cfm?c=water_coolers.pr_water_coolers
Water cooler, product list	http://www.energystar.gov/ia/products/prod_lists/water_coolers_prod_list.xls
Water cooler energy savings calculator (leasing)	http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorLea singWaterCooler.xls
Water cooler energy savings calculator (purchase)	http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorBul kPurchasingWaterCooler.xls
Copiers and scanners	http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup &pgw_code=CX
Copiers and scanners, energy saving calculator	http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_copiers. xls
Printers	http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup &pgw_code=PS
Printers, product list	http://www.energystar.gov/ia/products/prod_lists/image_equip_prod_list.xls
Printers, energy savings calculator	http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_printers. xls
Water heater practices	http://www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic= 13030
Lighting, general	http://www.energystar.gov/index.cfm?c=lighting.pr_lighting#ProductText
Compact fluorescent lights (CFL)	http://www.energystar.gov/index.cfm?c=cfls.pr_cfls
CFL product list	http://www.energystar.gov/index.cfm?fuseaction=cfls.display_products_excel
CFL energy saving calculator	http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CFLs_B ulk.xls
Fluorescent tube lighting (T8)	http://www1.eere.energy.gov/femp/procurement/eep_fluortube_lamp.html
Exit light, product list	http://www.energystar.gov/ia/products/prod_lists/exit_signs_prod_list.xls
Exit light, saving calculator	http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Exit_Si gns.xls
Packaged A/C calculator	http://www1.eere.energy.gov/femp/procurement/eep_unitary_ac_calc.html
Air-cooled chiller calculator	http://www1.eere.energy.gov/femp/procurement/eep_ac_chillers_calc.html
Water-cooled chiller calculator	http://www1.eere.energy.gov/femp/procurement/eep_wc_chillers_calc.html
Heat pump calculator	http://www1.eere.energy.gov/femp/procurement/eep_comm_heatpumps_calc.html
Boiler energy calculator	http://www1.eere.energy.gov/femp/procurement/eep_boilers_calc.html
Furnace calculator	http://energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Furnaces.xls

Appendix D. Example Calculations of GHG Emissions from Vehicles

As described previously in the report, the equation for calculating GHE emissions for conventional transportation fuels (such as reformulated gasoline and diesel fuel) is:

$$\begin{pmatrix} Vehicle \\ GHG \\ Emissions \end{pmatrix} = \left(\frac{gallon\_fuel}{mile}\right) \times \left(\frac{CO_2\_equivalent}{gallon\_fuel}\right) \times \left(\frac{miles}{year}\right)$$

Suppose we're evaluating the GHG emissions from a gasoline vehicle with a fuel economy of 25 mpg driving 12,000 miles/yr. If we assume that the carbon content of the gasoline dictates a CO_2e emissions rate of roughly 8.55 kg/gallon, then the equation to determine the vehicle's GHG emissions can be set up as:

$$\begin{pmatrix} Vehicle \\ GHG \\ Emissions \end{pmatrix} = \left(\frac{1\_gallon\_gas}{25\_mile}\right) \times \left(\frac{8.55\_kg\_CO_2e}{1\_gallon\_gas}\right) \times \left(\frac{12,000\_miles}{year}\right)$$

For this example, the vehicle produces 4.1 metric tons of CO2e per year. To modify this equation to calculate the emissions for an electric vehicle, simply replace the fuel economy term with a term describing electricity consumption (such as kW-hrs/mile) and replace the gasoline CO2e emissions rate with an equivalent electricity emissions rate (kg/kW-hr).

Appendix E. Fuel Economy and Price for EPA-Selected 2007 Model Year Vehicles

Vehicle Class	Make	Model	Fuel Economy (mpg)	Price ($US)
Subcompact	Toyota	Yaris	43	$12,000
Subcompact	Honda	Civic	42	$14,000
Subcompact	GM	Aveo 5	36	$10,000
Subcompact	GM	G5 Pursuit	35	$14,500
Subcompact	Toyota	IS 250	32	$32,000
Compact	Honda	Civic Hybrid	59	$21,000
Compact	Toyota	Corolla	42	$14,000
Compact	Kia	Rio	39	$10,500
Compact	Hyundai	Accent	38	$10,500
Compact	Mazda	Mazda3	36	$13,500
Compact	Ford	Focus FWD	36	$14,000
Compact	GM	Aveo	35	$12,000
Compact	GM	Ion	35	$12,000
Midsize	Toyota	Prius	66	$20,000
Midsize	Nissan	Altima Hybrid	47	$24,000
Midsize	Toyota	Camry Hybrid	46	$23,500
Midsize	Nissan	Versa	38	$12,500
Midsize	Hyundai	Elantra	37	$13,000
Midsize	Honda	Accord Hybrid	36	$29,000
Large	Hyundai	Sonata	33	$17,000
Large	Toyota	Avalon	30	$25,000
Midsize Pickup	Ford	Ranger 2WD	30	$13,500
Midsize Pickup	Toyota	Tacoma 2WD	30	$13,500
Midsize Pickup	GM	Colorado 2WD	26	$14,000
Large Pickup	Nissan	Frontier 2WD	27	$15,500
Large Pickup	GM	Colorado CC 2WD	26	$16,500
Large Pickup	Toyota	Tacoma 4WD	22	$14,500
Midsize Van	Toyota	Sienna 2WD	29	$22,000
Midsize Van	Ford	Freestyle FWD	27	$24,500
Midsize Van	Honda	Odyssey 2WD	25	$24,000
Midsize Van	GM	Uplander FWD	25	$20,500
Large Van	GM	G1500-2500	21	$38,000
Large Van	GM	G1500-2500 E	20	$38,000
Midsize Utility	Ford	Escape Hybrid	41	$26,000