A Carbon Footprint Benchmarking Tool for Small and Medium-Sized Businesses

Methods and Materials

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A. Detailed Methods of Benchmark Business Carbon Footprint Model

A carbon footprint of a business may be defined as the greenhouse gas emissions required to produce all economic activity of the enterprise. Emissions occur directly from burning fossil fuels and indirectly through the production of goods and services used by the business. For the purposes of the carbon calculator we aggregate emissions into three major categories: transportation, facilities (energy, waste and construction) and procurement. A basic formula for the carbon footprint of a business is:

$$\textbf{GHG Emissions (MT of } \mathbf{CO_2}\textbf{)} = \textbf{Transportation} + \textbf{Energy} + \textbf{Waste} + \textbf{Procurement}$$

1) Transportation

$$\textbf{GHG Emissions (MT of } \mathbf{CO_2}\textbf{)} = \sum_{i=1}^{4}\left[\left(\frac{\text{miles}}{\text{yr}}\right)_i \times \left(\frac{\text{gallon}}{\text{miles}}\right)_i \times \left(\frac{CO_2}{\text{gallon}}\right)_i\right]$$

i=1: Company vehicles (gasoline/diesel)
2: Air travel
3: Public transportation
4: Employee commute (optional)

2) Energy Consumption

$$\textbf{GHG Emissions (MT of } \mathbf{CO_2}\textbf{)} = \sum_{i=1}^{n}[(\text{Electricity used})_i + (\text{Natural Gas})_i + (\text{Other fuels})]$$

$$= \sum_{i=1}^{n}\left[\left(\frac{\text{kWh}}{\text{yr}} \times \frac{CO_2}{\text{kWh}}\right)_i + \left(\frac{\text{therms}}{\text{yr}} \times \frac{CO_2}{\text{therms}}\right)_i + \left(\frac{\text{gallon}}{\text{year}} \times \frac{CO_2}{\text{gallon}}\right)_i\right]$$

n= # of facilities

3) Procurement

$$\textbf{GHG Emissions (MT of } \mathbf{CO_2}\textbf{)} = \frac{\text{MT } CO_2}{\$} \times (\text{estimated revenue})$$

The biz calculator uses Economic Input-Output Life Cycle Assessment[3] (EIO-LCA) to calculate emissions from supply chains. The basic approach is to match line item expenditures of a business to a sector of the economy in EIO-LCA. The Calculator allow users to adjust emissions based on 20 different expenditures categories (different categories for each business based on the largest contributors).

1. Motor Vehicles

Emissions from motor vehicles include: 1) direct tailpipe emissions from fuel combustion in vehicles, 2) indirect "well-to-pump" emissions from the pre-consumer life cycle of fuels, 3) vehicle manufacturing, and 4) vehicle maintenance and repairs (including parts and services). Government-related indirect emissions from road construction and maintenance, policing, and other activities are currently not included in the model.

1.1. Direct tailpipe emissions

Direct tailpipe emissions from motor vehicles for each sector are estimated per dollar of revenue based on the Economic Input-Output Life Cycle Assessment model (EIO-LCA) as shown in Table 1. Twelve basic sectors in the calculator are mapped to U.S. business sectors in EIO-LCA. Miles per dollar of revenue are converted from estimates of gasoline consumption per dollar of revenue for each sector.

[3] www.eiolca.net

Table 1. Average gallons of gasoline consumption and vehicle miles traveled for U.S. business sectors

Calculator Sector	EIOLCA sector	Gasoline (TJ)/$M	gallons	miles (@20mpg)	miles/$
Education	Elementary schools	0.057	438	8,769	0.0088
Retail (food)	Retail trade	0.07	538	10,769	0.0108
Restaurant & food service	Food service & drinking places	0.035	269	5,385	0.0054
Health care	Hospitals	0.041	315	6,308	0.0063
Hotels & lodging	Hotels and motels	0.019	146	2,923	0.0029
Retail (other than food)	Retail trade	0.07	538	10,769	0.0108
Office	Office administrative services	0.091	700	14,000	0.0140
Public assembly	Promoters of performing arts	0.017	131	2,615	0.0026
Religious	Religious organizations	0.053	408	8,154	0.0082
Services	Other personal services	0.016	123	2,462	0.0025
Warehouse & storage	Warehousing	0.161	1,238	24,769	0.0248
Other	Straight average of all	0.057	441	8,811	0.0088

The average U.S. worker drove 4,288 miles for normal work-related travel and 241 miles of long-distance work-related travel.[4] We also include (optional) employee commute with a default of 5,400 commute miles per year = 12 miles x two directions x 225 work days per year. The weighted fuel economy of the U.S. vehicle fleet is about 22 miles per gallon (*1*). We assume a business fuel economy of 20 mpg. Combustion of a gallon of gasoline produces 8,874 gCO_2 and diesel produces 10,153 gCO_2 (*2*). For benchmarking purposes, all vehicles are initially assumed to be gasoline since diesel vehicles account for only a small fraction of the U.S. vehicle fleet, although users of the online tool[5] can further specify gasoline or diesel fuel type. Other vehicle fuels (e.g., biofuels and electricity) are currently not included in the model. Direct emissions are calculated as: $ revenues * miles per $ / 20 mpg * 8,874 gCO_2/gallon. Total miles are estimated as a single item in the calculator, but users can choose to break the miles into different vehicle classes, each with corresponding mpg.

1.2. Indirect "well-to-pump" emissions

Estimating emissions from the full life cycle of transportation fuels (from "well-to-wheels") has become increasingly important aspect of transportation policy. In order to compare emissions from disparate transportation energy sources, such as biofuels, natural gas and electricity, a life cycle

[4] http://www.bts.gov/publications/transportation_statistics_annual_report/2003/html/chapter_02/

assessment (LCA) approach is required. California's "Low Carbon Fuel Standard" (LCFS) mandates life cycle accounting in an effort to increase the use of low carbon transportation fuels in the State. The LCFS policy analysis report of 2007 (*3*) identifies 20% as a typical value of well-to-pump emissions for gasoline, citing the GREET (*4*) model in its technical report (*5*). Well-to-pump (WTP) gasoline emissions in GREET are 26% of tailpipe emissions (or roughly 20% of well-to-wheel emissions), while diesel WTP emissions are 23% of direct emissions. Delucci's (*6*) estimate of 20,778 gCO_2e/106 btu for pre-combustion gasoline emissions equates to 29% of direct emissions. EIO-LCA (*7*) produces a more conservative estimate of about 14% (*8*) and other studies have previously assumed a value closer to this lower estimate (*9*,*10*). The LCFS program in California is currently developing default well-to-wheels emission factors for transportation fuels, and a similar effort has been proposed at the national level. Until standard default values are determined by state or national policy directives, we have chosen the GREET model as the most representative emission factors for well-to-pump emissions.

1.3. Vehicle manufacturing

EIO-LCA is used to approximate emissions from motor vehicle manufacturing. The average retail price of a domestic automobile was $17,907 (*11*) in 1997. The average producer price was 80% of the retail price (*12*), or $14,326. Applying the 1997 EIO-LCA emission factor of 628 gCO_2e/$ for the "Automobile and light truck manufacturing sector" in EIO-LCA results in 9.0 $mtCO_2e$ per vehicle. This estimate is consistent with process-based LCA studies, which include the most significant emissions from vehicle manufacturing, but exclude economy-wide impacts further up the supply chain. Published studies include estimates of 4.4 $mtCO_2e$ for a Volkswagen Golf (*13*), 8-9 $mtCO_2e$ for Ford Galaxy and

[5] Results of this study have been made available in an open access online carbon management tool for U.S. households, available at http://coolclimate.berkeley.edu and http://coolcalifornia.org/calculator.

S-Max models (*14*), 9-10 $mtCO_2e$ for Mercedes S Class models (*15*) and 6.8 $mtCO_2e$ from vehicle components and assembly over the lifetime of a typical vehicle in the GREET (*16*) model.

Allocating emissions from motor vehicles, as with other consumer goods with long life spans, presents challenges to carbon footprint calculator designers. Should upstream emissions from the production of vehicles be allocated at the time of purchase, or over the lifetime of the vehicle? When a vehicle is sold, what portion of manufacturing emissions should be allocated to the new owner? Allocating emissions at the time of purchase produces a disincentive to purchase new, and potentially more fuel efficient vehicles. If, on the other hand, emissions are allocated over the lifetime of vehicles on a per-mile-basis, there is no incentive to reduce the very significant emissions from vehicle manufacturing. For the current calculator we chose to allocate emissions from vehicle manufacturing on a per mile basis for the following reasons: 1) the preferred method of allocation based on vehicle deprecation was not feasible, 2) allocating emissions on a per mile basis sends a signal to reduce vehicle miles traveled, which is arguably more important than limiting production of motor vehicles, and, 3) encouraging the purchase of more fuel efficient vehicles stimulates innovation, which can lead to future emission reductions.

Emissions per vehicle mile are calculated as:

$$\frac{9tCO2e}{vehicle} * \frac{vehicle}{160{,}000 miles} = \frac{56kgCO2e}{mile}$$

where 160,000 miles is the average expected lifetime of motor vehicles (*17*)

1.4. Vehicle maintenance and repairs

EIO-LCA is used to approximate emissions from motor vehicle maintenance and repairs. See Procurement discussion below.

2. Public Transportation

We used EIO-LCA to estimate benchmark public transportation expenditures per dollar of revenue. We then break out public transit miles for each mode (bus, train, light rail) based on averages provided by the Transportation Energy Data Book, 2007 (*22*). Air travel accounted for 93% of total passenger miles for all major public transport modes in 2004.

The final calculation for public transportation is:

$$\frac{\$}{year} * \frac{9.4 miles}{\$} * \frac{miles_{mode}}{miles_{total}} * \frac{CO2e}{mile_{mode}}$$

Emission factors for public transit modes are from the Greenhouse Gas Protocol (*18*), which incorporates studies by EPA and other sources (Table 1.5). These estimates assume average occupancy of public transit modes.

Table 1.5. Emission factors for public transit

Mode	gCO2e/mile
Bus	300
commuter rail (light & heavy)	165
transit rail (subway, tram)	160
Amtrak	191

Source: Greenhouse Gas Protocol (WRI-WBCSD)

Indirect well-to-pump emissions from transportation fuels are assumed to be 26% of direct emissions, as indicated by the GREET model (*19*)

3. Air Travel

Benchmark consumption of jet fuel is provided by EIOLCA per dollar of revenue for each sector. Air travel results in 1) direct CO_2 emissions from fuel combustion, 2) indirect life cycle ("well-to-pump") GHG emissions from fuel processing and other indirect emissions from the airline industry, and 3) non-CO_2 atmospheric effects on global and local temperatures and weather patterns.

GHG emissions from consumption have been shown to vary substantially depending on aircraft type, flight distance, number of stops, seat occupancy rate and seat class (*20*). Few online calculators, however, present this level of customization, presumably due to the additional modeling efforts required and the preference to build simple, user-friendly interfaces that require less time to complete. DEFRA, 2007 (*21*) is commonly cited as a reference for GHG emission factors. This report considers typical flights within the U.K., within the E.U. and transatlantic flights. Trip length and emission factors, converted to miles and gCO_2 per passenger mile, are:

Trip length	gCO2/passenger-mile
288 miles	254
688 miles	210
4027 miles	170

Shorter flights have higher emission factors due to relatively higher emissions at takeoff and landing per passenger-mile. Extrapolating these numbers using a logarithmic curve, and assuming typical trip length of ~1200 miles (*22*), yields the following emissions estimates per given trip length.

Trip length	gCO2/passenger-mile
Number of short flights (<400 mi)	254
Number of medium flights (400-1500)	204
Number of long flights (1500-3000)	181
Number of extended flights (>3000)	172
Typical flight (1200)	200

Indirect "well-to-pump" emissions are assumed to be 26% of direct emissions, following the GREET model (*23*). Other indirect emissions, e.g., from the airline industry, are excluded from this analysis.

Airplanes traveling at high altitude have large, varied and relatively uncertain effects on surface temperature. These impacts include warming from 0_3, H_20, soot, contrails and cirrus clouds, and cooling effects from breakdown of CH_4 and emissions of sulfates and aerosols. The average net result on global radiative forcing -not including the large but uncertain effects from cirrus clouds- is reported to be roughly equivalent to the warming effect of direct CO_2 emissions from fuel consumption (*24*). However, simply multiplying CO_2 emissions by a factor to account for radiative forcing can lead to false conclusions (*25*). The climate impact of individual flights varies considerably, ranging from net cooling in some cases to flights with several times the impact of typical flights. The particular contribution of warming and cooling factors depends on altitude, temperature, humidity, the chemical composition of air, geographic region, time of day, season and other factors. Impacts also occur over vastly different time scales, ranging from hours to centuries, thus complicating the selection of global warming potential of a single pulse of emissions. Furthermore, net radiative forcing models assume that warming in one location cancels cooling in another, rather than producing separate distinguishable impacts on local climates.

Despite the limitations of using radiative forcing, carbon calculator modelers need some way to express climate impacts from air travel without relying on highly complex models with detailed and time-consuming user interfaces. In the absence of standards, carbon footprint calculator modelers have typically chosen to either ignore non-CO_2 impacts, or include a factor to account for radiative forcing. In the current version of the calculator we use the radiative forcing multiplier of 1.9 as proposed by Sausen et al. (29) to account for non-CO_2 impacts. While this factor is not specific to individual flights is it is a reasonable representation of average climate impacts from air travel. This approach is consistent with the assumption of typical impacts from consumption in the rest of the calculator. The total multiplier to account for for non-CO_2 atmospheric effects and well-to-pump emissions (1.9 + 0.26) is rounded to 2, i.e., total air travel emissions = direct emissions x 2. This is very likely a conservative number considering we have not included the large but uncertain global warming impact of cirrus cloud formation or emission from airports.

4. Energy

Consumption of electricity and natural gas is estimated per business sector by square feet of buildings and climate zone using the Commercial Building Energy Consumption Survey (CBECS). Users can convert from estimates in dollars (default) or physical units. Fuel prices per U.S. state are from Energy Information Agency (EIA). We assume 47 gallons of other fuels for each business using a national building average from CBECS.

Direct emissions from energy

Businesses contribute direct GHG emissions from the burning of fossil fuels. Natural gas is typically the largest single contributor to direct emissions for U.S. buildings. Natural gas is assumed to produce 117 lbs CO_2/Mbtu (26). Considering the relatively small contribution to total GHG emissions from other fuels for most businesses, we use a single emission factors of 682 gCO_2e/$ provided by the EIO-LCA (*11*) model. Other direct emissions from wood burning, fertilizers, and chemical processes are assumed to be relatively small in comparison to other categories of emissions and are excluded from the current analysis.

Indirect emissions from electricity production

Greenhouse gas emission factors (EF) for electricity are from eGRID (*27*). This database aggregates air emissions for each generator at thousands of electricity power plants in the United States. Aggregation is available at the level of U.S. states and 25 grid sub-regions. The eGRID data provided at the level of U.S. states account for generated electricity only, excluding imports and exports of electricity, and therefore are not appropriate for the development of carbon footprint calculators. EPA recommends the use of eGRID sub-regions for accounting purposes; however, sub-regions do not always correspond well with U.S. states, which is currently the only geographic information asked by users in our online model. As a partial solution to this problem, we map the boundaries of U.S. states to individual eGRID subregions, with the exception of New York, which is assumed to be the average of three subregions.[6] In the case of California, users can select electric utility provider, with GHG emission factors for the year 2006 provided by the California Air Resources Board (*28*), as reported to the California Climate Action Registry.

Indirect emissions from electricity and natural gas life cycles

Electricity consumption also indirectly results in GHG emissions during the production, processing, transmission and storage of fuel, as well as during the construction and maintenance of power plants. Pacca and Horvath (*29*) first approximated pre-combustion and construction life cycle emissions from coal, natural gas, wind, hydro and solar power plants in the Upper Colorado River Basin. Total life cycle emissions were 9% higher than emissions from combustion alone for a coal-fired power plant and 14% higher for a natural gas plant. Using a different methodology, Jaramillo et al (*30*) produced roughly the same results for these fuel sources. We developed pre-combustion indirect electricity emission

[6] We are currently conducting research to offer more geographically-specific electricity emission factors in future versions of the calculator, but this work was not completed at the time of this writing.

factors for each eGRID subregion by multiplying the fuel mix in each region by emission factors (tCO2e/MWh) provided by Pacca and Horvath. When state boundaries include more than one eGRID subregion we used the average fuel mix for those regions. The results are shown in the table below. For the average U.S. fuel mix, pre-combustion emissions are 9% of combustion emissions. With the exception of Alaska, which is dominated by hydro power, indirect emissions are between 8%-12% of direct emissions. Considering the margin of error in this analysis is likely greater than the difference between indirect emission factors for U.S. states, the current online model applies the U.S. average indirect factor for all U.S. states. Future online versions of the calculator may incorporate the state-specific factors.

We assume indirect emissions from natural gas (including extraction, processing and piping natural gas to homes) add 14% to direct emissions per Jaramillo et al. (*37*).

tCO2e per 5.55 MWh/yr capacity of electricity generation per U.S. state and eGRID subregion

		Direct*			Indirect**						Indirect
State (eGRID subregion)	%***	Coal	Gas	Total	Coal	Gas	Wind	Hydro	Solar	Total	/ Direct
USA	78%	37.85	8.92	46.77	3.11	1.23	0.02	0.03	-	4	9%
Alabama (SRSO)	0.79	50.51	4.53	55.04	4.15	0.62	-	0.02	-	5	9%
Alaska (AKMS)	0.70	-	1.53	1.53	-	0.21	0.00	0.34	-	1	36%
Arizona (AZNM)	0.81	35.70	13.06	48.76	2.93	1.80	0.00	0.02	0.00	5	10%
Arkansas (SRMV)	0.68	16.54	18.66	35.20	1.36	2.58	-	0.01	-	4	11%
California (CAMX)	0.74	9.29	17.46	26.75	0.76	2.41	0.02	0.09	0.03	3	12%
Colorado (RMPA)	1.00	55.94	8.04	63.98	4.59	1.11	0.01	0.04	-	6	9%
Connecticut (NEWE)	0.58	11.82	15.14	26.96	0.97	2.09	0.00	0.03	-	3	11%
Delaware (RFCE)	0.56	35.19	3.98	39.17	2.89	0.55	0.00	0.00	-	3	9%
District of Columbia (SRVC)	0.57	39.38	2.04	41.42	3.23	0.28	-	0.01	-	4	9%
Florida (FRCC)	0.65	20.48	16.12	36.60	1.68	2.23	-	0.00	-	4	11%
Georgia (SRSO)	0.79	50.51	4.53	55.04	4.15	0.62	-	0.02	-	5	9%
Hawaii (HIMS)	0.05	1.15	-	1.15	0.09	-	0.00	0.02	-	0	10%
Idaho (NWPP)	0.95	26.81	4.48	31.29	2.20	0.62	0.01	0.25	-	3	10%
Illinois (RFCW)	0.76	56.83	1.13	57.96	4.67	0.16	0.00	0.00	-	5	8%
Indiana (RFCW)	0.76	56.83	1.13	57.96	4.67	0.16	0.00	0.00	-	5	8%
Iowa (MROW)	0.84	57.37	1.67	59.04	4.71	0.23	0.02	0.02	-	5	8%
Kansas (SPNO)	0.85	61.07	2.45	63.52	5.02	0.34	0.01	0.00	-	5	8%
Kentucky (SRTV)	0.78	52.08	1.48	53.56	4.28	0.20	-	0.04	-	5	8%
Louisiana (SRMV)	0.88	64.89	1.45	66.34	5.33	0.20	-	0.01	-	6	8%
Maine (NEWE)	0.58	11.82	15.14	26.96	0.97	2.09	0.00	0.03	-	3	11%
Maryland (RFCE)	0.56	35.19	3.98	39.17	2.89	0.55	-	0.00	-	3	9%
Massachusetts (NEWE)	0.58	11.82	15.14	26.96	0.97	2.09	0.00	0.03	-	3	11%
Michigan (RFCM)	0.81	52.20	5.68	57.88	4.29	0.78	-	-	-	5	9%
Minnesota (MROW)	0.84	57.37	1.67	59.04	4.71	0.23	0.02	0.02	-	5	8%
Mississippi (SRSO)	0.79	50.51	4.53	55.04	4.15	0.62	-	0.02	-	5	9%
Missouri (SRMW)	0.88	64.89	1.45	66.34	5.33	0.20	-	0.01	-	6	8%
Montana (NWPP)	0.95	26.81	4.48	31.29	2.20	0.62	0.01	0.25	-	3	10%
Nebraska (MROW)	0.84	57.37	1.67	59.04	4.71	0.23	0.02	0.02	-	5	8%
Nevada (NWPP)	0.95	26.81	4.48	31.29	2.20	0.62	0.01	0.25	-	3	10%
New Hampshire (NEWE)	0.58	11.82	15.14	26.96	0.97	2.09	0.00	0.03	-	3	11%
New Jersey (RFCE)	0.56	35.19	3.98	39.17	2.89	0.55	0.00	0.00	-	3	9%
New Mexico (AZNM)	0.81	35.70	13.06	48.76	2.93	1.80	0.00	0.02	0.00	5	10%
New York (YNLI/NYCW/NYUP)	0.44	5.60	11.73	17.33	0.46	1.62	0.00	0.05	-	2	12%
North Carolina (SRVC)	0.57	39.38	2.04	41.42	3.23	0.28	-	0.01	-	4	9%
North Dakota (MROW)	0.84	57.37	1.67	59.04	4.71	0.23	0.02	0.02	-	5	8%
Ohio (RFCW)	0.76	56.83	1.13	57.96	4.67	0.16	0.00	0.00	-	5	8%
Oklahoma (SPSO)	0.98	43.44	15.45	58.90	3.57	2.13	0.01	0.02	-	6	10%
Oregon (NWPP)	0.95	26.81	4.48	31.29	2.20	0.62	0.01	0.25	-	3	10%
Pennsylvania (RFCE)	0.56	35.19	3.98	39.17	2.89	0.55	0.00	0.00	-	3	9%
Rhode Island (NEWE)	0.58	11.82	15.14	26.96	0.97	2.09	0.00	0.03	-	3	11%
South Carolina (SRVC)	0.57	39.38	2.04	41.42	3.23	0.28	-	0.01	-	4	9%
South Dakota (MROW)	0.84	57.37	1.67	59.04	4.71	0.23	0.02	0.02	-	5	8%
Tennessee (SRTV)	0.78	52.08	1.48	53.56	4.28	0.20	-	0.04	-	5	8%
Texas (ERCT)	0.86	28.92	19.63	48.55	2.38	2.71	0.01	0.00	-	5	10%
Utah (NWPP)	0.95	26.81	4.48	31.29	2.20	0.62	0.01	0.25	-	3	10%
Vermont (NEWE)	0.58	11.82	15.14	26.96	0.97	2.09	0.00	0.03	-	3	11%
Virginia (SRVC)	0.57	39.38	2.04	41.42	3.23	0.28	-	0.01	-	4	9%
Washington (NWPP)	0.95	26.81	4.48	31.29	2.20	0.62	0.01	0.25	-	3	10%
West Virginia (RFCW)	0.76	56.83	1.13	57.96	4.67	0.16	0.00	0.00	-	5	8%
Wisconsin (MROE)	0.84	53.02	4.95	57.98	4.35	0.68	0.00	0.02	-	5	9%
Wyoming (NWPP)	0.95	26.81	4.48	31.29	2.20	0.62	0.01	0.25	-	3	10%

* Includes direct fuel combustion emissions from coal and natural gas power plants, as reported by Pacca and Horvath, 2002

** Includes indirect emissions from precombustion, steel, concrete and aluminum for hydro, wind and solar PV power plants, as reported by Pacca and Horvath, 2002

* *E*lectricity generation from coal, natural gas, hydro, wind and solar as a fraction of the total resources mix, as reported by eGRID. Resouces not included are nuclear, oil, geothermal, biomass, other fossil fuel and unknown sources

5. Waste

Production of waste and corresponding GHG emissions are calculated using the CalRecycle Carbon Calculator. CalRecycle provides average tons of waste and waste diversion per employee for each sector (Table 2) in addition a unique waste composition profile and corresponding GHG intensity per cubic yard of waste (Table 3).

Table 2. Disposal and Diversion rates per business sector

	Disposal	Diversion	Total	Diversion rate
	tons/employee	tons/employee	tons/employee	percent
Wholesale Durables	1.23	1.13	2.36	48%
Wholesale Nondurables	1.43	2.03	3.47	59%
Building Material, & Garden Big Box Sto	3.17	1.34	4.52	30%
Food Stores	2.38	5.91	8.29	71%
Retail Big Box Stores	1.43	2.47	3.90	63%
Hotels - Large	1.95	0.57	2.52	23%
Restaurants - Fast Food	2.13	1.13	3.26	35%
Restaurants - Sit Down	2.20	1.02	3.22	32%
Retail - Automotive Dealers and Servic	0.60	0.70	1.30	54%
Retail - Apparel and Furniture	1.30	1.51	2.81	54%
Retail - Misc.	0.90	1.04	1.94	54%
Trucking and Warehousing	1.90	1.74	3.64	48%
Motion Picture Industry	0.90	0.45	1.35	33%
Communications	0.30	0.45	0.75	60%
Finance, Insurance, Real Estate	0.60	0.45	1.05	43%
Services - Business Services	1.70	0.45	2.15	21%
Services - Education	0.80	0.45	1.25	36%
Services - Medical/Health	1.00	0.45	1.45	31%
Services - Other Misc.	0.90	0.45	1.35	33%
Services - Other Professional	1.20	0.45	1.65	27%
Government Facilities	0.90	0.45	1.35	33%
Hotels - Small	3.00	0.57	3.57	16%
Multi-Family	0.96	0.09	1.05	9%
Manufacturing - Food / Kindred	1.60	1.13	2.73	41%
Manufacturing - Apparel and Textiles	0.90	1.13	2.03	56%
Manufacturing - Lumber & Wood Produ	3.10	1.13	4.23	27%
Manufacturing - Paper and Allied Produ	1.00	1.13	2.13	53%
Manufacturing - Printing / Publishing	0.80	1.13	1.93	59%
Manufacturing - Chemicals and Allied P	0.90	1.13	2.03	56%
Manufacturing - Other	3.10	1.13	4.23	27%
Manufacturing - Primary and Fabricated	1.00	1.13	2.13	53%
Manufacturing - Industrial / Machinery	0.20	1.13	1.33	85%
Manufacturing - Electronic Equipment	0.50	1.13	1.63	69%
Manufacturing - Transportation Equipm	0.40	1.13	1.53	74%
Manufacturing - Furniture and Fixtures	6.40	1.13	7.53	15%

Table 3. Composition of waste stream and GHG emissions factor per business sector

	cardboard	paper	glass	mixed_metals	mixed_plastics	food_scraps	yard_waste	lumber	other	kgCO2 per cubic yard
Select	7%	18%	2%	4%	2%	15%	4%	8%	41%	25.8
Wholesale Nondurables	11%	8%	0%	2%	1%	27%	4%	10%	35%	32.0
Wholesale Durables	10%	10%	1%	5%	1%	3%	1%	30%	40%	4.3
Trucking and Warehousing	7%	22%	1%	8%	2%	4%	2%	13%	40%	15.0
Services - Other Professional	4%	21%	2%	1%	1%	12%	22%	2%	35%	20.9
Services - Other Misc.	7%	15%	2%	8%	3%	13%	7%	3%	43%	25.3
Services - Medical/Health	8%	19%	1%	2%	3%	21%	2%	0%	46%	36.5
Services - Finance, Insurance, Real Estate	4%	41%	1%	3%	3%	17%	1%	0%	32%	35.2
Services - Communications	8%	34%	1%	2%	1%	4%	1%	5%	44%	22.5
Services - Business Services	7%	20%	3%	1%	2%	7%	6%	3%	52%	23.3
Retail - Misc.	6%	10%	0%	3%	1%	18%	3%	15%	43%	24.0
Retail - Grocery Stores	12%	25%	2%	2%	1%	4%	9%	2%	43%	19.8
Retail - Building Material, & Garden Big Box Stores	4%	4%	1%	1%	1%	63%	1%	4%	21%	63.2
Retail - Big Box Stores	6%	4%	0%	4%	0%	2%	2%	33%	48%	1.8
Retail - Apparel and Furniture	9%	20%	0%	2%	1%	3%	0%	11%	55%	18.3
Retail - Automotive Dealers and Service	10%	14%	3%	10%	4%	6%	3%	6%	44%	18.8
Restaurants - Sit Down	4%	6%	3%	3%	1%	66%	0%	1%	17%	67.3
Restaurants - Fast Food	5%	7%	1%	1%	2%	51%	0%	1%	33%	57.4
Motion Picture Industry	11%	31%	2%	2%	2%	10%	3%	6%	34%	24.3
Manufacturing - Transportation Equipment	10%	21%	1%	7%	1%	5%	1%	15%	40%	15.2
Manufacturing - Printing / Publishing	10%	41%	1%	5%	2%	3%	1%	7%	31%	19.8
Manufacturing - Primary and Fabricated Metal	5%	14%	1%	11%	6%	4%	1%	9%	50%	17.1
Manufacturing - Paper and Allied Products	5%	32%	2%	4%	1%	4%	0%	5%	47%	22.9
Manufacturing - Other	7%	13%	0%	4%	1%	2%	4%	15%	54%	12.7
Manufacturing - Lumber & Wood Products	4%	8%	1%	7%	1%	1%	1%	35%	43%	0.2
Manufacturing - Industrial / Machinery	10%	19%	1%	11%	1%	3%	4%	9%	42%	15.3
Manufacturing - Furniture and Fixtures	4%	2%	0%	3%	1%	5%	1%	9%	76%	20.6
Manufacturing - Food / Kindred	6%	12%	1%	4%	2%	22%	0%	6%	46%	33.4
Manufacturing - Electronic Equipment	7%	19%	2%	8%	2%	6%	1%	5%	50%	22.0
Manufacturing - Chemicals and Allied Products	6%	14%	0%	2%	4%	3%	0%	8%	62%	19.3
Manufacturing - Apparel and Textiles	1%	16%	0%	0%	0%	4%	0%	0%	77%	27.2
Hotels - Small	6%	25%	7%	1%	1%	33%	4%	5%	17%	40.0
Hotels - Large	3%	21%	4%	2%	2%	36%	4%	4%	23%	43.1
Government Facilities	5%	20%	7%	3%	3%	23%	4%	2%	34%	34.8
Education - Univerisities, junior colleges	3%	17%	1%	4%	2%	20%	27%	0%	24%	24.2
Education - Elementary schools	3%	17%	1%	4%	2%	20%	27%	0%	24%	24.2

6. Building Construction

The average square feet of buildings for each sector is from CBECS. An emissions factor of 930 gCO_2 per square feet is applied following Jones and Kammen (2010).

7. Procurement

We use the Economic Input-Output Life Cycle Assessment model (*10*), EIO-LCA, designed by the Green Design Institute at Carnegie Mellon University, and the Comprehensive Environmental Database Archive (*31*), CEDA4.0 to calculate emissions from Procurement. EIO-LCA and CEDA are widely used economy-wide models of cradle-to-gate emissions of all major greenhouse gases for >420 economic sectors of the U.S. economy, of which 289 sectors are applicable to consumer demand (the rest are intermediate goods). Since emission factors are provided per dollar of industry output, and not per dollar of consumer expenditure, only the fraction of consumer dollars that is received by manufacturing industries should be input into EIO-LCA to determine emissions from manufacturing (*32*). We further calculate separate emission factors for transport to market (truck, rail, air) and wholesale and retail trade by multiplying the fraction of consumer dollars received at each life cycle stage to the corresponding emission factor in EIO-LCA, similar to (*33,34*) and outlined in (*35*). In order to update these emission factors from 1997 benchmark year, we adjust for inflation using the Producer Price Index (PPI).(*36*)

New EIO-LCA greenhouse gas emission factors for 2005 are therefore estimated as:

$$EF_{C,i} = \left(\frac{PV_i}{CV_i} * EF_{P,i} + \frac{Truck}{CV_i} * EF_{P,t} + \frac{Rail}{CV_i} * EF_{P,r} + \frac{Air}{CV_i} * EF_{P,a} + \frac{WT}{CV_i} * EF_{P,wt} + \frac{RT}{CV_i} * EF_{P,rt} \right) * PPI_i$$

where GHG emission factor (EF) is given in consumer dollars (C) or producer dollars (P) for each industry (i). PV represents the total value received by the producing industry (i) of dollars spent by consumers (CV) of commodities from industry (i). Truck, Rail and Air represent the value received by each sector to ship products to market, while wholesale trade (WT) and retail trade (RT) is the value-added from wholesale and retail trade.(*37*) Emission factors (EF) for trucking (t), rail transport (r), air transport (a), wholesale trade (wt) and retail trade (rt) are in given in producer dollars in EIO-LCA. The sum of all factors produces total emissions per consumer dollar at the point of sale for each of 589 commodities or services in the BEA accounts (*38*). PPI is the Producer Price Index for each (of 70) I-O sector (i).

Next, we created a concordance table between 589 products in BEA input-output accounts into 6 categories of food, 7 categories of goods, and 10 categories of services, consistent with the calculator and the CES datasets. Emissions for each category of consumption in the calculator are an average of emissions for all individual products in that category, weighted by average national expenditures on those products. For example, although adhesives and glues have an unusually high emission factor, at more than 700 gCO_2e/consumer $, they account for less than 2% of expenditures on office supplies. Therefore, the overall emission factor for office supplies is not greatly affected by the high emission factor of adhesives and glues. A list of final emission factors is provided in Appendix A of this report.

A note on uncertainty: While emission factors using input-output (I-O) analysis are generally robust on the aggregate, there are basic well-understood limitations of the approach. It is essential to understand that I-O assumes average cost and average emissions for product categories and emissions are scaled linearly based in dollars spent on each category of goods. The second major limitation is that all products produced within the same sector of the economy (of which there are about 420 in the EIO-LCA model used in this analysis) are assumed to have the same emissions per dollar of sector output. Other sources of uncertainty included: 1) geographic variation (e.g., accounting for the effect of imports), 2) time lag due to infrequent updates of emission factors, 3) source data uncertainty and error, 4) modeling error, and 5) user input error (*42*).

B. Greenhouse Gas Mitigation Measures

The Take Action page of the calculator allows users to estimate greenhouse gas and financial savings from a set of low carbon technology investments and behavior change opportunities, collectively called "Actions". Each individual Action is itself a mini-calculation tool, allowing users to adjust multiple settings (depending on the action) to reflect their personal options and preferences. Results are based on local energy and fuel prices (based on data from 28 major US metropolitan regions and all U.S. states), emissions from residential electricity production (at the level of U.S. states or utilities in the case of California), and local heating and cooling needs (for 250 U.S. regions).

Carbon footprint savings are presented in metric tons of CO_2 equivalent gases per year for each action and in total (including all pledged actions). Financial metrics include annual financial savings from changes in annual expenditures (e.g., reduced energy bills), 10-year net savings, upfront cost, 10-year net present value (NPV), return on investment (ROI) and simple payback period (in years). Users can adjust the discount rate (set to 8% by default) and annual inflation rate (set to 3% by default), which affects NPV and ROI. ROI is defined as ten year NPV over upfront cost. NPV is defined as:

$$NPV = \sum_{t=1}^{10} \frac{C_t}{(1+r)^t} - C_0 \qquad (3)$$

where Ct is the financial saving at year t over 10 years, C_0 is the upfront cost in year 0 and r is the real discount rate of 5%.

Salvage value is assumed to be zero for all measures considered, only three of which include capital expenditures. In the case of motor vehicles, households are trading in existing used vehicles for other used vehicles so there is no additional salvage value. Similarly, refrigerators are not replaced, but rather Energy Star refrigerators are chosen at the time of purchase, rather than a non-Energy Star model. In the case of light bulbs, we assume there is no market value for used incandescent light bulbs.

Where appropriate, interaction effects are considered. For example, fuel efficiency is increased by purchasing more fuel-efficient models, reducing top highway speeds, reducing rough braking, replacing air filters and keeping tires inflated. This new fuel efficiency is used to estimate savings from reducing vehicle miles traveled. Since many upgrades include interaction effects, e.g., replacing water heaters and reducing water consumption, we have limited the number of actions in homes to actions the do not interact.

8A: Buildings & Facilities Measures

Purchase Energy Efficient Heating Equipment

Description

This measure is a purchasing policy requiring the purchase of Energy Star qualified natural gas furnaces instead of conventional furnaces for buildings. This measure does not evaluate the benefits of replacing existing inefficient systems with new systems, but rather it assumes the city chooses Energy Star instead of a non-Energy Star model at the time of replacement. All heating is assumed to be forced air furnaces.

Heating demand of all buildings = square feet of buildings* heating intensity * (HDD City / HDD CA Average

Where,

- Square feet of all buildings is user defined (or a default value per sector)
- Heating intensity = 13.5 kBtu/square foot (CBECS 2005, Table E7A for Pacific Region)

- HDD City = heating degree days for city (NOAA 30-year average, interpolated in GIS for every zip code and city)
- HDD CA Average = 2531 heating degree days = average heating degree days for CA (NOAA 30-year average)

Energy demand of heating equipment replaced each year = heating demand of all buildings / average lifespan of heating equipment (Equation 6A-9)

Where,

- Average lifespan of heating equipment = 25 years (assumption)

Annual energy savings (kbtu) = heating demand replaced each year / efficiency conventional units – heating demand replaced each year / efficiency Energy Star units (Equation 6A-10)

Where,

- Efficiency conventional units = 78% (current minimum standard for natural gas furnaces)
- Efficiency Energy Star units = 90% (current minimum standard for Energy Star natural gas furnaces)

Annual financial savings = Annual energy savings * 1000 cubic feet natural gas / 1027 kbtu * price of fuel (Equation 6A-11)

Where,

- Price of fuel = $0.00844 $/cu.ft natural gas (user defined)

Upfront cost = heating demand replaced each year / average heating demand per unit * incremental cost Energy Star (Equation 6A-12)

Where,

- Average heating demand per unit = 49,000 cubic feet natural gas for a 50k btu/hr unit (RECS 2003)
- Incremental cost of Energy Star = $300 per unit (Energy Star Calculator)

CO_2 saved per year = annual energy savings * natural gas emissions factor (Equation 6A-13)

Where,

- Natural gas emissions factor = 0.000065 CO_2/cubic foot natural gas

Example

A typical California city with 3,141 employees has 2,659,000 square feet of building space, requiring 36M kbtu per year for heating (about $300k per year), of which 1.4M kbtu (4%) of heating demand is replaced with new equipment each year. Purchasing efficient Energy Star furnaces instead of conventional models saves 244,000 cubic feet of natural gas, or $2,000, on average in heating costs. The upfront incremental cost of purchasing Energy Star units is $8,700, for a payback of 4.3 years. The units save 16 tons of CO_2 per year and 388 tons over the 25-year lifetime of the units. If this measure were in effect over 10 years total financial savings would be 3,884 tons of CO_2 at a net present value of $61,400.

Interaction effects
Increasing the efficiency of heating technology reduces the impact of conservation measures.

Co-benefits / tradeoffs
Improved indoor air quality, reduced lifecycle environmental impacts of natural gas

Purchase Energy Efficient Cooling Equipment

Description

This measure is a purchasing policy requiring the purchase of Energy Star qualified air conditioning equipment instead of conventional air conditioning for business buildings. This measure does not evaluate the benefits of replacing existing inefficient systems with new systems, but rather it assumes the city chooses Energy Star instead of a non-Energy Star model at the time of replacement.. All cooling is assumed to be forced air.

EPA Energy Star calculator uses full-load cooling hours (FLCH), which is an estimate of annual cooling demand in hours of cooling with the equipment operating at full capacity. EPA provides full-load cooling hours for seven locations in California, with an average value of ~1,100 FLCH. Since EPA does not provide FLCH for all California locations we use cooling degree days (CDD) as a proxy; the average CDD for California cities is also about 1,100.

Number of 3-ton equivalent air conditioning units replaced each year = square feet of municipal buildings / lifetime of cooling equipment / 2500 square feet (Equation 6A-14)

Where,
- Square feet municipal buildings is derived from population estimate (see Table 2)
- Lifetime of cooling equipment = 20 years (assumption)
- 2500 square feet = average size of building 3-ton air conditioning unit cools, approximately the size of average U.S. home.

Annual energy savings (kWh/yr) = number of 3-ton equivalent air conditioning units replaced each year * cooling capacity of air conditioner * CDD * (1/SEER rating conventional – 1/SEER rating Energy Star) * (k/1000) (Equation 6A-15)

Where,
- Cooling capacity of air conditioner = 36,000 btu/hr for 3-ton unit
- CDD = cooling degree days for each city (NOAA 30-year average, interpolated in GIS for every zip code and city)
- SEER rating conventional = 13 btu/w-h

- SEER rating for Energy Star = 14.5 btu/w-h

Annual financial savings = Annual energy savings * daytime electricity rate (Equation 6A-16)

Where,

- Daytime electricity rate = $0.14 / kWh (user defined)

Upfront cost = Number of 3-ton equivalent air conditioning units replaced each year * differential upfront cost per unit (Equation 6A-17)

Where,

- Differential upfront cost per unit = $556 (Energy Star Calculator)

CO_2 saved per year = annual energy savings * electricity emissions factor (Equation 6A-18)

Where,

- Electricity emissions factor = 0.000385 tCO_2/kWh (by default. Actual emission factor is based on utility selected by user (ARB, 2010)

Example

A typical California city with 3,141 employees has 2,659,000 square feet of building space, requiring the equivalent of 1,060 3-ton air conditioning units, of which 53 need replacing each year. Purchasing efficient Energy Star air conditioning instead of conventional models saves 16,000 kWh of electricity each year for these units, or $2,300, on average in cooling costs. The upfront incremental cost of purchasing Energy Star units is $29,553, for a simple payback of 13.0 years. The coolers save 97 tons of CO_2 over the 20-year lifetime of the units, accounting for expected improvements in carbon-intensity of electricity over time. If this measure were in effect over 10 years the total savings would be 971 tons of CO_2, although with a payback period of 13 years, the measure results in a negative net present value when calculated at a 5% real discount rate.

Interaction effects

Increasing the efficiency of cooling technology reduces the impact of conservation measures.

Co-benefits / tradeoffs

Improved indoor air quality, reduced lifecycle environmental impacts of electricity

Install Cool Roofs

Description

This measure requires cool roofs be installed for all municipal government roofing projects.

Area of roofs replaced each year = square feet of municipal buildings / average lifespan of roofs (Equation 6A-19)

Where,

- Square feet of municipal buildings is determined by the municipal governments benchmarking model, or set by users
- Average lifespan of roofs = 30 years (assumption)

Annual electricity savings of cool roofs = area of roofs replaced each year * kWh savings intensity of cool roofs (Equation 6A-20)

Where,

- kWh savings intensity of cool roofs is given in Table 3

Annual natural gas savings (cost) of cool roofs = area of roofs replaced each year * natural gas savings (cost) intensity of cool roofs (Equation 6A-21)

Where,

- natural gas savings (cost) intensity of cool roofs is given in Table 3

Table 4. Savings and (costs) of installing cool roofs in different CA climate zones

Climate Zone	kWh/1000 cu.ft.	therms/1000 cu.ft.
1	115	-8.3
2	295	-5.9
3	184	-4.9
4	246	-4.2
5	193	-4.7
6	388	-4.1
7	313	-2.6
8	413	-3.7
9	402	-4.5
10	340	-3.6
11	268	-4.9
12	286	-5.3
13	351	-5.1
14	352	-4.7
15	380	-1.7
16	233	-10.6

Source: Levinson et. al, 2002

Upfront cost = Area of roofs replaced each year * cost of cool roofs (Equation 6A-22)

Where,

- Cost of cool roofs = 20 cents per square foot (the upper end of range estimated by Levinson et. al, 2002).[5]

Example
A typical California city with 100,000 residents has municipal government buildings totaling 2,659,000 square feet, of which 89,000 square feet of roof area is replaced each year. Installing cool roofs for these replacements costs $17,800 and saves $4,680 per year (payback of 3.8 years), while reducing 10 tons of CO_2 per year and 243 tons over a 30-year lifespan of the roofs (accounting or improvements in carbon-intensity of electricity over time).

Interaction effects
Reducing cooling demand reduces the effectiveness of energy efficient cooling technologies

Co-benefits / tradeoffs
Reduced heat island effect / small increase in natural gas consumption for heating

Co-benefits / tradeoffs
CoolCalifornia Cool Roofs Website: http://coolcalifornia.org/cool-roofs

Retrocommissioning of Existing Buildings

Description
Businesses own and operate a diverse range of buildings, each with different heating, cooling, lighting and other energy demands. This measure includes hiring permanent staff or consultants to retrocommission, or tune-up, the energy-consuming equipment and controls in buildings to improve the performance of installed equipment to meet the energy demands of the building and its occupants.[7]

Annual electricity savings = adoption rate * electricity consumption of municipal buildings * percent energy savings (Equation 6A-23)

Where,

- Adoption rate = percent of buildings that will be covered by the measure (user-defined, 50% by default)
- Electricity consumption of buildings is determined by the benchmark model for each sector, based on the square feet of buildings and cooling degree days, or is user-defined.
- Percent energy savings = 16% (Mills, 2009)[6]

Annual natural gas savings = adoption rate * natural consumption of municipal buildings * percent energy savings (Equation 6A-24)

[7] See Lawrence Berkeley National Laboratory's commissioning website for definitions of different types of building commissioning: http://cx.lbl.gov/definition.html.

Where,

- Adoption rate = percent of buildings that will be covered by the measure (user-defined, 50% by default)
- Natural gas consumption of municipal buildings is determined by the benchmark model for each city, based on the square feet of buildings and heating degree days, or is user-defined.
- Percent energy savings = 16% (Mills, 2009)[6]

Upfront cost = square feet of buildings * cost of retrocommissioning * adoption rate (Equation 6A-25)

Where,

- Cost of retrocommissioning = $0.30 per square foot (average cost of retrocommissioning in Mills, 2009 study)
- Adoption rate = the percentage of buildings undergoing retrocomissioning

Example
A typical California City with 100,000 people has municipal government buildings totaling 2,659,000 square feet. Retrocommissioning 50% of these buildings, at a cost of $400,000 (at 30 cents per square feet) would save 5M cubic feet of natural gas and 3M kWh of electricity each year, for financial savings of over $455,000. The payback time of such investment is 0.9 years. The measure saves 1,372 metric tons of CO_2 per year, or 25,000 tons of CO_2 after 20 years.

Interaction effects
Retrocomissioning reduces total building energy consumption and therefore the effectiveness of other building efficiency measures

Co-benefits / tradeoffs
Increasing employment

Resources
LBNL Commissioning website: http://cx.lbl.gov/cx.html

Purchase Energy Efficient Desktop Computers

Description
This measure is a purchasing policy for businesses to choose Energy Star models when purchasing desktop computers.

Annual energy savings = number of employees / employees per computer / average lifespan of computers (1 - % computers usually Energy Star) * kWh saving per computer (Equation 6A-26)

Where,

- Number of employees is determined by the benchmark model, based on the city's population

- Employees per computer = 5 (assumption)
- Average lifespan of computers = 4 years (Energy Star)
- % computers usually Energy Star = 30% (assumption)
- kWh savings per computer = 133 kWh / year (Energy Star Calculator)

Upfront cost = $0 (Energy Star Calculator)

Annual financial savings = annual energy savings * daytime price of electricity (Equation 6A-27)

Annual CO_2 savings = annual energy savings * electricity emissions factor (Equation 6A-28)

CO_2 savings over lifetime of computers = annual CO_2 savings * average lifespan of computers (Equation 6A-29)

Example
A typical California city with 3,100 employees purchases approximately 155 desktop computers each year, of which an estimated 70% are not Energy Star qualified. A purchasing policy to only purchase Energy Star models would save the city 14,000 kWh per year in electricity, an annual savings of $2,020 per year. Energy Star computers do not necessarily cost more than conventional models, so no upfront cost is assumed for this measure. Over the four year expected lifespan of the computers, this measure saves 21 metric tons of CO_2. If the same measure were implemented over 10 years, the savings would be roughly tenfold.

Purchase Energy Efficient Office Copiers

Description
This measure is a purchasing policy for businesses to choose Energy Star models when purchasing office copiers.

Annual energy savings = number of employees / employees per copier / average lifespan of copiers (1 - % copiers usually Energy Star) * kWh saving per copier (Equation 6A-30)

Where,
- Number of employees is determined by the benchmark model, based on the city's population
- Employees per copier = 50 (assumption)
- Average lifespan of copiers = 6 years (Energy Star)
- % copiers usually Energy Star = 50% (assumption)
- kWh savings per copier = 151 kWh / year (Energy Star Calculator)

Upfront cost = $0 (Energy Star Calculator)

Annual financial savings = annual energy savings * daytime price of electricity (Equation 6A-31)

Annual CO_2 savings = annual energy savings * electricity emissions factor
(Equation 6A-32)

CO_2 savings over lifetime of copiers = annual CO_2 savings * average lifespan of copiers * RPS adjustment factor (Equation 6A-33)

Where,

- RPS Adjustment factor = factor to account for average GHG-intensity of electricity production over project lifetime due to California's Renewable Portfolio Standard (source: ICLEI SEEC Tool).

Example
A typical California city, with 3,100 employees, purchases approximately 10 office copiers each year, of which an estimated 50% are not Energy Star qualified. A purchasing policy to only purchase Energy Star models would save the city 780 kWh per year and 4,700 kWh over the lifetime of the units. Annual financial savings of this measure are $110, with a savings of $660 over the lifetime of the copiers. Energy Star copiers do not necessarily cost more than conventional models, so no upfront cost is assumed for this measure. Over the six year expected lifespan of the copiers, this measure saves 2 metric tons of CO_2. If the same measure were implemented over 10 years, the savings would be roughly tenfold.

Purchase Energy Efficient Printers

Description
This measure is a purchasing policy for municipal governments to choose Energy Star models when purchasing office printers.

Annual energy savings = number of employees / employees per printer / average lifespan of printers (1 - % printers usually Energy Star) * kWh saving per printer (Equation 6A-34)

Where,

- Number of employees is determined by the benchmark model, based on the business sector (or is user defined)
- Employees per printer = 20 (assumption)
- Average lifespan of printers = 5 years (Energy Star)
- % printers usually Energy Star = 30% (assumption)
- kWh savings per printer = 133 kWh / year (Energy Star Calculator)

Upfront cost = $0 (Energy Star Calculator)

Annual financial savings = annual energy savings * daytime price of electricity (Equation 6A-35)

Annual CO_2 savings = annual energy savings * electricity emissions factor (Equation 6A-36)

CO_2 savings over lifetime of printers = annual CO_2 savings * average lifespan of printers * RPS adjustment factor (Equation 6A-37)

Where,

- RPS Adjustment factor = factor to account for average GHG-intensity of electricity production over project lifetime due to California's Renewable Portfolio Standard (source: ICLEI SEEC Tool).

Example

A typical California city with 3,100 employees purchases approximately 31 office printers each year, of which an estimated 22 are not Energy Star qualified. A purchasing policy to only purchase Energy Star models would save the city 2,885 kWh per year and 14,400 kWh over the lifetime of the units. Annual financial savings of this measure are $404, with a savings of $2,020 over the lifetime of the printers. Energy Star printers do not necessarily cost more than conventional models, so no upfront cost is assumed for this measure. Over the six year expected lifespan of the printers, this measure saves 5 metric tons of CO_2. If the same measure were implemented over 10 years, the savings would be roughly tenfold.

Replace T12 Bulbs with More Efficient T8 Linear Florescent Lighting

Description

This measure assumes businesses change fluorescent T12 lights and lighting ballasts to more efficient T8 lighting. By default, we assume 50% of government buildings already have T8, or even more efficient lighting. This measure could be easily modified by advanced users to account for replacing T8 with T6 or more efficient lighting. We have not including this option since T6 lights require different fixtures, whereas T12 lights can be readily adapted to support T8 fluorescent lighting.

# of T12 bulbs needing replacement each year = square feet of municipal buildings * lighting efficiency * (1000 watts / 3412 kbtu) * percent of lighting currently T-12 / lifetime of old bulbs in kWh (Equation 6A-38)

Where,

- Square feet of buildings is determined by benchmark model, or is user-defined
- Lighting efficiency = 18.7 kbtu/sq.ft.
- Percent of lighting currently T-12 = 50% (default assumption)
- Lifetime of old bulbs in kWh = 880 kWh/lamp

Annual energy savings (kWh/yr) = (Power of a T-12 – Power of a T8) * # T12 bulbs needing replacement each year * hours of operation per year * (k/1000) (Equation 6A-39)

Where,

- Power of T12 = 44 Watts

- Power of T8 = 25 Watts
- Hours of operation per year = 2250 hours = 225 work days per year * 10 hours per work day

Upfront cost = T12 bulbs needing replacement each year * (differential cost of T8 from a T12 + electronic ballast cost + installation cost of electronic ballast) (Equation 6A-40)

Where,

- Differential cost of T8 from a T12 = $0.60 per lamp
- Electronic ballast cost = $15,000 per lamp
- Installation cost of electronic ballast = $5/lamp (assumption)

Example

A typical California city has 2,659,000 square feet of municipal buildings and 12.57M kWh per year of lighting demand. Replacing 50% of this lighting with T8 lamps instead of T12 lamps would save 354,000 kWh and $49,600 per year. The total upfront cost is $170,000 for a simple payback of 3.4 years.

Plant Shade Trees

Description

This measure estimates the direct energy saving benefits from planting one tree for every building. Benefits include reduced electric cooling from increased shading, decreased heating from wind blockage, and indirect benefits from decreasing outdoor temperature.

Total number of trees planted = Total square feet / 2000 (Equation 6A-41)

Where,

- Total square feet is determined by the benchmark model, or estimated by users

Annual public and private financial savings from reduced HVAC loads = total square feet * HVAC savings per 1000 square feet (Equation 6A-43)

Where,

- Total HVAC savings per 1000 square feet = $5 (Akbari, 2002)[7]

Upfront cost = $200 per tree (including tree planting, maintenance and removal. Average cost from various studies cited in Akbari, 2002.[7]

Example

A typical California city with 100,000 residents has about 86M square feet of homes, small offices and municipal buildings. Planting one tree for every 2,000 square feet adds 43,000 trees to the city. The upfront public cost to plant all the trees is $8.6M. The total annual private savings, from reduced HVAC loads is $431,000, in addition to 1,380 tons of CO_2 per year. Trees sequester CO2 as they grow, but release the CO_2 when they decompose. The trees could be turned into mulch, compost or other organic products, offsetting some fossil fuel-based fertilizers, however, we have not included CO_2 benefits of biomass in this calculation. Since the cost of the measure is largely public, but savings are largely private, this measure would be best implemented through community donations and fundraising.

Interaction effects
Decreasing HVAC loads decreases the effectiveness of purchasing energy-efficient technologies.

Co-benefits / tradeoffs
There are many co-benefits of tree planting including increasing natural beauty of city landscapes, reducing pollution, cooling outside temperatures, providing wood, fruit and other beneficial products.

Purchase LED Exit Signs

Description
This measure considers benefits of replacing all existing exit signs in buildings with efficient LED signs.

Annual electricity savings = number of employees / employees per exist sign * electricity savings per unit

Where,

- Number of employees is determined by the benchmark model, or is user-defined
- Employees per exit sign = 100 (assumption)
- Electricity savings per unit = 325 kWh/sign (Energy Star Calculator)

Upfront cost = $64 per sign (Energy Star Calculator)

Example
A typical California city has 3,100 employees and 31 exit signs. Replacing these signs with LED models would cost about $2,000 and save about $3,400 per year in electricity bills, for a simple payback of less than one year. The signs save about 3 tons of CO_2 per year, or 54 tons of CO2 over an expected 16 year lifetime.

Interaction effects
None

Co-benefits / tradeoffs
None

Purchase Energy Efficient Water Heaters

Description
This measure evaluates the benefits of purchasing energy efficient (Energy Star) water heaters instead of conventional models at the time of replacement.

Natural gas consumed by water heaters replaced each year = square feet of municipal buildings * water heating intensity / lifetime of water heater (Equation 6A-50)

Where,

- Square feet of buildings is determined by the benchmark model, or is user-defined
- Water heating intensity = 6.75 kbtu/sq.ft. (CBECS, 2003. Water heating intensities: 50% * Intensity of schools + 25% * Intensity of Public Safety + 25% * Intensity of offices)
- Lifetime of water heaters = 15 years (Energy Star Calculator)

Annual natural gas savings = natural gas consumed by water heaters replaced each year * % savings Energy Star (Equation 6A-51)

Where,

- % savings Energy Star = 5% (Itron, DEER Database, 2005)

Upfront cost = $150 per 50 gallon equivalent unit (by default, based on online research using Google Shopping) * natural gas consumed by water heaters replaced each year / average consumption of 50 gallon water heater (Equation 6A-52)

Where,

- Number of units = average consumption of 50 gallon water heater = 24,000 cubic feet (RECS, 2003)

Example
A typical California city with 2,659,000 square feet of building space requires 17M cubic feet of natural gas heating per year. If a water heater last 15 years, on average, the city purchases the equivalent of 49 50-gallon natural gas water heaters per year at an upfront cost of $7,350. The water heaters save 59,000 cubic feet of natural gas, equating to $500 and 4 metric tons of CO_2 per year. The simple payback of the investment is 15 years, with negative net present value calculated at 5% real discount rate.

Interaction effects
Improved efficiency of water heaters reduces the benefits of faucet aerators and other water savings improvements.

Power Management of Computers

Description

This measure evaluates the benefits of putting computers and monitors in sleep or hibernate mode during nights and weekends. The policy could be implemented by installing software on computers that do not have this capability and an awareness campaign directed at government staff.

Number of computers affected by policy = number of employees / number of employees per computer * (1 - % computers currently turned off) * adoption rate (Equation 6A-53)

Where,

- Number of employees is from the default model, or us user-defined
- Number of employees per computer = 5 (assumption)
- % computers currently turned off = 36% (Energy Star Calculator)
- Adoption rate = 50% by default, or is defined by user on the introduction page

Annual electricity savings computers = number of computers affected by policy * savings per computer + number of monitors affected by the policy * savings per monitor (Equation 6A-54)

Where,

- Savings per computer = 500 kWh (Energy Star Calculator)
- Number of monitors affected by the policy = number of computers affected by the policy
- Savings per monitor = 245 kWh (Energy Star Calculator)

Upfront cost = number of computers affected by policy * incremental cost per computer (Equation 6A-55)

Where,

- Incremental cost per computer = $10 (assumption to account for cost to install software on computers that do have the capacity to be programmed and to run an awareness campaign to encourage adoption of the practice as part of the Energy Star Challenge campaign.)

Example

A typical California city with 3,100 employees has an estimated 620 computers and computer monitors, of which about 200 could be reasonably affected by this policy (50% adoption rate * (1-36% of computers already using power management)). Managing power for 200 computers and monitors saves 148,000 kWh and $17,700 per year. The upfront cost of the measure is $4,000, with a simple payback of 0.2 years. Note: even if Energy Star overestimates the total annual savings, and the cost of managing computers is more than $10 per computer, this would still likely be a very cost-effective measure.

Interaction effects

Turning off computes at nights and weekends reduces the benefits of purchasing more energy-efficient units.

Resources
Energy Star Challenge website: http://www.energystar.gov/index.cfm?c=challenge.bus_challenge
Energy Star Low Carbon IT Campaign:
http://www.energystar.gov/index.cfm?c=power_mgt.pr_power_mgt_low_carbon

8B: Power Measures

Establish On-site Solar Systems

Description
This measure evaluates the costs and benefits of establishing on-site solar to cover all of the business's electricity needs. Solar panels may be installed on schools, parking lots, buildings or in large ground-based facilities. Financing options make solar an increasingly attractive option for cities to lower their large monthly electricity bills. Purchasing solar at large commercial rates improves the cost-effectiveness of this option.

Upfront cost = adoption rate *installed cost of power * total power requirements (Equation 6B-1)

Where,

- Adoption rate = % of power city will produce using solar photovoltaic systems (50% by default, or is defined by use on the introduction page.
- Installed cost of power = $3.4 per watt (estimate for large utility-scale power greater than 2 MW from Barbose et. al, 2012[8])
- Total power requirements = annual electricity consumption / generation capacity
    - Where generation capacity is given for each California state in Table 4

Table 5. Average on-site solar generation capacity for CA counties

Average Generation per kW Installed Capacity	kWh/yr
Amador	1619
Antelope Valley	1678
Bay Area	1643
Butte	1619
Calaveras	1619
Colusa	1619
El Dorado	1758
Feather	1619
Glenn Orland	1619
Great Basin	1836
Imperial	1706
Kern	1694
Lake	1619
Lassen	1758
Mariposa	1688
Mendocino	1643
Modoc	1758
Mojave Desert	1962
Monterey Bay	1643
North Coast	1360
Northern Sierra	1619
Northern Sonoma	1644
Placer	1619
San Joaquin Valley	1688
San Luis Obispo	1782
Santa Barabara	1782
Shasta	1360
Siskiyou	1454
South Coast	1678
Tehama	1619
Tuolumne	1619
Ventura	1678
Yolo-Solano	1619

Source: ICLEI-SEEC Tool, adapted from CAPCOA, 2010

Annual electricity savings = adoption rate * annual electricity consumption (Equation 6B-2)

Example

A typical California local government with 100,000 residents consumes approximately 37M kWh of electricity in all government buildings each year. A program to produce 50% of the city's government building electricity needs would require 11 MW of solar generation capacity. Such a system, if produced at a single large facility would cost $19M (at an average utility-scale price of $3.4 per watt). They system would save the city $2.5M per year in electricity, for a simple payback of 7.2 years. If financed over 20 years at 8% nominal interest rate, the system would save the city over $1M per year (annual levelized cost).

Interaction effects
The emissions factor for energy-consuming appliances would be dramatically reduced (although non-zero from a lifecycle perspective) if all electricity were produced with solar energy

Co-benefits / tradeoffs
Co-benefit: green job growth / Tradeoff: mining and disposal of toxic materials.

Install Solar Water Heaters

Description
This measure evaluates the cost and benefits if installing solar hot water systems on municipal buildings. Solar hot water systems are more common in residential settings. They may also be installed in small offices or buildings with standard tank water heaters. This measure assumes solar hot water systems are installed in small offices or schools, primarily for demonstrations purposes and for educational benefits.

(Missing the calculations – see tool)

Upfront cost = $2,500. A solar hot water system for a California family of four costs $6,500 and qualifies for a state rebate of $1,875 and a federal tax credit of $1388 for a total installed cost of $3237 (Shoemaker, 2010[9]). The average California household only has 2.8 persons so a system with net cost of $2500 should be sufficient.

Annual natural gas savings. The Solar Rating & Certification Corporation estimates natural gas savings for residential solar hot water systems (Table 5).

Table 6. Average therms of natural gas saved for residential solar hot water heater in CA climate zones

CA Climate Zone	Average Therms Saved
AVERAGE	136
1	112
2	139
3	137
4	142
5	148
6	139
7	139
8	146
9	147
10	144
11	133
12	137
13	141
14	147
15	142
16	136

Source: Solar Rating & Certification Corp.

Example

A typical California city has an annual hot water heating demand of 17M cubic feet of natural gas (calculated at 6.75 kbtu/sq.ft. – see measure 6L). If 10% of this demand were met with solar hot water heating the city would save 1.7M cubic feet of natural gas, $15,000 and 110 metric tons of CO_2 per year. The total upfront cost of installing 120 solar hot water systems would be about $300,000, for a simple payback of 20 years. In this scenario, given the high upfront cost of this system it would be more cost-effective to purchase additional solar photovoltaic panels and choose an electric hot water heating system.

Interaction effects

Adding a solar hot water system decreases the benefits of more efficient natural gas hot water system and conservation measures to reduce hot water consumption

Co-benefits / tradeoffs

Potential educational co-benefits, although it is not clear that cities should be recommending this technology until prices become more cost-competitive.

8C: Solid Waste Measures

Reduce Solid Waste

Measure type: **Program**
Entities involved: Households

Description

This measure includes the GHG benefits of reducing the total amount of municipal solid waste (MSW), including recyclable and non-recyclable materials, generated by businesses. This measure does not include benefits of recycling or composting.

The first line of defense in waste campaign is to reduce the total volume of waste materials, including waste sent to landfills, recycled materials and compostable materials. It is usually far better to purchase food and products with no to minimal packaging, than to recycle the packaging. It is far better to reduce food waste than to compost that waste.

The default values in the tool are based on a community-based marketing (CBSM) campaign to reduce MSW in households and businesses. CBSM is a type of targeted social marketing campaign that focuses on understanding and overcoming barriers to adoption of specific activities using prompts, norms, feedback, commitments, and other social elements to encourage behavior change.[10] The cost-effectiveness of a CBSM campaign will vary greatly depending on a large number of factors. At a minimum, cities interested in participating in a CBSM project should learn the most effective strategies before beginning such a program (see Resources below).

Case study

The state of Colorado employed the consulting firm, Skumatz Economic Research Associates, to evaluate a number of waste intervention campaigns using community-based social marketing.[10] The outcome of this study is a helpful toolkit designed for practitioners to implement CBSM for household waste management and recycling (see Resources). The study concluded that door-to-door interventions and incentives (money, points or prizes) to be the most effective strategies. It also provides a cost calculator and cost-effectiveness table to help programs choose strategies.

Cost

The cost of CBSM depends on the number of elements employed. Using evidence from a recent study on CBSM for waste and recycling,[10] a 10% reduction in MSW would be effective at $10 per household, employing a number of different techniques, including door-to-door interventions, door hangers, e-mail, phone calls, survey and other forms of intervention. Our default assumption is that the program is rolled out to 50% of households in a community and focuses on MSW reduction (recycling and composting are covered separately, but we assume the same cost per household). This represents are fairly mature program. Pilot programs at a much smaller scale should be tried before scaling up a program to this level.

While the costs for the proposed intervention is public, the savings are based on average cost of waste management avoided. These savings may be distributed between multiple entities in a community (households, public or private waste removal company, landfills, etc.) By default, the tool is agnostic to the recipient of savings as bearer of costs.

GHG reductions

This measure considers the GHG reduction benefits of decreasing (scope 1) methane emissions in landfills. This measure does not take into consideration any emission reductions resulting from composting or recycling, but instead assumes that less material will be thrown away. Although not all waste produces methane, this measure calculates the reduction based on an average emission factor of landfill waste. Each metric ton of waste produces, on average, about 0.6 tCO2e from methane per ton of landfilled waste (EPA WARM, CAPCOA). Other emissions that occur during the transport and processing of waste are not included in this estimate.

Example

A community in Alameda County with 100,000 households produces 96,000 tons of waste per year at a cost of $258 per ton of waste, or $24.8M. Reducing waste by 10% in 50% of homes, at a cost of $10 per home would cost $357,143 per year and save ~$459,022 in MSW costs by all entities, as well as 1,033 tCO_2e per year.

Resources

1. Social Marketing Outreach and Education: A Community Guide http://www.socialmarketinghowto.com/
2. Fostering Sustainable Behavior: Community-based Social Marketing. Free online book: http://www.cbsm.com/pages/guide/preface/
3. Behavior, Energy and Climate Change Conference. http://beccconference.org

Interaction effects

The benefits of landfill waste reduction depend on the emission rate of landfilled waste. The emission factor of landfilled waste in this measure is dependent up on the presence or absence of flaring and waste to energy technologies specified elsewhere in the tool.

Co-benefits: Waste Reduction; Reduction of toxins to land and water; Education, Volunteerism; Social Cohesion.

8D. Lighting Measures

Outdoor lighting requires electricity and many traditional style bulbs require more energy than their more modern counterparts. A number of different bulbs and lamps are currently used for outdoor lighting, including incandescent, fluorescent, HIDs (High-intensity discharge lamps), and steady state lighting. LEDs (light-emitting diodes) are preferred because of their superior lifecycle and efficiency and quick turn-on time. Mercury vapor lamps, metal halide lamps and sodium lamps (available in high and low pressure for all HID varieties) convert more electricity to light than fluorescent and incandescent lamps and can cover a wider area, but their use of electric arc still requires an expensive ballast, some toxic chemicals and they take a few minutes to turn on. Fluorescent lamps are sometimes criticized for their lighting quality and the inefficiency of old varieties, but they are a popular replacement for incandescent lamps because of their significantly lower energy use and longer life spans. Incandescent lamps have a lower upfront cost than HIDs and fluorescents because they do not require a ballast, but their lifecycle is significantly shorter, making them a bad deal in terms of money or efficiency. (For more information see Energy Savers.)

Energy and monetary savings can be acquired by optimizing the lighting needs with the available technology. These types of efficiency and efficacy measures will reduce Scope 2 emissions by reducing electricity required, and can help to minimize unnecessary light pollution. Additionally, a variety of Scope 3 emissions could be reduced by increasing the durability of the technology, supporting reusable materials and modular component parts, encouraging the use of nontoxic substances, and minimizing the processes and extraction of limited resources (among other strategies) to reduce lifecycle costs. Outdoor lights, including streetlights and parking lights, differ significantly from indoor lights. Parking lights and streetlights are included separately because they can use different technology.

ISSUES TO CONSIDER: Lighting is in many more places than simply on highways, exit signs or traffic signals. Thus, the following reduction suggestions should be noted, but applied more broadly than just as “streetlighting”. The International Dark-Sky Association has provided a number of recommendations for parking lighting and roadway lighting (Dark Sky 2011). Although the watts, prices and lifetime vary by manufacture, we did our best to choose some appropriate averages of the ranges we saw through the available resources. For example, using shielded fixtures can help to guide the direction of the light and bi-level LED lighting can better meet the needs of the area without using excess energy (Dark Society; UC Davis). In all cases, a number of different technologies are available, thus, a lighting specialist may be required to determine the precise needs of an area.

Measures not considered

- Reduce hours of outdoor parking lighting. Reason: Safety, security
- Indoor Parking. Reason: new Title 24 standards in 2014 will require advanced lighting for new indoor parking, including higher efficient luminaries, daylight sensors and motion sensors.[8] Not all cities own municipal parking garages, but since lighting is typically 24/7 in indoor garages, advanced lighting may be an attractive technology to consider.

Use LED Street Lights

Description

The most common technology currently used for streetlights in California is high-pressure sodium (HPS); however, most cities that have developed comprehensive streetlighting plans are switching to

[8] Updated Title 24 standard for indoor parking lighting:
http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Nonresidential/Lighting_Controls_Bldg_Power/2013_CASE_NR_Parking_Garage_Lighting_and_Controls_Oct_2011.pdf

LED lamps. LED lamps are more expensive per unit, but they last much longer than conventional bulbs, and therefore require dramatically lower annual labor costs to install and maintain.

Case Study[9]

The city of Los Angeles is embarking on the largest street LED street lighting retrofit program ever undertaken globally, replacing roughly two-thirds of the 209,000 street lights within the city. Once fully implemented, at a cost of $57M, the project is expected to save the city over $10M annually in energy savings and reduced labor costs while reducing over 40,000 metric tons of CO2 per year. As of July 2011, the project had replaced 51,000 units with higher than expected financial savings than originally estimated as the cost of LED lamps continues to decrease and work crews are able to increase their productivity in replacing the units. The energy savings have also been higher than expected, reaching 59% reductions over previously installed units. The project has been financed largely by the city-owned utility, LADWP.

Cost

The total installed cost of an HPS lamp is $150 compared to $425 for LED's, for an incremental upfront cost of $275 per bulb. LED's last 65,000 hours compared to 12,800 hours for HPS (DOE), thus HPS lamps need to be replaced about 5 times for every 1 time an LED is replaced. LED bulbs consume 80 Watts, on average, while HPS lamps consume 190 Watts, for a savings of 110 Watts (LA case study). If streetlights are used 4380 hours per year (assuming no lighting reduction plan has been implemented) then each LED saves 480 kWh and $72 per year (at 15 cents per kWh). HPS lamps need to be replaced every 3 years (for annualized installation and labor cost of $50, while LED lights last 15 years, with an annualized labor cost of $28, for net savings of $22. The total annual savings per lamp is $94, for a simple payback of 2.9 years.

GHG reductions

If each LED lamp saves 480 kWh per year, then total GHG savings are 120 $kgCO_2$ per year (at 250 gCO2/kWh).

Example

A typical California city with a population of 100,000 residents has about 7,700 streetlights (1 streetlight for every 14 residents).[10] Streetlights are used 4,380 hours per year. A program to replace 50% of the existing streetlights, at a net replacement cost of $275 per bulb would require $2.1M in upfront capital. After three years the project would save the city $362,000 per year in labor and lamp replacement costs and reduce 1.85 MW of electricity and 462 metric tons of CO_2 per year.

Interaction effects

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[9] For a detailed case study of Los Angeles's street lighting retrofit program see: http://c40citieslive.squarespace.com/storage/cci_casestudy_laledlighting_2011.pdf

[10] Based on average of 13 California cities for which we could find data.

Improving streetlight lamp technology will reduce the benefits of reducing the number of hours lights are turned on at night.

Co-benefits / tradeoffs
Co-benefits: Increase light quality, reduce waste to landfill. Potential reduction of toxins (more study needed to understand implications of different technologies on toxic releases).

Resources
Los Angeles Case Study:
http://c40citieslive.squarespace.com/storage/cci_casestudy_laledlighting_2011.pdf

Upgrade to More Efficient Outdoor Parking Lights

Description
Ensuring sufficient lighting of outdoor parking lots is an important safety measure for municipal governments. Advanced lighting technologies can improve the quality of light while reducing energy consumption and lowering energy bills. Businesses should strongly consider advanced lighting technologies when installing new parking lots, however, the vast majority of annual lighting needs are for existing parking lots.

This measure considers the energy and financial savings from retrofitting municipal governments existing outdoor parking lights with bi-level LED lights and motion sensors

Number of lights affected by measure = adoption rate * number of employees * (1 light / 8 employees) (Equation 6D-1)

Where,

- Adoption rate = percent of outdoor parking light affected by this measure = 50% by default, or user-defined
- Number of employees is provide by the default model, or is user-defined
- 1 light / 8 employees = assumed number of employees per outdoor parking light

Annual electricity savings (kWh/yr) = (power of old light – power of LED) * hours used per year * number of lights affected by measure (Equation 6D-2)

Where,

- Power of old light = 200 Watts (DOE, 2002)
- Power of LED = 100 Watts (DOE, 2002)
- Hours used per year = 3650 (DOE, 2002)

Annual O&M savings = (annual O&M old lamps * 12 * number of lights affected by measure) – (annual O&M LED lamps * 12 * number of lamps affected by measure) (Equation 6D-3)

Where,

- Annual O&M old lamps = $2.91 per month per lamp (EERE Financial Tool)
- Annual O&M LED lamps = $0.47 per month per lamp (EERE Financial Tool)

Upfront cost = (labor to install new lamps – labor to install old lamps + cost of motion sensor) * number of lamps affected by measure (Equation 6D-4)

Where,

- Labor to install new lamps = $200 (assumption).
- Labor to install old lamps = $50 (assumption)
- Cost of motion sensor = $50 (motion sensor cost about $15 per unit. We add $35 per labor to install)

Example
A typical California city with 100,000 residents has an estimated 388 parking lights in municipal government parking lots. This measure replaces 194 of those lights with LED lights and adds motion sensor technology. The total project cost is $38,800. The new lights save the city $8,500 per year in electricity and $5,680 per year in lamp replacement and maintenance for a simple payback of 2.7 years. The project also reduces 53 metrics tons of CO_2 per year.

Interaction effects
None

Co-benefits / tradeoffs
LED lights often improve the quality of lighting in parking lots, increasing safety. The motion sensor technology reduces light pollution.

8E: Transit Measures

Utilize/Purchase Alternative Fuel Vehicles

Description
This measure explores the cost and benefits of purchasing alternative fuel vehicles for the businesses fleet.

Number of vehicles replaced each year = fleet vehicle miles / miles vehicles driven while in service * adoption rate (Equation 6E-1)

Where,

- Fleet vehicle miles is from the benchmark model, or is user-defined
- Miles driven while in service = 80,216 (Transportation Energy Data Book, Volume 31, Table 7.2 – average of all vehicle types)
- Adoption rate = % of new vehicles purchased that will use alternative fuels = 20% by default, or is set by user

Incremental upfront cost = $4,300 per vehicle (Differential cost between Honda Civic conventional and hybrid models minus $2,000 rebate)

Annual financial savings = number of vehicles * (miles per vehicle / miles per gallon old vehicle * price of old vehicle fuel) – (miles per vehicle / miles per gallon equivalent new vehicle * price of new vehicle fuel) (Equation 6E-2)

Where,

- Miles per vehicle = 24,384 (Transportation Energy Data Book, Volume 31, Table 7.3)
- Miles per gallon old vehicle = 32 by default, or is user-defined
- Miles per gallon equivalent new vehicle = 31 or is user-defined
- Price of old vehicle fuel is provided in Table 6. The default fuel type is diesel
- Price of new fuel is provided in Table 6. The default fuel type is CNG

Table 7. Price of alternative fuels

	$/gallon	Source
Gas	4.2	(EIA 2011)
Diesel	4.4	(EIA 2011)
B20	3.91	(EERE 2011)
CNG	2.09	(EERE 2011)
B100	4.18	(EERE 2011)
E85	3.19	(EERE 2011)
LNG	3.06	(EERE 2011)
LPG	2	(EERE 2011)

EIA website: http://www.eia.gov/petroleum/gasdiesel/
Energy Efficiency & Renewable Energy. (October 2011) Clean Cities Alternative Fuel Price Report. US Department of Energy.

CO_2 saved per year = number of vehicles * (miles per vehicle / miles per gallon old vehicle * emissions factor old vehicle fuel) – (miles per vehicle / miles per gallon equivalent new vehicle * emissions factor new vehicle fuel) (Equation 6E-3)

Where,

- Miles per vehicle = 24,384 (Transportation Energy Data Book, Volume 31, Table 7.3)
- Miles per gallon old vehicle = 32 by default, or is user-defined

- Miles per gallon equivalent new vehicle = 31 or is user-defined
- Emissions factor old vehicle fuel is provided in Table 7. The default fuel type is diesel
- Emissions factor new fuel is provided in Table 7. The default fuel type is CNG

Table 8. Motor vehicle GHG emissions per fuel type

	Fuel Type	kg CO2/gallon equiv.
	Gas	8.78
	Diesel	10.21
*	B20	8.91
	CNG	6.84
**	LNG	4.46
*	E85	6.20
*	B100	9.45
**	LPG	5.79

Source: U.S. EPA, Inventory of Greenhouse Gas Emissions and Sinks: 1990-2007 (2009), Annex Table A-34, A-39, A-42. Except those marked * EPA Climate Leaders, Mobile Combustion Guidance, Table B-3, B-4, B-5, B-6, B-7(2008) and ** from California Climate Action Registry General Reporting Protocol Version 2.2, 2007, Table C.3. A fraction oxidized value of 1.00 is from the IPCC, Guidelines for National Greenhouse Gas Inventories (2006).

Example

A number of vehicle types are good candidates for alternative fuels. For example, many cities are switching to compressed natural gas and hydrogen for large commercial vehicles and buses that are driven tens of thousands of miles and year and that can be fueled at a central facility. The Honda Civic is the only commercially available CNG vehicle sold in the United States and is used here as the default example.

The municipal government of a typical California city of 100,000 residents purchases about 40 new vehicles each year. If the city purchased 4 CNG Honda Civics instead of comparable gasoline models, at a differential upfront cost of $17,200 total, and the vehicles were driven an average of 24,000 miles per year, the city would save $6,200 per year, with a simple payback of less than 3 years. Since vehicles are typically driven only 80,000 miles before they are retired, this policy would pay off before the vehicles would normally be sold. Since the resale market for CNG vehicles may not be as strong as for conventional vehicles, the city may decide to keep the vehicles longer. CNG is much less corrosive than gasoline so the vehicles will likely last longer without serious engine-related maintenance issues. This measure would save about 11 metric tons of CO_2 per year. If implemented incrementally, with 4 CNG vehicles purchased every year for ten years, the measure would save 424 tons of CO_2.

Interaction effects

Increasing the fuel economy of the vehicle fleet decreases the benefits of reducing driving

Co-benefits / tradeoffs

Co-benefits: biofuel production reduces foreign oil imports.
Tradeoffs: biofuel production may have negative environmental and/or social externalities.

Utilize/Purchase Electric Vehicles

Description

This measure explores the cost and benefits of purchasing electric vehicles for the municipal government fleet.

Number of vehicles replaced each year = city fleet vehicle miles / miles vehicles driven while in service * adoption rate (Equation 6E-4)

Where,

- City fleet vehicle miles is from the benchmark model, or is user-defined
- Miles driven while in service = 80,216 (Transportation Energy Data Book, Volume 31, Table 7.2 – average of all vehicle types)
- Adoption rate = % of new vehicles purchased that will use alternative fuels = 10% by default, or is set by user

Incremental upfront cost = $10,000 per vehicle (Assumption. This is the net cost after rebates and incentives compared to the vehicle that the city would otherwise have purchased.)

Annual financial savings = number of vehicles * (miles per vehicle / miles per gallon old vehicle * cost of old vehicle fuel) – (miles per vehicle / miles per kWH electric vehicle * night time electricity rate) (Equation 6E-5)

Where,

- Miles per vehicle = 18,000 (We use 18,000 miles to be somewhat conservative since 20,000 miles is the maximum number of miles the vehicles could be driven on a single charge (80 miles per charge * 250 days per year)
- Miles per gallon old vehicle = 30 by default, or is user-defined
- Miles per kWh = 4 (EPA rates Nissan Leaf at 3.4 miles per kWh, but we assume most driving is in town with higher efficiency)
- Cost of old vehicle fuel is provided in Table XX. The default fuel type is gasoline
- Night time electricity rate = $0.12 / kWh (user defined)

CO_2 saved per year = number of vehicles * (miles per vehicle / miles per gallon old vehicle * emissions factor old vehicle fuel) – (miles per vehicle / miles per kWh * electricity emissions factor) (Equation 6E-6)

Where,

- Miles per vehicle = 18,000 (Transportation Energy Data Book, Volume 31, Table 7.3)
- Miles per gallon old vehicle = 30 by default, or is user-defined
- Emissions factor old vehicle fuel is provided in Table XX. The default fuel type is gasoline

- Miles per kWh = 4 (EPA rates Nissan Leaf at 3.4 miles per kWh, but we assume most driving is in town with higher efficiency)
- Electricity emissions factor = 0.000385 tCO_2/kWh (by default. Actual emission factor is based on utility selected by user (ARB, 2010)

Example
The municipal government of a typical California city of 100,000 residents purchases about 40 new vehicles each year. If the city purchased 4 electric vehicles instead of comparable gasoline models, at a differential upfront cost of $40,000 total, and the vehicles were driven an average of 18,000 miles per year, the city would save $8,000 per year, with a simple payback of 5 years. Since vehicles are typically driven only 80,000 miles before they are retired, this policy would pay off before the vehicles would normally be sold. This measure would save 20 metric tons of CO_2 per year. If implemented incrementally, with 4 electric vehicles purchased every year for ten years, the measure would save 870 tons of CO_2.

Interaction effects
Increasing the fuel economy of the vehicle fleet decreases the benefits of reducing driving.

Co-benefits / tradeoffs
Tradeoff: increasing demand for electricity. Toxic heavy metals are used in electric vehicle production.

Utilize/Purchase Hybrid Cars

Description
This measure explores the cost and benefits of purchasing hybrid electric vehicles for the municipal government fleet.

Number of vehicles replaced each year = city fleet vehicle miles / miles vehicles driven while in service * adoption rate (Equation 6E-7)

Where,

- Fleet vehicle miles is from the benchmark model, or is user-defined
- Miles driven while in service = 80,216 (Transportation Energy Data Book, Volume 31, Table 7.2 – average of all vehicle types)
- Adoption rate = % of new vehicles purchased that will be hybrid vehicles = 20% by default, or is set by user

Incremental upfront cost = $4,000 per vehicle (assumption)

Annual financial savings = number of vehicles * (miles per vehicle / miles per gallon old vehicle * price of old vehicle fuel) – (miles per vehicle / miles per gallon equivalent new vehicle * price of new vehicle fuel) (Equation 6E-8)

Where,

- Miles per vehicle = 24,384 (Transportation Energy Data Book, Volume 31, Table 7.3)
- Miles per gallon old vehicle = 25 by default, or is user-defined
- Miles per gallon equivalent new vehicle = 40 or is user-defined
- Price of old vehicle fuel is provided in Table 6. The default fuel type is gasoline
- Price of new fuel is provided in Table 6. The default fuel type is gasoline

CO_2 saved per year = number of vehicles * (miles per vehicle / miles per gallon old vehicle * emissions factor old vehicle fuel) – (miles per vehicle / miles per gallon equivalent new vehicle * emissions factor new vehicle fuel) (Equation 6E-9)

Where,

- Miles per vehicle = 24,384 (Transportation Energy Data Book, Volume 31, Table 7.3)
- Miles per gallon old vehicle = 25 by default, or is user-defined
- Miles per gallon equivalent new vehicle = 40 or is user-defined
- Emissions factor old vehicle fuel is provided in Table 7. The default fuel type is gasoline
- Emissions factor new fuel is provided in Table 7. The default fuel type is gasoline

Example

The municipal government of a typical California city of 100,000 residents purchases about 40 new vehicles each year. If the city purchased 8 hybrid vehicles instead of comparable gasoline models, at a differential upfront cost of $40,000 total, and the vehicles were driven an average of 24,380 miles per year, the city would save $6,800 per year in fuel costs, with a simple payback of 5 years. Since vehicles are typically driven only 80,000 miles before they are retired, this policy would pay off before the vehicles would normally be sold. This measure would save 31 metric tons of CO_2 per year. If implemented incrementally, with 8 hybrid vehicles purchased every year for ten years, the measure would save 1,000 tons of CO_2.

Interaction effects

Increasing the fuel economy of the vehicle fleet decreases the benefits of reducing driving

Co-benefits / tradeoffs

None

Reduce Air Travel

Description

This measure explores the costs and benefits of reducing air travel for business meetings, events, etc. This measure assumes air travel is reduced through increasing video-conferencing. Several video-conference technologies are free or low-cost and require minimal equipment, such as a computer and telephone.

Annual financial savings = miles flown per year by municipal employees * adoption rate * price airfare (Equation 6E-10)

Where,

- Miles flown per year by business is derived from the benchmarking model
- Adoption rate = 20% reduction in air travel (by default, or set by user)
- Price airfare = $1 per mile (BTS, air travel domestic revenue is roughly equivalent to flight length ($650 for 650 miles: http://www.bts.gov/publications/multimodal_transportation_indicators/july_2004/html/domestic_flight_availability_and_distance.html)

CO_2 saved per year = miles flown per year by municipal employees * adoption rate * air travel emissions factor (Equation 6E-11)

Where,

- Miles flown per year by municipal employees is derived from the benchmarking model
- Adoption rate = 20% reduction in air travel (by default, or set by user)
- Air travel emissions factor = 446 gCO_2/mile (Jones and Kammen, 2011)

Example

Municipal government employees of a typical California city with 100,000 residents fly an estimated 200,000 miles per year. If the city reduced flights by 20% and flights cost $1 per mile, then the city would save $40,000 per year and 18 tons of CO_2.

Interaction effects

None

Co-benefits / tradeoffs

Reduction in air travel means less other harmful air pollutants are emitted and healthier environments for those living around airfields.

Discount Transit for Municipal Employees

Description

This measure explores the costs and benefits of offering discounted transit to local government employees. This action assumes that discounting transit will increase ridership and reduce the use of cars for employee commutes, thus replacing personal vehicle miles traveled (VMT) with public transit miles.

Doubling the price of gasoline leads to about at 10% increase in public transit ridership.[11] The average price of public transit is 25 cents per mile (BTS, 2012), while the average price of gasoline is about 19 cents per mile. We can conservatively expect that decreasing the relative cost of public transit by 20% would lead to a 2% increase in public transit ridership by price signal alone. We assume the city employs a social marketing effort to further encourage public transit, which results in a 5% total increase in public transit ridership.

Upfront cost (paid by city): Number of employees * adoption rate * miles per week * cost of public transit per mile * percent discount * work weeks per year (Equation 6E-12)

Where,

- Number of employees is determined by the benchmarking model or is defined by user on the intro page
- Adoption rate = percentage of employees who will take public transit instead of driving because of the discount provided by the city
- Cost of public transit per mile = $0.25 (National Transit Database)
- Work weeks per year = 50 (by default)

Annual financial savings = Number of employees * adoption rate * miles per week * work weeks per year * operating costs of vehicles per mile – number of employees * adoption rate * weeks per year * miles per week * cost of public transit per mile * (1- percent discounted) (Equation 6E-13)

Where,

- Cost of public cost per mile = $0.25 (National Transit Database)
- Operating costs of vehicles per mile = 1/mpg * price of fuel + tires and maintenance + depreciation, Where
  - mpg = 22 miles per gallon by default
  - price of fuel is given by Table XX. Default fuel is gasoline
  - Tires and maintenance = 5 cents (AAA)
  - Depreciation = 22.5 cents per mile (AAA for medium sedan) / 2 (assuming half of deprecation is age, not miles)

CO_2 saved per year = (number of employees * adoption rate * miles per week * work weeks per year / mpg * emissions factor gasoline) – number of employees * adoption rate * miles per week * weeks per year * emissions factor public transit (Equation 6E-14)

Where,

- Emissions factor gasoline is provided in Table 7
- Emissions factor public transit = 0.000163 tCO2/mile

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11 http://www.apta.com/members/memberprogramsandservices/international/Documents/U.S.%20National%20Transit%20Database.pdf

Example
A typical California city with 100,000 residents has 3,100 local government employees. If 5% of employees commute 30 miles per week on public transit instead of driving and the city pays a 20% public transit discount, the total cost to the city would be $11,600 per year. Commuters will save $35,700 per year on gasoline, vehicle maintenance and mile-related depreciation. A total of 74 metric tons of CO_2 would be reduced.

Interaction effects
Reducing VMT of households reduces the benefit of increasing household vehicle fuel economy; however, no current measures seek to increase fuel economy of privately owned vehicles.

Co-benefits / tradeoffs
Reduced air pollution from motor vehicles, reduced accidents, reduced traffic

Support Telecommuting

Description
This measure explores the costs and benefits of implementing a telecommute policy for business employees. It is assumed that telecommuting will translate into GHG reductions associated with a worker's typical commute and that these will not be offset by the the household lights (ex. scope two emissions) or errands run with a car. This allows for reduced work space, potentially different work schedules more in line with in-demand electricty time and potentially happier employees (Transportation Demand Management Institute of the Association for Commuter Transportation 1997.)

Upfront cost (paid by city): $0

Annual financial savings (by employees) = (# of employees * adoption rate * days telecommuting per month * miles per day of commute * 12 months per year * operating costs of vehicles per mile + # of employees * adoption rate * days telecommuting per month * miles per day of commute * 12 months per year / average vehicle speed * value of workers' time) – (employees * adoption rate * days telecommuting per month * 12 months per year * energy rebound effect) (Equation 6E-15)

Where,

- Adoption rate = percentage of municipal government employees who telecommute due to shift in policy
- Days telecommuting per month = 4 by default
- Miles per day of commute = 20 by default
- Operating costs of vehicles per mile = 1/mpg * price of fuel + tires and maintenance + depreciation, where
  - Mpg = 22 miles per gallon by default
  - Price of fuel is given by Table 6. Default fuel is gasoline

  - Tires and maintenance = 5 cents (AAA)
  - Depreciation = 22.5 cents per mile (AAA for medium sedan) / 2 (assuming half of deprecation is age, not miles)
- Average vehicle speed = 35 miles per hour by default
- Value of workers' time = $0 per hour by default
- Energy rebound effect = 0.5, an assumption to account for additional energy demand of employees working at home. Kitou and Horvath (2005) show telecommuting reduces GHG emissions by 10 – 30%, including transportation and office energy. We assume much of telecommuters work in a shared public space, increasing the benefits of telecommuting.[11]

CO_2 saved per year = # of municipal employees * adoption rate * days telecommuting per month * miles per day of commute * 12 months per year * / mpg * emissions factor gasoline * energy rebound effect (Equation 6E-16)

Where,

- Adoption rate = percentage of municipal government employees who telecommute due to shift in policy
- Days telecommuting per month = 4 by default
- Miles per day of commute = 20 by default
- Mpg = fuel efficiency of vehicles (22 by default)
- Emissions factor for gasoline is provided in Table 7

Example

A typical California city with 100,000 residents has approximately 3,100 local government employees. If 5% of employees telecommute 20 miles four times per month. Commuters will save $26,000 per on net expenses (transportation savings minus energy cost). A total of 36 metric tons of CO_2 would be reduced.

Interaction effects

None

Co-benefits / tradeoffs

An important tradeoff is a potential increase in household energy consumption. It is generally much more efficient to heat, cool and provide energy-related services for an office space of multiple people rather than an individual. We have accounted for this potential tradeoff by reducing the GHG benefits by 50%.

Properly Maintain Vehicle Fleet (tire pressure, oil changes)

Description

This measure recommends regularly maintaining tire pressure and oil changes for all business-owned vehicles. Keeping tires inflated, changing oil and replacing air filters are small measures that make a large difference in the efficiency of the operation of your vehicle. Increasing the efficiency of the vehicle reduces the scope one emissions from fuel consumption.

We assume 50% of the city's municipal vehicle fleet does not regularly receive tire pressure or have regularly scheduled oil changes.

Upfront Cost = $0. We assume that the costs associated with keeping tires inflated and replacing oil and oil filters is offset by prolonging the life of tires and reducing vehicle depreciation.

Annual financial savings = (miles per year * adoption rate / mpg existing vehicles * cost of fuel) – (miles per year * adoption rate / mpg new vehicles * price of vehicle fuel) (Equation 6E-17)

Where,

- Miles per year is provided by benchmark model or is defined by users
- Adoption rate = 50% by default
- Mpg existing vehicles = miles per gallon of existing vehicles = 22 by default
- Price of vehicle fuel is provided in Table 6. The default fuel type is gasoline
- Mpg new vehicles = mpg existing vehicles + mpg existing vehicles (oil + inflate tires), where
    - Oil changes = 1%[12]
    - Inflate tires = 3.3%[13]

CO2 saved per year = (miles per year * adoption rate / mpg existing vehicles * emissions factor fuel) – (miles per year * adoption rate / mpg new vehicles * emissions factor fuel) (Equation 6E-18)

Where,

- Miles per year is provided by benchmark model or is defined by users
- Adoption rate = 50% by default
- Mpg existing vehicles = miles per gallon of existing vehicles = 22 by default
- Emissions factor fuel is provided in Table 7. The default fuel type is gasoline
- MPG new vehicles = mpg existing vehicles + mpg existing vehicles (oil + inflate tires), where
    - Oil changes = 1%[14]
    - Inflate tires = 3.3%[15]

Example

A municipal vehicle fleet of a typical California city with 100,000 residents is driven 3.1 million miles per year. If 50% of the vehicles regularly receive tire pressure and oil maintenance, the average fuel

[12] DOE EERE http://www.fueleconomy.gov/feg/maintain.shtml
[13] DOE EERE http://www.fueleconomy.gov/feg/maintain.shtml
[14] DOE EERE http://www.fueleconomy.gov/feg/maintain.shtml
[15] DOE EERE http://www.fueleconomy.gov/feg/maintain.shtml

efficiency of the vehicle fleet would increase by 4.3%, or from 22 to 23 miles per gallon. This measure saves $12,575 per year in fuel costs and 32 metric tons of CO_2 per year.

Interaction effects
Increasing the fuel efficiency of vehicles may reduce the benefits of a measure to reduce VMT.

Co-benefits / tradeoffs
Reduced air pollution, extending life of vehicles

Provide Ride Sharing Programs

Description
Ride sharing programs usually rely on unpaid drivers who want to share costs associated with gas or tolls. These relationships can be casual, organized by pick-up spots as "casual carpool" is in the SF Bay Area, or more formal, employer-organized relationships. Various transportation strategies can support each other; ride sharing can be supplemented by guaranteed rides home.[16] This measure assumes that the local government runs the program, taking over some of the administrative costs.

Upfront cost = employees * marketing (Equation 6E-19)

Where,

- Employees = number of municipal government employees from benchmarking model
- Marketing = $10 per employee, assumed by default, for initial marketing of the program

O&M expenses = employees * $2 + employees * adoption rate * $10 (Equation 6E-20)

Where,

- $2 is annual marketing expense to reach all city employees
- $10 is marketing for all participating employees

Annual financial savings by employees = annual fuel savings + annual depreciation savings – cost recovery (Equation 6E-21)

Where,

- Annual fuel savings = miles reduced / mpg * price of fuel (Equation 6E-22)
    - Where miles reduced = length of commute * days per week * 48 weeks * (occupancy-1)/occupancy * employees * adoption rate (Equation 6E-23)
        - Where, length of commute = 20 by default, days per week = 2 by default, occupancy = 3 by default
    - Mpg = 22 miles per gallon by default

[16] CEC Energy Aware Planning Guide (2011) http://www.energy.ca.gov/energy_aware_guide/index.html

- price of fuel is found in Table 6. Default fuel is gasoline

CO_2 saved per year = miles reduced / mpg * fuel emissions factors (Equation 6E-24)

Where,

- miles reduced is given in Equation 6E-23
- mpg = 22 miles per gallon by default
- Emissions factor for gasoline is provided in Table 7

Example
A typical California city with 100,000 residents has approximately 3,100 local government employees. If 5% of employees ride share two times per week a distance of 20 miles per day with two other people, the commuters will save $280, and $43,800 in total. The cost of the program is assumed to be $30,000 up front, with the annual operations cost of the program covered by a small fee of $50 per year for the employees. The program saves 95 metric tons of CO_2 per year.

Interaction effects
None

Co-benefits / tradeoffs
Reduced air pollution, reduced traffic and traffic accidents, potential for increased worker productivity.

8F: Water Measures

Install Low Flow Toilets in Community Buildings

Description

This measure would replace existing toilets with current models that meet or exceed the current standard of 1.28 gallons per minute. One of the primary benefits of this measure is setting a good example for the community. Seeing low flow and ultra low flow toilets in community spaces may encourage employees and customers to choose low flow or ultra low flow models in their own homes and businesses.

Gallons saved per year = # municipal employees / employees per toilet * % toilets already low flow * adoption rate * daily flushes per employee * (efficiency old toilets – efficiency new toilets) * 225 work days per year (Equation 6G-1)

Where,

- Employees per toilet = 20 (assumption)
- % toilets already low flow = 30% (assumption)
- adoption rate = % of toilets city will replace (defined by user on intro page, 25% by default)
- daily flushes per employee = 3 (assumption)
- efficiency old toilets = 2.6 gallons per flush (average of 3.6 gpf (1980 CA standard) and 1.6 gpf (1992 CA standard)
- efficiency new toilets = 1.28 gallons per flush (2011 CA standard)

Upfront cost = $250 per toilet replaced (assumption)

Annual financial savings = gallons saved per year * water rate (Equation 6G-2)

Where,

- Water rate = $0.0020 per gallon for CA average (Black & Veatch, 2006 California Water Rate Survey is used for rates specific for cities and counties)

CO_2 saved per year = gallons saved per year * indoor water intensity * carbon intensity of water (Equation 6G-3)

Where,

- Indoor water intensity = 7,153 kWh/MG for avg. CA city (see Table 8 for values per hydrologic zone)
- Carbon intensity of water = 387 gCO_2/kWh for avg. CA city (see Table 8 for values per hydrologic zone)
- Savings from reduced water heating are not included in this estimate, but should be somewhat less than savings from reduced water consumption (since a smaller fraction of water is hot compared to home usage, which is dominated by showers).

Table 9. Water energy and GHG intensity for 10 hydrologic zones

Hydro Zone Name	Hydrologic Zone	Total Water Used, TAF (2010)	Total Water Used, MG (2010)	Physical Energy, GWh (2010)	Embedded Energy, GWh (2010)	Total Energy, GWh (2010)	Energy Intensity from conveyence, kWh/MG	Indoor Energy Intensity, kWh/MG	Outdoor Energy Intensity, kWh/MG	Carbon Intensity (gCO2e/k
Colorado River	CR	4,697	1,530,517	2,000	400	2,400	1,568	4,862	2,951	
South Lahonta	SL	730	237,871	600	600	1,200	5,045	8,339	6,428	
North Lahonta	NL	691	225,162	0	0	0	0	3,294	1,383	
Tulare Lake	TL	11,258	3,668,419	6,800	3,200	10,000	2,726	6,020	4,109	
San Joaquin Ri	SJ	10,448	3,404,481	2,600	1,200	3,800	1,116	4,410	2,499	
Sacramento Ri	SR	21,545	7,020,438	1,000	1,000	2,000	285	3,579	1,668	
South Coast	SC	5,408	1,762,197	800	6,000	6,800	3,859	7,153	5,242	
Central Coast	CC	1,219	397,211	400	600	1,000	2,518	5,812	3,901	
San Francisco	SF	1,277	416,110	200	200	400	961	4,255	2,344	
North Coast	NC	3,251	1,059,338	200	200	400	378	3,672	1,761	

Source: GreenPoint Rated Climate Calculator, Version 2.

Example

The typical California community with 3,141 employees has an estimated 157 toilets, of which 30% are assumed to already be low flow. Replacing 50% of the remaining toilets (55 total) with low flow models would save 1.0 M gallons of water per year and 3 tons of CO_2. Over 10 years (lifetime of toilets minus expected remaining lifetime of existing toilets) this measure would save nearly 10M gallons of water and 27 tons CO_2.

Interaction effects

None

Co-benefits / tradeoffs

Education (setting an example for residents of the community)

Install Low-Flow Faucet Aerators in Community Buildings

Description

Most faucets in residential and commercial buildings have an efficiency rating of 2.5 gallons per minute (gpm), the standard for faucets installed between 1980 and 1998. These standards were changed to 2.2 gpm in 1999 and 1.8 gpm in 2011. Installing low flow aerators is a low-cost measure to save water and hot water heating.

Gallons saved per year = # municipal employees / employees per faucet * % faucets already low flow * adoption rate * daily uses per employee * duration * (efficiency old faucets – efficiency new faucets) * 225 work days per year (Equation 6G-4)

Where,

- Employees per faucet = 20 (assumption)
- % faucets already low flow = 30% (assumption)
- adoption rate = % of faucets city will replace (defined by user on intro page, 50% by default)

- daily uses per employee = 4 (assumption, including employees and non-employees)
- duration = 0.25 minutes per use (CalGreen)
- efficiency old faucets = 2.5 gallons per minute (1975 – 1998 standard)
- efficiency new faucets = 1.8 gallons per minute (2011 CA standard)

Upfront cost = $10 per aerator replaced (assumption, including parts and labor)

Annual financial savings = gallons saved per year * water rate (Equation 6G-5)

Where,

- Water rate = $0.0020 per gallon for CA average. (Black & Veatch, 2006 California Water Rate Survey is used for rates specific for cities and counties)

CO_2 saved per year = gallons saved per year * indoor water intensity * carbon intensity of water (Equation 6G-6)

Where,

- Indoor water intensity = 7,153 kWh/MG for avg. CA city (see Table 8 for values per hydrologic zone)
- Carbon intensity of water = 387 gCO_2/kWh for avg. CA city (see Table 8 for values per hydrologic zone)

Example

The typical California community with 3,141 employees has an estimated 157 faucets, of which 30% are assumed to already be low flow. Replacing 25% of the remaining faucets (27 total) with low flow models would save 85,444 gallons of water per year and 0.24 tons of CO_2. Over 10 years (lifetime of faucets minus expected remaining lifetime of existing faucets) this measure would save 850,000 gallons of water and 2.4 tons CO_2.

Interaction effects

Lowering flow of faucets decreases the benefit of installing more efficient water heater.

Co-benefits / tradeoffs

Educational benefits

Install Water Efficient Landscaping

Description

This measure evaluates the costs and benefits of water efficient landscaping. California building codes now require municipalities to enact local water efficient landscaping ordinances; however, projects under a specified size, typically 2,000 square feet of landscaped area, are not subject to these requirements. This measure would require landscapes owned and operated by the business to meet or exceed these requirements.

Gallons of water per year = area of irrigated landscape * ET Factor X 0.62 * ET Adjustment Factor (Equation 6G-11)

Where,

- Area of irrigated landscape = square feet of municipal buildings x 2 (by default), where square feet of buildings is from the benchmark model, or is defined by users on the introduction page
- ET Factor (inches per square foot) = evapotranspiration factor for the city (See Table 13)
- 0.62 = a constant to convert to gallons
- ET Adjustment Factor = Reference ET rate / weighted irrigation efficiency
    - Where,
        - Reference ET rate = ET grass * % grass + ET plants * % plants + ET drought-tolerant plants * % drought-tolerant plants

          Where,
            - ET grass = 0.8
            - ET plants = 0.6
            - ET drought-tolerant plants = 0.3
        - Where,
            - Weighted Irrigation Efficiency = % irrigated by sprinklers * 0.6 + % irrigated by drip * 0.9

Table 10. Evapotranspiration factor by county

COUNTY	ETO
ALAMEDA	44.3
ALPINE	40.6
AMADOR	48.9
BUTTE	51.6
CALAVERAS	48.8
COLUSA	51.8
CONTRA	44.8
DEL NORTE	27.7
EL DORADO	47.3
FRESNO	54.5
FRESNO	54.2
GLENN	51.7
HUMBOLDT	31.4
IMPERIAL	75.5
INYO	72.7
KERN	55.0
KINGS	57.0
LAKE	44.1
LASSEN	46.9
LOS ANGELES	51.2
MADERA	51.1
MARIN	40.4
MARIPOSA	46.4
MENDOCINO	37.9
MERCED	52.2
MODOC	43.2
MONO	43.0
MONTEREY	45.3
NAPA	45.5
NEVADA	47.7
ORANGE	47.0
PLACER	42.6
PLUMAS	39.8
RIVERSIDE	67.6
SACRAMENTO	53.4
SAN BENITO	47.1
SAN BERNADI	69.3
SAN DIEGO	49.0
SAN FRANCIS(	35.1
SAN JOAQUIN	49.1
SAN LUIS OBI	44.5
SAN MATEO	42.0
SANTA BARBA	47.0
SANTA CLARA	44.9
SANTA CRUZ	40.4
SHASTA	44.1
SIERRA	40.5
SISKIYOU	39.6
SOLANO	50.2
SONOMA	44.9
STANISLAUS	52.6
SUTTER	48.5
TEHAMA	53.0
TRINITY	40.1
TULARE	51.0
TUOLUMNE	47.6
Valley	46.1
VENTURA	48.9
YOLO	52.2
YUBA	46.7
YUBA	50.2

Annual CO2e saved = (Gallons of water per year of existing system – gallons of water per year of improved system) * outdoor water intensity * water carbon intensity (Equation 6G-12)

Where,

- Gallons of water per year of existing system and improved system are given in equation 6G-11
- Indoor water intensity = 7,153 kWh/MG for avg. CA city (see Table 8 for values per hydrologic zone)
- Carbon intensity of water = 387 gCO2/kWh for avg. CA city (see Table 8 for values per hydrologic zone)

Annual financial savings = (gallons of water per year of existing system – gallons of water per year of improved system) * water rate

- Water rate = $0.0020 per gallon for CA average (Black & Veatch, 2006 California Water Rate Survey is used for rates specific for cities and counties)

Upfront cost = area of new drip irrigation * incremental cost of drip irrigation + area of new drought-tolerant plants * incremental cost of drought-tolerant plants (Equation 6G-13)

Where,

- Incremental cost of drip irrigation = $0.20 per square foot (default assumption)
- Incremental cost of drought-tolerant plants = $0.20 per square foot (default assumption)

Example for Typical CA Community

A typical California community with 100,000 residents has an estimated 5 million square feet of landscaped area owned and operated by municipal governments. Replacing 25% of this area with drought-tolerant plants instead of grass and using 100% drip irrigation, instead of 25%, would save 10.5 million gallons of water per year, and $21,000 per year in water bills. Total greenhouse gas savings would be 21 tCO2e per year. The upfront cost of the system would be $930,000, resulting in a simple payback of 44 years. While greenhouse gas benefits are relatively small, and this is not a cost-effective measure, this policy may be considered for water conservation benefits.

Interaction effects

None

Co-benefits / tradeoffs

Reduced water consumption, educational benefits, and habitat restoration.

Water Efficient Landscaping Ordinance

Description

This measure evaluates the costs and benefits of water efficient landscaping. California building codes now require municipalities to enact local water efficient landscaping ordinances; however, projects under a specified size, typically 2,000 square feet of landscaped area, are not subject to these requirements. This measure allows analysts to develop scenarios that would increase the stringency of these standards.

The default assumptions in the tool may be adjusted to users' preferences. As currently modeled, this measure applies to households, but the tool can be adjusted to include businesses changing the "square feet of homes" to "square feet of homes and businesses." The model assumes landscaped area is equivalent to 1x the area of homes.

Gallons of water per year = area of irrigated landscape * ET Factor X 0.62 * ET Adjustment Factor (Equation 6G-11)

Where,

- Area of irrigated landscape = square feet of municipal buildings x 2 (by default), where square feet of municipal buildings is from the benchmark model, or is defined by users on the introduction page
- ET Factor (inches per square foot) = evapotranspiration factor for the city (See Table 13)
- 0.62 = a constant to convert to gallons
- ET Adjustment Factor = Reference ET rate / weighted irrigation efficiency
    - Where,
        - Reference ET rate = ET grass * % grass + ET plants * % plants + ET drought-tolerant plants * % drought-tolerant plants

          Where,
            - ET grass = 0.8
            - ET plants = 0.6
            - ET drought-tolerant plants = 0.3
        - Where,
            - Weighted Irrigation Efficiency = % irrigated by sprinklers * 0.6 + % irrigated by drip * 0.9

Annual CO_2e saved = (Gallons of water per year of existing system – gallons of water per year of improved system) * outdoor water intensity * water carbon intensity (Equation 6G-12)

Where,

- Gallons of water per year of existing system and improved system are given in equation 6G-11
- Indoor water intensity = 7,153 kWh/MG for avg. CA city (see Table 8 for values per hydrologic zone)
- Carbon intensity of water = 387 gCO_2/kWh for avg. CA city (see Table 8 for values per hydrologic zone)

Annual financial savings = (gallons of water per year of existing system – gallons of water per year of improved system) * water rate

- Water rate = $0.0020 per gallon for CA average (Black & Veatch, 2006 California Water Rate Survey is used for rates specific for cities and counties)

Upfront cost = area of new drip irrigation * incremental cost of drip irrigation + area of new drought-tolerant plants * incremental cost of drought-tolerant plants (Equation 6G-13)

Where,

- Incremental cost of drip irrigation = $0.20 per square foot (default assumption)
- Incremental cost of drought-tolerant plants = $0.20 per square foot (default assumption)

Example for Typical CA Community

A typical California community with 100,000 residents has an estimated 64 million square feet of landscaped area. Replacing 5% of this area with drought-tolerant plants instead of normal plants and using 30% drip irrigation, instead of 20%, would save over one billion gallons of water per year, and $139,000 per year in water bills. Total greenhouse gas savings would be 141 tCO_2e per year. The upfront cost of the installed systems would be $1.6M, resulting in a simple payback of 12 years.

Interaction effects

None

Co-benefits / tradeoffs

Reduced water consumption, educational benefits, and habitat restoration.

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