Electricity and Natural Gas:
Baseline information to enable cities to reduce GHG emissions and save money
GHG Inventory Project, Sonoma County, California
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Edward C. Myers

Significant amounts of greenhouse gas (GHG) come from cities' use of electricity and natural gas for activities such as heating and cooling buildings, lighting, traffic signals, and water pumping and treating. Electricity and gas costs[1] for the eight cities in this survey exceeded $5.5 million in fiscal year 2001-02, as shown in the following table.

City	Electric	Gas	Total
Cloverdale	$311,104	$2,113	$313,217
Cotati	$150,783	$1,071	$151,854
Healdsburg	$440,845	$18,063	$458,908
Petaluma	$1,807,053	$40,061	$1,847,114
Rohnert Park	$1,206,759	$55,805	$1,262,565
Sebastopol	$280,484	$13,518	$294,002
Sonoma	$144,172	$1,925	$146,097
Windsor	$1,102,566	$10,200	$1,112,766
All Cities	**$5,443,767**	**$142,755**	**$5,586,523**

Reductions in GHG emissions, energy use and costs produce multiple benefits. One basic advantage of saving energy is freeing general fund money that can be then be used for other purposes.

In this report we explain how electricity and gas usage are converted to greenhouse gas emissions, how this information was reported and can be used, and how data quality was assured. There is a discussion at the end of ideas and approaches for reducing GHG emissions.

Electricity: How much GHG does it emit?
To determine the amount of emissions from electricity, kilowatt-hours (KWH) consumed are multiplied by an **emissions coefficient**, a measure of the GHG produced when the electricity is generated. The result is **pounds equivalent carbon dioxide** (lbs eCO2), the standard measure for greenhouse gas. Although the procedure is relatively simple, many complex factors determine the emissions coefficient, as the following discussion describes.

[1] Raw data provided by PG&E, except for Healdsburg electricity. Healdsburg purchases its own power from Northern California Power Authority and provided the billing records for this study. Natural gas costs could be understated in cases where cities contract with gas suppliers and PG&E only charges transmission fees.

To generate electricity, we tap some other form of energy - falling water, wind, geothermal steam, nuclear, natural gas, oil, or coal. Power generation releases greenhouse gas – mainly carbon dioxide. The combustion of fossil fuel such as natural gas, oil, or coal, releases relatively more greenhouse gas than electricity generated from renewable resources, e.g., hydropower, wind, and biomass, as displayed in the following table.

GHG Emissions	**Power Plant Energy Source**	**Comments**
Least | |	Hydro, Wind, Solar Thermal, Biomass fuels	Biomass fuels (such as wood) emit carbon dioxide when burned, but extract carbon dioxide from the atmosphere when they are growing.
| | | | | | | ↓	Geothermal, Solar Photovoltaic (PV), Nuclear	Geothermal steam contains carbon dioxide which is usually vented. The production of PV panels is energy intensive; however, if renewable energy sources were used in their manufacture, then GHG emissions would be minimal. Electricity is needed to produce enriched uranium nuclear fuel, often from coal powered plants. Waste from nuclear energy generation makes this a controversial energy source.
Most	Natural Gas	Carbon/Hydrogen Ratio (C/H) = 1:4
	Oil	C/H =~1:2
	Coal	C/H =~1:1

Each fossil fuel power plant has its own emissions coefficient. Plants' coefficients are based on two factors, the type of fuel burned and the plant's thermal efficiency. Differences among fossil fuels are caused primarily by the fuel's ratio of carbon and hydrogen: the more carbon, the more carbon dioxide. Thermal efficiency is a function of the power plant's design, and indicates how much of the heat created during combustion becomes electricity. The range for this is about 30 to 60 percent, resulting in wide variation in power plants' emissions coefficients.

Many atmospheric gases, both natural and man-made, have heat-trapping properties that define them as greenhouse gases. Carbon dioxide is the major GHG culprit from electricity generation, with minor contributions from methane and nitrous oxide. The effect of these minor components are converted to an equivalent carbon dioxide strength, so all the effects can be aggregated into a single coefficient.

California's electricity grid receives power from many locations and energy sources. The mix can vary from one hour to the next. To determine the exact amount of greenhouse gas emitted by the electricity we consume would require identifying the exact sources, coefficients, and mix for the electricity. Because such a precise undertaking is impractical, experts estimate for each locale the average amount of power supplied from various sources, and estimate the corresponding overall emissions coefficient. As one might guess from this description, there is much discussion among experts currently about how best to compute emissions coefficients.

To determine an emissions coefficient for this inventory project, we relied on guidance from Ryan Bell, ICLEI[2] Technical Assistance Associate. ICLEI uses the U.S. Department of Energy's (DOE) calculation of emission coefficients as its standard. The DOE calculates annual emissions coefficients on a statewide basis, but does not account for interstate power flow. According to Ryan, Sonoma County's power generation mix closely reflects DOE's coefficient for California.

The current best estimate for our emissions coefficient - the amount of equivalent carbon dioxide from our power mix - is **0.73 lbs eCO2/KWH**. In comparison, if all our electricity came from burning coal, the figure would be about 2 lbs eCO2/KWH. California's coefficient is low relative to the rest of the nation because our power plants use little coal and oil, the fuels that emit the most GHG pollution.

Healdsburg is the only city in the county that does not buy power from PG&E. Instead, it purchases power from the Northern California Power Authority (NCPA). Healdsburg staff provided us the breakdown of their electricity generation mix, as shown in the first and second column of the table below. This is substantially different than the PG&E power mix, which relies more heavily on natural gas power plants. Therefore, we calculated and used a separate emissions coefficient for Healdsburg. We made a best estimate of the GHG emissions coefficient from each of the power sources (third column) based on our research for this project. We combined the components using a weighted average to determine an overall coefficient of **0.3 lbs eCO2/KWH**. This is substantially lower than the overall California coefficient, and demonstrates how cities could lower their GHG emissions by changing their power generation mix.

Power Source	% of Healdsburg energy mix	Emissions Coefficient, lbs eCO2/KWH
NCPA Geothermal (Geysers)	45.3	0.12[3]
NCPA Hydro	10.3	0
NCPA Gas Turbines	3.4	1.39[4]
Federal Central Valley Project Hydro	14.0	0
Wholesale power market	27.0	0.73
Weighted Average		**0.30**

[2] ICLEI stands for the International Council of Local Environmental Initiatives, the leader of the climate protection campaign in which Sonoma's cities and the County participate. For information: www.iclei.org

[3] Some carbon dioxide is usually mixed with geothermal steam, and is vented to the atmosphere. We were unable to obtain specific CO2 emissions data for the Geysers. We relied on a worldwide study from the International Geothermal Association News, July-September 2002 issue, entitled "Geothermal Power Plant CO2 Emission Survey", Bertani and Thain. We chose the 55 gm CO2/KWH average from Bertani and Thain's survey, an average which left out some particularly prolific CO2 emitting fields and represents more typical geothermal fields. This translates to 0.12 lbs eCO2/KWH.

[4] We assume these are "peaker" plants, which operate intermittently and have lower thermal efficiency.

Natural Gas: How much GHG does it emit?
Unlike electricity, converting natural gas usage to GHG emissions requires no coefficient specific to area or time period. Regardless of where natural gas originates, when it combusts, the proportionate amount of GHG it yields is fairly standard. Once it's commercially processed, natural gas is almost entirely methane (CH_4). Each molecule of methane becomes one molecule of carbon dioxide upon combustion. This translates into about 12 pounds of carbon dioxide released for each therm (100,000 BTU) of natural gas consumed.

Natural gas consumption contributes less than electricity consumption to city operations' greenhouse gases production. Cities' natural gas use is limited primarily to heating air for buildings and water for swimming pools.

Data for Electricity and Natural Gas Usage
Along with determining the emissions coefficients for electricity and natural gas, another project task was accessing and analyzing data for electricity and natural gas usage, including cost information. Pacific Gas and Electric (PG&E) supplied electronic records of the quantities of KWH and therms and their associated costs for each account in the eight cities – approximately 700 accounts in all.[5] These records also provided cost data, which as noted below we used for quality control. Using a database program we created for this project, we digested this mass of utility data into summary reports for each city, described in the next section. Consistent with the time frame of the whole of this inventory, we selected data from Fiscal Years 2000-2001 and 2001-2002 (July 2000-June 2002). In the 2000-2001 period the raw financial data provided by PG&E did not always reflect the true cost, due to changing billing rules prompted by the power crisis. However, we believe the electricity consumption data (KWH), which actually determines the greenhouse gas emissions, was reliable during that period.

Reports to help cities save money and reduce GHG emissions
Our goal is providing cities information that enables them to identify strategies to both save money on their utility bills and simultaneously reduce their greenhouse gas emissions. With this goal in mind, we specified two main objectives for our reports.

1) Have the reports be a valuable guide for taking action. Keep sufficient account detail visible that city staff can readily identify their bigger greenhouse gas contributors; the accounts are sorted according to cost to facilitate this. Conversely, don't make the reports overwhelming by including trivial or repetitive utility account information. Minor accounts, like irrigation controllers, traffic signals, or buildings with multiple electric meters, were lumped together as though they were one account.

2) Keep track of missing monthly account data. We found the account data supplied by PG&E was occasionally missing some of the monthly billing entries needed to

[5] We gratefully acknowledge Randy de Caminada and Alan Lacson, Pacific, Gas and Electric Company, for their extra efforts to fulfill our requests for data.

accurately calculate both fiscal years. To identify these cases, we added a "Data Availability" column to each line item. An availability of less than 100% indicates missing data, so that particular entry is not completely accurate.

To meet these two objectives, we designed a series of custom reports, eight per city, outlined as follows.

1) Facility Reports: Provide the utility data in a form that the project interns could directly input to the ICLEI software. This meant using categories that followed the ICLEI classifications of buildings, streetlights, and water/sewer. Each city has four Facility reports: Two for electricity, broken down by fiscal year; and likewise two for natural gas.

2) Administrative Reports: Provide the same data categorized in a way that makes the most sense to city organizations: grouped by the department, e.g., Public Works, Utilities, responsible for the facility. This allows each department to understand the magnitude of the impact of its operations on greenhouse gas generation. Similarly, there are four of these for each city.[6]

Quality Control

To ensure that the PG&E records were complete and that our data processing software was accurate, we "followed the money," knowing cities do the same and thus could verify our figures. We tracked the cost of the utility bills along with the KWH and therms throughout the data processing. For the reasons noted above, we were only able to use the fiscal year 2001-2002 financial data for this quality control procedure. Once our draft reports were complete, we showed them to cities' accounting staff for verification. The accountants concluded in general that we had faithfully tallied the utility costs. Where there were exceptions, we asked project interns to note this in their cities' GHG inventory software, for reference in the future.

Because this inventory represents the GHG "baseline," a starting point from which future improvements will be measured, the more accurate it is, the better it is for tracking progress. Since we expect to measure improvements on the order of 10%, the baseline accuracy should be substantially better. A reasonable accuracy target should be 3%.

[6] The reports described above can be found in each city's supplemental city report produced for this project. These are posted online at www.skymetrics.us

Summary of results: Amount of GHG emitted from cities' electricity and natural gas usage – tons eCO2[7]

City	Electric	Gas	Total
Cloverdale			
FY 00-01	155	7	162
FY 01-02	178	13	191
Cotati			
FY 00-01	209	4	213
FY 01-02	200	4	204
Healdsburg			
FY 00-01	192	160	352
FY 01-02	186	176	362
Petaluma			
FY 00-01	1992	366	2358
FY 01-02	1905	415	2320
Rohnert Park			
FY 00-01	1554	505	2059
FY 01-02	1682	520	2202
Sebastopol			
FY 00-01	250	47	297
FY 01-02	231	42	273
Sonoma			
FY 00-01	339	18	357
FY 01-02	323	14	337
Windsor			
FY 00-01	564	116	680
FY 01-02	563	97	660
All Cities			
FY 00-01	**5255**	**1223**	**6478**
FY 01-02	**5268**	**1281**	**6549**

[7] Raw data provided by PG&E, except for Healdsburg electricity. Healdsburg purchases its own power from Northern California Power Authority and provided the billing records for this study.

Discussion: Opportunities for reducing GHG emissions

Learning from past success

What is the potential for reductions in greenhouse gas emissions? It's instructive to look at the past to see what has been accomplished, using electricity supply and demand as an example.

Before 1976 Californians used almost as much electricity per capita as the rest of the country. These days we use 40% less relative to our fellow citizens in other states. This is largely the result of appliance and building efficiency standards developed and implemented by the California Energy Commission since 1976[8]. Other power demand management programs funded through the California Public Utilities Commission and administered by the private utilities and others played a supporting role. And the private sector, through energy consulting firms and energy services companies, performed much of the outreach to power consumers, particularly to encourage retrofits of existing buildings and other infrastructure. In spite of the proliferation of personal computers and all the other electric gadgets introduced in the meantime, California's per capita energy consumption has remained constant in the last quarter century, while it has climbed steadily in the remainder of the country. Currently we estimate all of Sonoma County emits 900,000 annual tons of eCO2 from electricity consumption alone; if per capita we were like the rest of the US we would be around 1.5 million annual tons.

Management of Californians' per capita energy consumption in the past required a sustained, committed effort by the different agencies and private firms noted above, backed up policy in the form of a code of regulations to establish energy efficiency as an ongoing program – an institution. Appliance manufacturers, builders, and others affected by the policy knew they would have to adhere to it if they wanted to do business in one of the world's larger markets. And the California economy benefits from substantially reduced dependence on out of state natural gas and electricity. With a sustained focused effort, energy efficiency improvements can be dramatic over time. Similarly, greenhouse gas emissions – largely the result of the fossil fueled energy infrastructure – could similarly be reduced.

Building on California's commitment

Looking forward, an Energy Action Plan[9] was jointly approved last Spring by the three state agencies with responsibility for California's energy future: the Energy Commission, the Public Utilities Commission, and the recently formed Power Authority. Balancing electric supply and demand in the future was summarized as follows:

> "The Action Plan envisions a "loading order" of energy resources that will guide decisions made by the agencies jointly and singly. First, the agencies want to optimize all strategies for increasing conservation and energy efficiency to minimize increases in electricity and natural gas demand. Second, recognizing

[8] "Energy Efficiency, Cool Communities, and Demand Response in California", Prepared for Haagen-Smit 2002 Conference, Arthur H. Rosenfeld, Commissioner, California Energy Commission
[9] Adopted May 8, 2003.

> that new generation is both necessary and desirable, the agencies would like to see these needs met first by renewable energy resources and distributed generation. Third, because the preferred resources require both sufficient investment and adequate time to 'get to scale,' the agencies also will support additional clean, fossil fuel, central-station generation."

An additional excerpt relevant to Cities' efforts to improve energy efficiency, from a list of recommended actions:

> "7. Increase local government conservation and energy efficiency programs."

Therefore, the Sonoma County cities should expect increased policy and agency support for efficiency programs, so they can continue to receive financing and incentives for energy efficiency improvements. What other forms of assistance will be made available remains to be determined.

Overcoming complexity and flux

However, one of the barriers to implementing widespread energy efficiency is the inherent technical and political complexity. And both technology and policy are in a constant state of flux. Technical improvements, such as the LED traffic signals which are brighter yet use a fraction of their predecessor incandescent bulbs, appear on the scene all the time. Policy instruments, such as loans, incentives, electricity pricing, building codes, and so forth, change over time. With all these changes, windows of opportunity open and close for projects and programs that can both save money for cities and reduce greenhouse gases.

Energy "czar" to maintain focus

We believe as a solution, cities should consider having a local energy "czar" who can be the focal point for information, policy, and action. This department could fund its operations out of utility cost savings. The City of Ann Arbor fund their energy manager through energy savings with great success.

Beyond the cities' own operations, larger gains can clearly be made in the residential, commercial, and industrial sectors. Is there a role for city agencies? Because the economic vitality of the business community will be impacted by volatile energy costs, it is in the community's financial interest to be insulated from this turbulence. Perhaps the energy czar could also be an information clearinghouse for public outreach on energy efficiency. One example of such an outreach effort is PG&E's Pacific Energy Center in San Francisco, which has seminars, demonstration equipment, and a "tool library" for specialized equipment used by energy efficiency practitioners. While it may not make sense to duplicate all these functions, there may be a place for a local center to showcase energy efficiency solutions targeted to the local economy, such as wineries and dairies. It could conceivably be funded through a state program.

Developing an energy ethic

But regardless of the choice of action, it will take an ongoing, long term commitment to energy efficiency in its many forms to achieve the levels of reduction of greenhouse gases that will stabilize the climate. In a larger sense, it means developing an "energy ethic." We develop codes of ethics in other facets of society, such as business conduct, to describe appropriate behavior and help society run smoothly. From the mounting evidence on greenhouse gases, we may be wise to develop an energy ethic that balances the short term benefits of fossil fuel energy with the long term costs.[10]

Edward C. Myers is President of Provimetrics, specializing in conservation measurement solutions.
131A Stony Circle, Suite 500, Santa Rosa, CA 95401, (707) 577-7445, www.provimetrics.com ,
ed@provimetrics.com This report is posted at www.skymetrics.us